2. Applied Battery Research

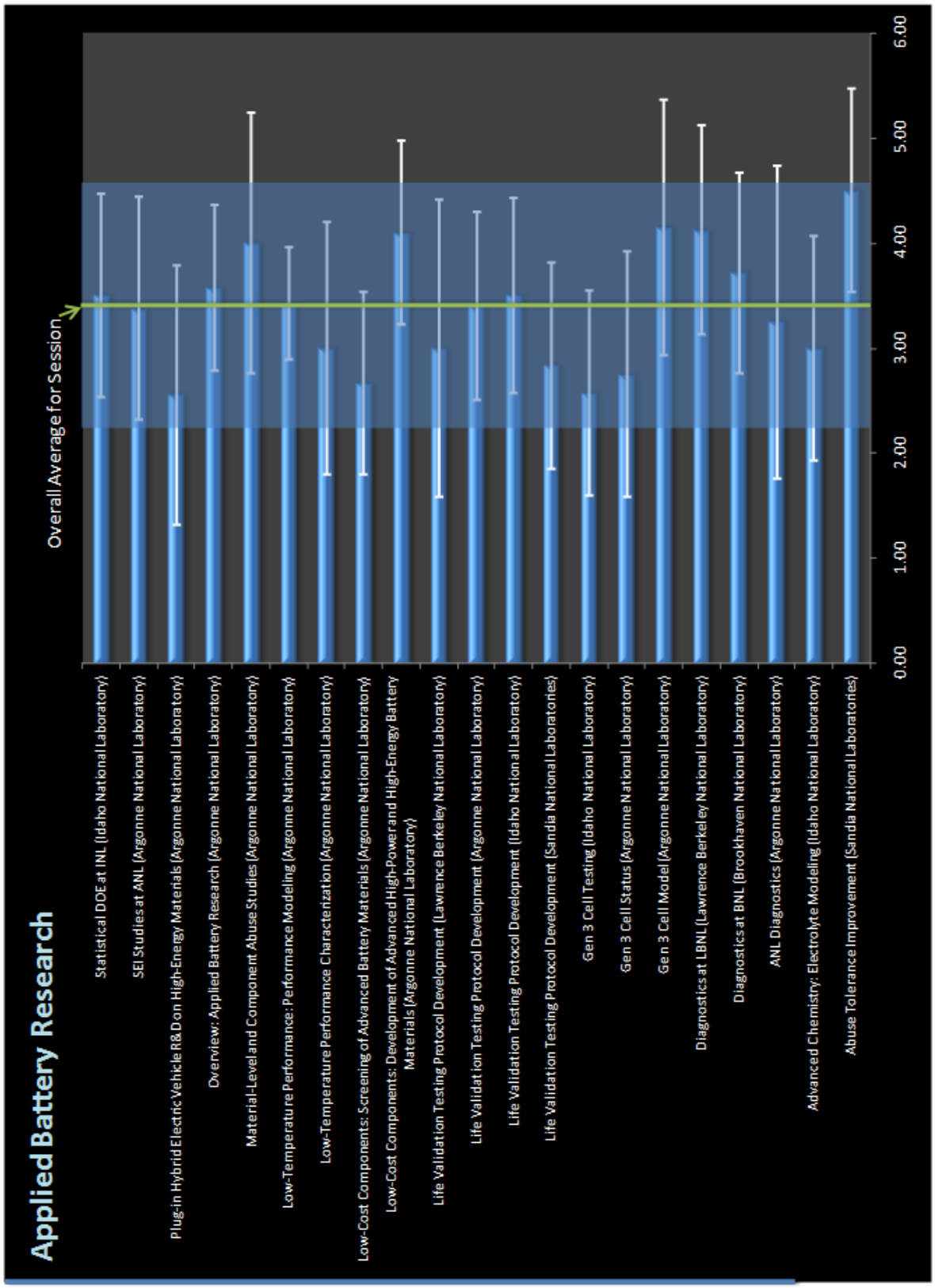
Introduction

Applied battery research focuses on addressing the cross-cutting barriers facing the lithium-ion systems that are closest to meeting all of the technical energy and power requirements for hybrid electric vehicle (HEV) and electric vehicle (EV) applications. In addition, the applied battery research activity concentrates on technology transfer to ensure that the research results and lessons learned are effectively provided to U.S. automotive and battery manufacturers. The work concentrates on four research areas: battery system development and electrochemical diagnostics, battery testing and electrolyte development, spectroscopy and microscopy diagnostics, including X-ray diagnostics, and abuse evaluation, accelerated life test protocol development, and statistical analysis. Several types of batteries have been investigated for use in EVs and HEVs, among them lithium-aluminum-iron-sulfide, nickel-metal hydride, lithium-ion, and lithium-polymer. Lithium-ion systems come closest to meeting all of the technical requirements, but they face four barriers: calendar life, low-temperature performance, abuse tolerance, and cost.

In this merit review activity, each reviewer was asked to respond to a series of six questions, involving multiple-choice responses, expository responses where text comments were requested, and one numeric score response. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in pictorial form in eight graphs as the last page of each project, and the expository text responses will be summarized in paragraph form for each question. A table and graph presenting the average and standard deviation for each project relative to the overall average and standard deviation for this session is presented below.

Page	Project Title and Principal Investigator	Project Average Score	Project Score Standard Deviation
2-4	Abuse Tolerance Improvement (Pete Roth, Sandia National Laboratories)	4.50	0.97
2-8	Advanced Chemistry: Electrolyte Modeling (Kevin Gering, Idaho National Laboratory)	3.00	1.07
2-12	ANL Diagnostics (D. Abraham, Argonne National Laboratory)	3.25	1.49
2-15	Diagnostics at BNL (W-S Yoon, Brookhaven National Laboratory)	3.71	0.95
2-18	Diagnostics at LBNL (F. McLarnon, Lawrence Berkeley National Laboratory)	4.13	0.99
2-21	Gen 3 Cell Model (Dennis Dees, Argonne National Laboratory)	4.14	1.21
2-24	Gen 3 Cell Status (Gary Henriksen, Argonne National Laboratory)	2.75	1.16
2-28	Gen 3 Cell Testing (J. Christopherson, Idaho National Laboratory)	2.57	0.98
2-31	Life Validation Testing Protocol Development (V. Battaglia, Lawrence Berkeley National Laboratory)	3.00	1.41
2-34	Life Validation Testing Protocol Development (I. Bloom, Argonne National Laboratory)	3.40	0.89

Page	Project Title and Principal Investigator	Project Average Score	Project Score Standard Deviation
2-37	Life Validation Testing Protocol Development (J. Christopherson, Idaho National Laboratory)	3.50	0.93
2-41	Life Validation Testing Protocol Development (Ed Thomas, Sandia National Laboratories)	2.83	0.98
2-44	Low-Cost Components: Development of Advanced High-Power and High-Energy Battery Materials (Khalil Amine, Argonne National Laboratory)	4.10	0.88
2-48	Low-Cost Components: Screening of Advanced Battery Materials (Andrew Jansen, Argonne National Laboratory)	2.67	0.87
2-51	Low-Temperature Performance Characterization (Andrew Jansen, Argonne National Laboratory)	3.00	1.20
2-55	Low-Temperature Performance: Performance Modeling (Dennis Dees, Argonne National Laboratory)	3.43	0.53
2-58	Material-Level and Component Abuse Studies (Khalil Amine, Argonne National Laboratory)	4.00	1.25
2-63	Overview: Applied Battery Research (Gary Henriksen, Argonne National Laboratory)	3.57	0.79
2-66	Plug-in Hybrid Electric Vehicle R&D on High-Energy Materials (Jack Vaughey, Argonne National Laboratory)	2.56	1.24
2-70	SEI Studies at ANL (D. Abraham, Argonne National Laboratory)	3.38	1.06
2-73	Statistical DOE at INL (Kevin Gering, Idaho National Laboratory)	3.50	0.97
	Overall Session Average and Standard Deviation	**3.41**	**1.15**


Applied Battery Research
Overall Average for Session
0.00
1.00
2.00
3.00
4.00
5.00
6.00
Statistical DOE at INL (Idaho National Laboratory)
SEI Studies at ANL (Argonne National Laboratory)
Plug-in Hybrid Electric Vehicle R&D on High-Energy Materials (Argonne National Laboratory)
Overview: Applied Battery Research (Argonne National Laboratory)
Material-Level and Component Abuse Studies (Argonne National Laboratory)
Low-Temperature Performance: Performance Modeling (Argonne National Laboratory)
Low-Temperature Performance Characterization (Argonne National Laboratory)
Low-Cost Components: Screening of Advanced Battery Materials (Argonne National Laboratory)
Low-Cost Components: Development of Advanced High-Power and High-Energy Battery Materials (Argonne National Laboratory)
Life Validation Testing Protocol Development (Lawrence Berkeley National Laboratory)
Life Validation Testing Protocol Development (Argonne National Laboratory)
Life Validation Testing Protocol Development (Idaho National Laboratory)
Life Validation Testing Protocol Development (Sandia National Laboratories)
Gen 3 Cell Testing (Idaho National Laboratory)
Gen 3 Cell Status (Argonne National Laboratory)
Gen 3 Cell Model (Argonne National Laboratory)
Diagnostics at LBNL (Lawrence Berkeley National Laboratory)
Diagnostics at BNL (Brookhaven National Laboratory)
ANL Diagnostics (Argonne National Laboratory)
Advanced Chemistry: Electrolyte Modeling (Idaho National Laboratory)
Abuse Tolerance Improvement (Sandia National Laboratories)

Abuse Tolerance Improvement (Pete Roth, of Sandia National Laboratories)

Reviewer Sample Size
This project had a total of 10 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
Comments were all positive. One reviewer said "Absolutely. This work is of paramount importance. Please fund them to the maximum!" Another person simply stated that abuse tolerance improvement is very important for the DOE Battery program, while another noted that safety is a key requirement for a practical cell. A related comment stated that abuse tolerance is critical to the safety of battery packs in PHEVs and HEVs and that this development is state-of-art and will greatly support the implementation of new vehicles battery systems. One reviewer felt that the presenter provided a better description of the project goals than in Dr. Amine's talk. They felt that the effect of materials on thermal runaway and looking at overcharge hazards goes towards achieving the goals identified. Another commenter remarked that this work has identified degradation mechanisms of gas and heat-producing reactions in lithium ion rechargeable cells, and has identified and developed advanced materials or combination of materials that minimize the sources of cell degradation during abuse events, thus enhancing safety and supports the overall DOE objectives. Another reviewer commented that this project provides critical and timely observations in key areas, specifically including gas generation and generation sequence characterization, forced internal short response characterization, overcharge response characterization, and separator abuse response characterization, among others. The final reviewer noted that Roth has gathered data that will be useful to battery manufacturers to produce safe batteries for HEVs and PHEVs, which will reduce the use of oil for transportation.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
Comments to this question were generally positive. One person pointed out that the Sandia group has always done very thorough and credible work using very well-thought out experiments. Another person noted that to deploy any technology, enhanced safety is required; thus the work by Pete Roth and group at Sandia shows that they do have a good strategy. One commenter also agreed that the work plan and strategy are very good, adding that significant data has been generated and that correlation of this data to future work may help in the choice of less hazardous materials. Another person felt that the researchers had good focus on separator safety and evaluation of internal shorts to address manufacturing defects. Another reviewer indicated that the key barriers have been identified and studied with an adequate scientific and technological approach looking at the study of the mechanisms of the thermal runaway and overcharge, at the analysis of the effects on cell behavior (gas and heat generation) of new materials (anode, cathode and electrolyte). Another reviewer agreed, stating that the project has made significant progress in overcoming barriers to the identification and/or characterization of the mechanisms of gas and heat-producing reactions. One person acknowledged that Roth et al. have developed excellent tools for gathering data from lithium ion cells during abuse conditions. They noted that these data will be useful to battery manufacturers to help them develop safe cells for HEVs and PHEVs. The final reviewer commented that besides manufacturing defects (which cannot be studied in the program), the PI has selected a good array of materials to test for abuse tolerance. They pointed out that one item that has not been studied is the chemical change with cycling leading to decreased abuse tolerance; and suggested implementing this to look at cycled chemicals and changes that may affect the reactivity of components.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

One reviewer simply stated that they always look at SNL for providing the definitive results on cell/pack behavior. They added that their work cannot be overemphasized. Another person noted that the researchers have very good facilities for testing various abuse scenarios and have rendered good interpretations of the scenarios. They acknowledged that studies and comparison of different systems have been done, as well as gas generation studies and the work on separators, which is new this year, is a great addition. One person pointed out that the researchers (1) demonstrated Thermal Abuse Response in High Power Cells with broader range of materials ($LiCoO_2$, spinels, $LiFePO_4$, (2) characterized electrolyte composition and additives that reduce peak thermal runaway reactions, (3) identified sequence of gas generation during overcharge showing H_2 as the first gas released, (4) characterized Role of Commercial Separators in Cell Abuse Response and showed improved high temperature melt integrity for new commercial separators, and (5) showed comparable response to voltage breakdown both at material and cell level which can lead to internal hard shorts and thermal runaway. One person noted that the project gives scientific and practical answers to the problem of abuse tolerance with interesting solutions. They pointed out that the large scope of the analysis covers most of the materials used in the ATD program. The reviewer felt that the collaboration with ANL is not well described and that some optimization and better collaboration on similar analysis would be preferable. One person acknowledged that Sandia's work, as always, has been excellent. The collaboration between Dr. Amine's work and Dr. Roth's is obvious; however, more collaboration should be carried out with Dan Abraham's group to study the abuse tolerance of the materials used for high cycle life and calendar life for HEV and PHEV as in cells using the Gen3 + additive materials. The use of a spark may hinder the actual results. For example, in the iron phosphate test, the presence of a spark during the release of a flammable electrolyte causes a flame; however, if there is no ignition source, there will be no flame as the iron phosphate will not produce oxygen and will not spontaneously ignite. This would produce excessive gassing and smoke, but rarely a fire. One reviewer has very detailed comments, stating that Dr. Roth has been a leader in developing practical methods for characterizing cell safety, and his work has been very useful for the battery developers. It would be particularly useful for future work to focus on developing improved methods for characterizing component safety - both heat generation and gas generation. The existing techniques (ARC, DSC) are useful, but suffer from problems with reproducibility, especially for gas generation. The reviewer was very pleased to see Sandia trying to develop methods to characterize cell response to an internal short, since this is a very important area, particularly given all the present discussions in regulatory agencies on this subject. They noted that the methods presented seem to rely on starting at a high initial temperature, or overcharging the cell to 20 V, however they encouraged future work to focus on developing better methods to generate internal shorts. One person commented on the important findings showing safety relative to $LiCoO_2$ benchmark, but even more important is their realistic testing of a total cell to supplement ARC and fundamental studies. They added that the real-time gas analysis and linkage with ARC/DSC studies and partnership with ANL is really paying off. They felt that the PI has effectively addressed reviewers' requests for science and understanding, not just data and results. The reviewer noted that the researcher's technology leading insights on separator behavior and the best assessment of the impact of manufacturing defects the reviewer had seen. The final reviewer commented that Roth has not developed the capability of analyzing his data in a modern manner, which would consist of comparing his data to models that could be used to predict the outcome of his experiments.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

One person noted that insights from the test will help companies identify and mitigate the unsafe conditions of a cell, which will lead to safe battery systems. Another reviewer commented that while increased thermal stability is an improvement, it may need to get to a point where there is no thermal runaway or fire to be able to be used in the HEV and PHEV. One reviewer indicated that the findings from this work in the area of identification and characterization of mechanisms of gas and heat-producing reactions provide significant and valuable advancement of knowledge in this area, which is directly transferable to the marketplace. Another person pointed out that this task's value comes in developing best methods for evaluating cell and component safety, and then teaching those methods to cell and component producers.

One person had detailed comments, stating that like ANL's work, it is not yet clear which of these safety approaches will "win" in the market place, but this work is critical in getting realistic abuse data and understanding on real cells. They noted that their work has led emphasis to industry efforts to improve separator safety. The reviewer pointed out that safety of defect cells (soft/hard shorts) will be key in moving to a practical cell; such defects will inevitable be part of the population of any mass produced cells from time to time. The reviewer commented that they are still not happy with the lack of safety goals from the car makers. They caution that they do not need complete safety since, they believe, that 10,000 or so cars catch fire in the U.S. every year, along with quite a few gas stations, so by saying you want a "safe" product is far too “wishy-washy” as an engineering and program goal. One reviewer observed that most of their work are of analytical nature and were unsure how much of them can be directly transferable; however, the knowledge they provide to developers from their work is invaluable in designing a safer battery. They concluded by mentioning that techniques they have developed to evaluate separators could be transferable. The last person cautioned that some solutions require better evaluation (economical? and existing process compatibility) to verify their transferability to the marketplace. The final reviewer mentioned that Roth has been working with separator manufacturers to help them develop their separators; however, he has not developed tools that could be used to predict the effect of design changes in the cell or in the components of the cell.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

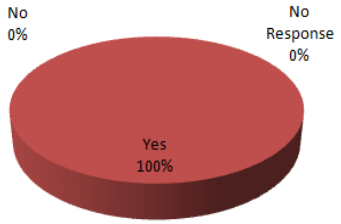
One person simply stated that the group has performed excellent work for the funding obtained. Another reviewer was very positive of the group’s progress, highlighting that the testing is very tedious, time-consuming and resource-intensive, and that the group should be funded more. One person felt that it was quite hard to make an estimation of the resources when an important funding is already in place ($750K) in respect to the important experimental work done and planned. Another mentioned that the amount of resources in the areas of this project devoted to identification and characterization of mechanisms of gas and heat-producing reactions should be increased. One reviewer questioned whether the PI has enough resources to do a significant number of replicates, since cell-to-cell variation in this type of testing is usually quite large. The final reviewer had dissenting a opinion stating that the funding for program is excessive relative to the results produced.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

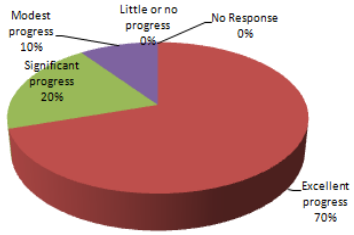
There were no expository comments for this question: refer to the graphic on the next page for this project’s summary score.

Project: Abuse Tolerance Improvement

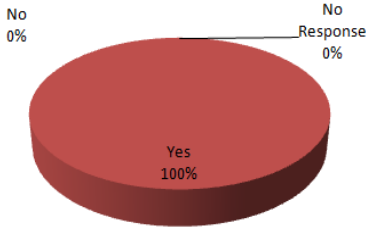
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



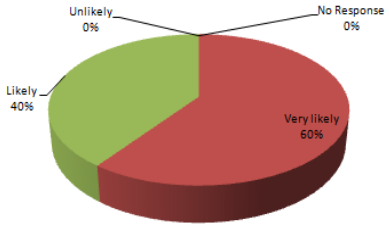
Question 3: Characterize the technical accomplishments and progress toward goals.



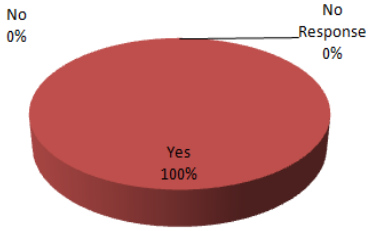
Question 2a: Are the goals of the project technically achievable?



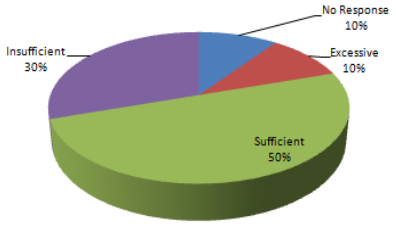
Question 4: How likely is the project team to move technologies into the marketplace?



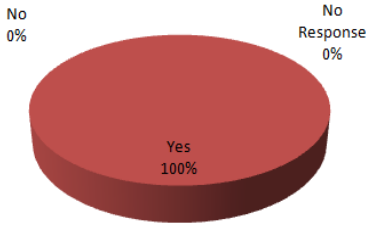
Question 2b: Have the technical barriers been identified and addressed?



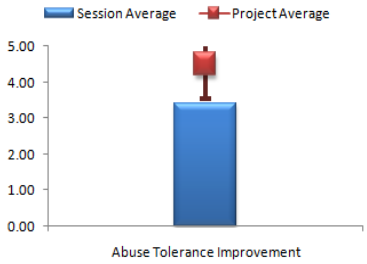
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Advanced Chemistry: Electrolyte Modeling (Kevin Gering, of Idaho National Laboratory)

Reviewer Sample Size
This project had a total of 8 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
Responses to this prompt were generally positive. One reviewer stated that low temperature performance is very important, while another person similarly remarked that low temperature behavior of li-ion batteries is still a key target for the DOE program. One other reviewer commented that electrolyte properties are key to obtaining good ionic conductivity at low temperatures. So focusing on electrolyte transport properties and modeling will actively support the improvement in low temperature performance of li-ion cells. Another respondent indicated that useful modeling of li-ion electrolytes can provide useful information towards improving cell performance in general and towards potential improvements in low temperature performance more specifically. Additionally, this work may help to better determine the root causes for limitations in li-ion electrolytes. One reviewer indicated that Gering's work on modeling electrolytes will reduce the time needed to develop electrolytes for lithium ion cells for HEVs and PHEVs, thus reducing oil use. The last reviewer stated that this was nice work, but added that recent lab work by Jansen shows that the electrolyte properties are probably not the problem for low temperature performance.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
The first reviewer indicated that the use of an already developed and validated model AEM is a reasonable approach to look at the low temperature mechanisms at the anode. In this way, the behavior can be analyzed and technical barriers better identified. One individual commented that, as mentioned above, electrolyte and ionic transportation in the electrolyte is a critical aspect at low temperatures to obtain good performance. Hence focus on this aspect will provide good insight into factors affecting low temperature performance. Another reviewer noted that Gering's electrolyte model has already been used successfully for electrolyte optimization studies. He has recently extended his model to include transport modeling and transport through cell separators, which will provide help to cell developers. One person stated that actual improvements in Li-ion electrolyte performance may not be directly achieved within the scope of this project, but the output of this project may be helpful towards overcoming the identified barriers through other future research activities. Another reviewer commented that the work is quite interesting, but this reviewer is not sure it is the factor that is responsible for the poor low-temperature behavior. Andy's results show no big dependence on electrolyte composition. Similarly, one person noted that this is nice work, but recent lab work by Jansen shows that the electrolyte properties are probably not the problem for low temperature performance.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
One reviewer stated that the use of binary salts is a good approach. Transportation of the ions and their diffusion has been included in the desolvation model. Variation of concentration profiles with respect to spatial distance and time is a good factor to be taken into consideration. The information on the concentration profile comparisons between 30°C and -30°C provides valuable data. Another response indicated that a useful estimation of the limitations in li-ion electrolyte and/or separator systems on high-rate or low temperature performance can better guide the direction of future

development activity with regards to separator development versus electrolyte solvent composition development versus salt composition/concentration development. One other person wrote that Gering's work has lead to a deeper understanding of how the electrolyte affects cell performance. Cell developers have used this understanding and his computational tool to predict the effect of changing electrolyte components on the performance of the cell. It is expected that his recent work will continue to contribute to improved cell performance based on developing electrolytes using his modeling instead of using a trial and error experimental approach. To contrast, one reviewer remarked that the results are interesting but of a limited impact in giving solutions. The porosity of the separator may improve the situation but other affecting mechanisms are not analyzed. Another reviewer indicated that it is really not clear what this task has done that is of actual use to the battery community. The presentation describes a lot of basic transport modeling, and asked how that is providing any new insight. Similarly, one other respondent wrote that the modeling is very good but some of the results are a bit hard to understand – this really needs a much more in-depth review. This is a very hard topic to explain in such a fast format. The final reviewer commented that the researcher's rigorous nature of work deserves credit. But this reviewer is not sure that this is getting us to the final goal. This reviewer thinks that the time has come to call it a day and focus on something else.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

The first respondent indicated that the AEM transport model takes into account ionic and bulk transport properties, desolvation of lithium, etc. It is a good model that considers the electrolyte properties, which will provide significant insight into low temperature performance. Another reviewer noted that Gering's work may be used to reduce the development time for improved electrolytes for lithium cells as advances are made in the active materials which may require different electrolytes from those commonly used now in lithium ion cells. One response stated that technology transfer is mainly done through publications. One reviewer commented that deployment will only occur if they find a solution. This reviewer adds that there are currently no results to generate such an interest. Another reviewer indicated that this task has yet to publish any papers describing the mysterious electrolyte model that has it has advertised for several years now. That makes the task appear more like snake oil than science. Would this model stand up to peer review? This task would be much more useful if it published a library of transport properties for electrolytes, accompanied by documentation of how the measurements were done and what is the measurement error. It would be sufficient for the library to be password protected for participants in the USABC program. This reviewer added that, if the measurement of these properties has been funded by the DOE ATD program, then the results should be available to everyone in the USABC program. One final reviewer said this is nice work, but recent lab work by Jansen shows that the electrolyte properties are probably not the problem for low temperature performance.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

One reviewer indicated that this is good work for the funding obtained, while another wrote that the funding for Gering's work is sufficient. Another person commented that, for the level of funding that this task is presently receiving, it should be publishing more results in peer-review papers and/or a USABC library. Another reviewer stated the project requires more effort to accelerate results. In contrast, one respondent indicated that he or she would not fund this anymore. One other reviewer acknowledge that he or she had supported this work before as it had a novel desolvation theory that might have explained the cell problems at -30°C. However, the data shows the problem is related to interfacial issues that do not change much even with major changes in the electrolyte. Certainly, a

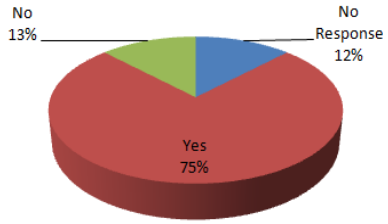
separator effect seems irrelevant. Therefore, this reviewer has to question the utility of continuing this work unless it can be used to guide Andrew Jansens' work.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

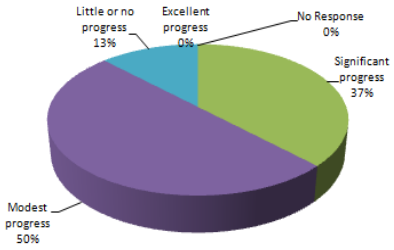
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Advanced Chemistry: Electrolyte Modeling

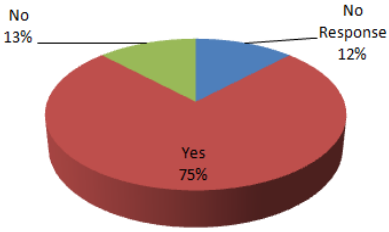
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



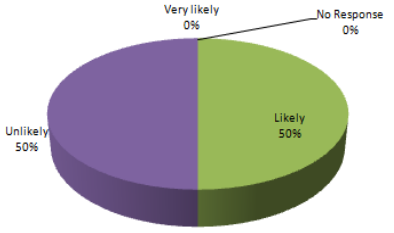
Question 3: Characterize the technical accomplishments and progress toward goals.



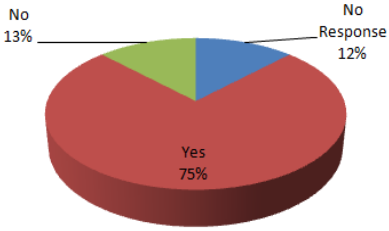
Question 2a: Are the goals of the project technically achievable?



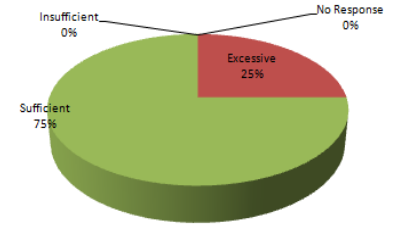
Question 4: How likely is the project team to move technologies into the marketplace?



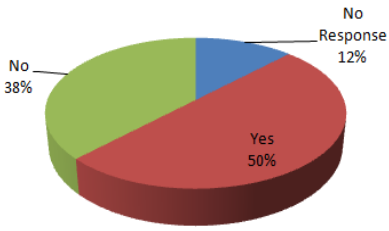
Question 2b: Have the technical barriers been identified and addressed?



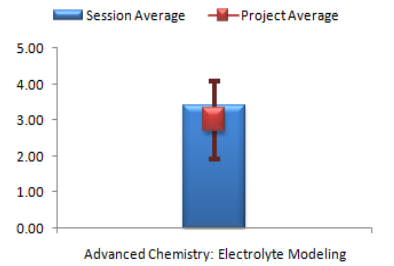
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



ANL Diagnostics (D. Abraham, of Argonne National Laboratory)

Reviewer Sample Size
This project had a total of 8 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
One person simply stated that the project is critical to understanding and progress. Another commented that the project helps to better understand the cell behaviors. One person indicated that the project is another basic brick supporting lithium battery development for 15-year calendar life. Another remarked that determining the mechanisms limiting life is in line with the DOE goals for the PHEV program. The last person commented that the project will lead to more rapid development of batteries for HEVs and PHEVs thus reducing oil use.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
One reviewer simply noted that the researcher has shown sound approaches to attack the issues. Another person acknowledged that the researcher has worked in close collaboration with some universities and tries to understand the results in depth. One reviewer felt that the researchers showed a very good approach, although they thought that a lot can be learned by tear downs of commercial power tool batteries. One person noted that the researcher's approach to understanding capacity loss and aging of cells has lead to a deeper understanding of the data obtained at ANL and at INL. One person felt that the multi-institution approach has allowed the team to well identify technical degradation barriers. They added that the project shows solutions to overcome barriers; however, a limitation seems to be the absence of comparison with other chemistry and engineering test results (such as those discussed in the Battery Development Projects with developers projects). The final reviewer highlighted that the project plan is to identify the life limiting factors by studying the various components of a cell including electrode, electrolyte and separator studies. The reviewer added that the results from the study will be used to improve materials to extend the life of the battery to 15-years as required for the PHEV. The last reviewer cautioned that the scope of the project may be too large. They suggested that future work may be more productive if focused more on only one of either (1) diagnostics of cell aging, or (2) life improvement through cell configuration (additives, electrode design, etc.). If focus is on 1.), then incorporation of similar studies of widely available mass-produced cells of the most relevant configurations should be included.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
One person simply stated that the researcher's solid presentation showed good work. Another person noted that the project tries to find the reasons behind the results obtained. One person commented that the results are interesting but the evaluation is not sufficient because it is mostly limited to in-house cells. One reviewer commented that the researchers have shown good consistency of effect of additive across various electrode vendors. The reviewer felt the approach was very good, and noted the use of reference work and XPS. However, the reviewer was a little disappointed at the relatively low amount of progress since the 2006 review, adding that they expected more. Another person commented that the researcher has used analysis tools to understand the cell data from various vendors. They concluded by observing that the work is leading to improvement in the design and fabrication of cathodes in particular that will probably last longer. The last reviewer had detailed comments, mentioning that different methods have been used under this study: the first method

involved a study using electrodes from different manufacturers; the next method evaluated Gen 3 cells made by ANL, and the third method studied Gen 3 cell with an additive (fluorinated LIBOB). The reviewer noted that the use of the additive has shown to reduce impedance growth with cycling. They suggested that the researchers need to carry out long-term cycling at temperatures and loads seen for the PHEV. They indicated that accelerated aging tests are good to make quick improvements, but baseline cells should be placed on long-term test. They concluded by mentioning that the researchers need to also work with Sandia to obtain safety test data since the Gen3 with the additive looks promising.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

Reactions to this question were mixed. One reviewer commented that the project provides key fundamental information, but that the progress just needs to be accelerated in some way. One person acknowledged that the use of additive to the Gen 3 cells shows promise for technology transfer and commercialization if it can meet the long life required. Another person commented that the work shows that an additive reduces the resistance build-up in cells and can lead to longer life; the utility of this additive is clear and may be used by battery vendors to improve the life of their cells. One person observed that the industry collaboration is quite limited and the plan for technology transfer is not clear. The last reviewer pointed out that this project involves analytical work, which is of interest to developers, but not necessarily of licensable nature.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

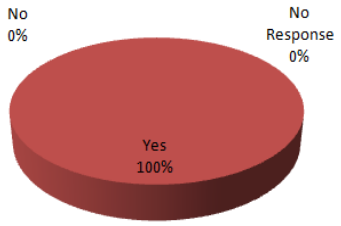
One reviewer simply noted that the funding for this project is sufficient, while another mentioned that extensive work was carried out for the funding received. Another reviewer thought that the staffing is acceptable and the quality is good, but wondered whether they are being diverted too much by other duties. The last reviewer, however, felt that the presentation gave no clear indication of the effort, so an adequate evaluation was not possible.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

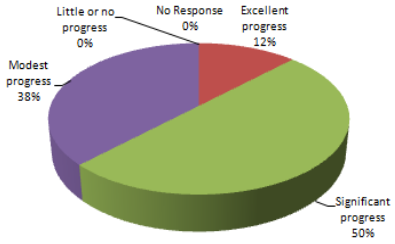
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: ANL Diagnostics

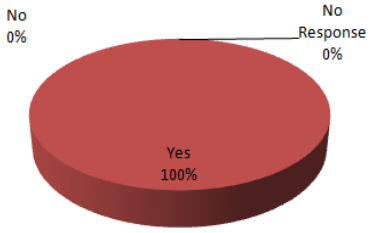
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



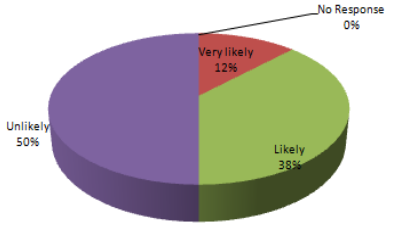
Question 3: Characterize the technical accomplishments and progress toward goals.



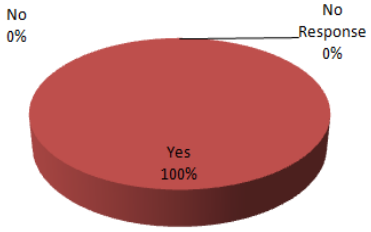
Question 2a: Are the goals of the project technically achievable?



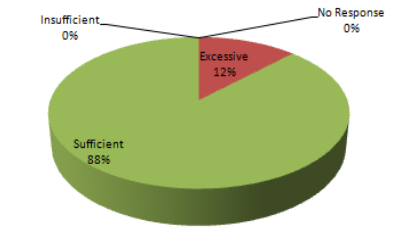
Question 4: How likely is the project team to move technologies into the marketplace?



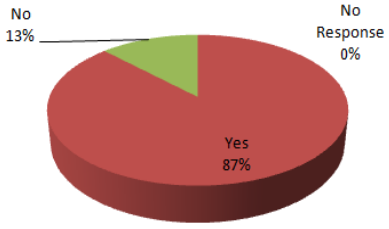
Question 2b: Have the technical barriers been identified and addressed?



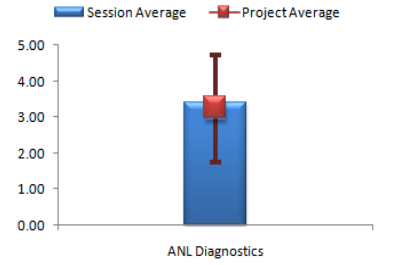
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Diagnostics at BNL (W-S Yoon, of Brookhaven National Laboratory)

Reviewer Sample Size
This project had a total of 7 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
Responses were positive overall in this section. One reviewer stated the diagnostics work is relevant to DOE objectives of better performance and safer batteries, while another respondent commented that in-situ work is very relevant and helps support fundamental experimental work and modeling studies. Adding to this, one other person wrote that in-situ work provides significant data on the products obtained during the charge/discharge process and can be correlated back to improving or changing not only the components but also operating conditions. One reviewer noted that the studies of how a crystal structure decomposes are important for the improvement of materials, which subsequently leads to improved safety and cycle life. One person stated Yoon's work will lead to a better understanding of the use of low temperature additives for lithium ion cells. This work will lead to faster development of better lithium ion batteries, thus bringing HEVs and PHEVs to the market faster, and thus reducing the need for oil.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
The first reviewer indicated that there is a good plan going forward. One respondent added that the introduction of new diagnostic techniques for in-situ evaluation is a very good approach to improve the knowledge of degradation mechanisms of electrode materials of lithium batteries. Another individual stated that Yoon's use of X-ray tools to study in-situ phenomena that occur during aging of lithium ion cells is useful and should lead to a better understanding of the degradation mechanisms that occur during use of the cells. The last person wrote that no mention was made for the purpose of the study – the main goal was to obtain cells with a 15-year life for HEV and PHEV applications.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
One reviewer wrote that the results are complete and complementary to those on anode studies, adding that the evaluation of cathodes is important as well. Another reviewer said that there are outstanding results on many systems showing the interplay of charge rate on stability. In particular, this reviewer liked the understanding and interpretation of their data and linkage with the other labs (Berkeley and ANL). This reviewer suggests this work be expanded to look at charge voltages as well. One other reviewer stated that Yoon's work has provided X-ray results showing that structural changes in LG spinal cells occur due to high discharge rates. He has showed that cycling changes the structure of the cells to a greater extent relative to high temperature storage. The data obtained in this project will be useful to battery manufacturers. For example, Yoon's X-ray data shows the utility of using a surface coating such as MgO. One individual remarked that good work has been carried out. A lot of work has been carried out that provides very good data on the transients formed during the discharges at high rates as well as high temperatures. The data on the cobaltate does not correlate with known data. Cobaltates are known to release oxygen at higher voltages more readily due to the instability of the crystal structure at higher voltages. TRXRD indicates that only the nickel is unstable both in the surface and bulk according to the data presented. There may be other factors that induce this and that needs to be expressed. Another reviewer commented that the group appears to be studying old electrodes that are already known not to be used in batteries that are state of the art li-ion

battery technology. One final reviewer wrote that the work is more of the same compared to what has done in the past. Nevertheless it is solid good work.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

The first respondent commented that the group is doing good work that is critical for improvements in understanding life of Li-ion cells. One reviewer remarked on the good results, noting that there are easy to understand and very relevant to cell designers. One person stated that improvement of materials leads to better product. Another individual simply wrote that the technology transfer is ok. One final reviewer said Yoon's work will be useful to battery manufacturers to help them understand better how the Gen-2 and Gen-3 cells function. For example, Yoon's work indicates that the use of Ni in the cathode should be minimized due to the degradation in the cathode material due to Ni.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

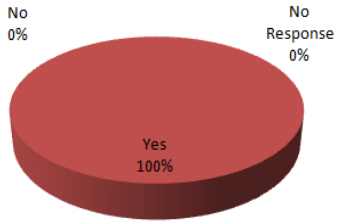
Multiple reviewers indicated that the current resources are adequate or sufficient, suggesting that they remain at the same level. One other reviewer noted there is a good volume of work for the funding provided. One final respondent stated the work is very good, adding that the group can do good work with what they have. This reviewer especially likes the new ability to study XRD of complete cells.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

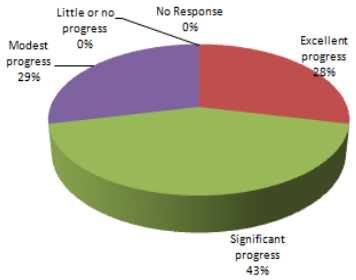
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Diagnostics at BNL

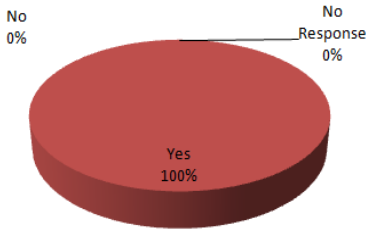
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



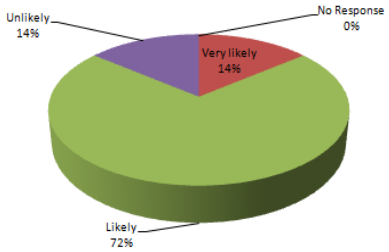
Question 3: Characterize the technical accomplishments and progress toward goals.



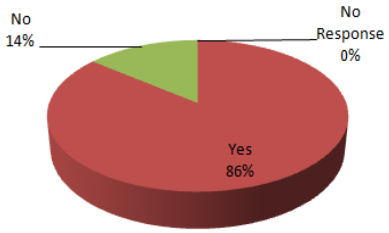
Question 2a: Are the goals of the project technically achievable?



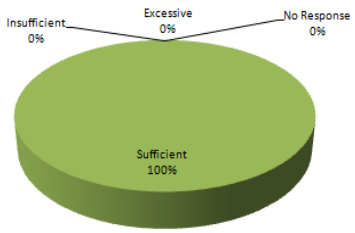
Question 4: How likely is the project team to move technologies into the marketplace?



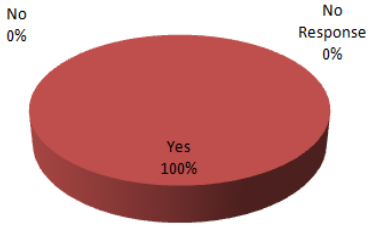
Question 2b: Have the technical barriers been identified and addressed?



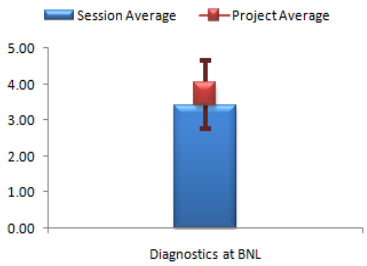
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Diagnostics at LBNL (F. McLarnon, of Lawrence Berkeley National Laboratory)

Reviewer Sample Size
This project had a total of 8 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
Responses to this question were all positive. One reviewer simply stated that the project is key to understanding electrode chemistries. One person noted that the project's diagnostic work supports the DOE objective of longer lithium life. Another person added that diagnostic studies of fresh and cycled cells provide a lot of data to make improvements in materials used in the cells. One reviewer pointed out that understanding the degradation mechanisms on a detailed level is important for cycle and calendar life. The last person noted that the researcher's work will lead to a better fundamental understanding of lithium ion cells that will help produce better batteries more rapidly to reduce oil use.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
One person simply noted that the project tackles relevant problems. One person acknowledged that the use of spectroscopic, microscopic, X-ray, chromatographic, and related techniques to characterize cell components are considered to be good strategies for deployment. Another person commented that this diagnostic work is of critical importance because it addresses the fundamental mechanism of the formation process and the results of the study will be useful to those who are developing explicit formation mechanisms. Another reviewer commented that the proposed diagnostic approach is likely to conveniently address the key technical issues reducing life and improving performance of Gen-2 lithium cells. The reviewer added that as a design tool it may assist cell development and formation process optimization, but the extension to other chemistries is not clearly addressed. One person suggested that the project will improve the cycle life performance of the cells if the results of the diagnostics are used to make improvements to future materials used. One person acknowledged the great work, but indicated that if safety is a desire for study (which was part of the objectives of the barriers slide) DSC or ARC on aged materials and the correlation should be studied, noting that it was not obvious whether this was the case from the presentation. The last person commented that the project would be more useful and would benefit by including a scope which was not limited to only the Gen-3 chemistry, but which also included chemistries and materials from cells from significant mass-producers of li-ion consumer cells.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
One person simply noted that the project includes solid materials characterization studies. Another person observed that this project is basic chemical analysis tools such as Raman spectroscopy to determine the components that exist at the surfaces of the materials in the cells that are used, for example, to produce Gen-2 cells. One reviewer acknowledged that the project provided key information on anode SEI characteristics, and demonstrated important differences between Gen-2 and Gen-3 cathodes. Another person noted that the determination of the molecular weight of some components of the SEI via GPC is one particularly useful aspect of this work. One person commented that the work is of high quality with results giving significant advancements in the degradation and formation processes comprehension. They added that the extension of the approach to other chemistries will be of extreme importance for other activities in the Battery Program. Another

reviewer pointed out that this study is being carried out simultaneous to the work done by D. Abraham and provides data on how good the materials are that Dan is using, for example, the stability of the Gen-3 cathodes are confirmed with this study. One reviewer indicated the anode surface studies were interesting and that the cathode studies on homogeneity are useful and the results on Gen-3 quite promising. The last person had detailed comments, stating that the researchers have made good use of complementary diagnostic techniques to carefully develop a consistent understanding of failure mechanisms. They add that regarding anode studies of growth of disordered carbon regions over the course of aging and the hypothesis that stress causes the disordering; it would be very useful if you could try to validate this hypothesis by looking at anode materials that may have different stress properties, e.g. particle size or degree of turbostratic disorder. They were not sure why the researchers believe that a Sn coating on carbon would improve the stability of the SEI layer, given the known issues with volume change in Sn.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

One reviewer commented that the main result for technology transfer is the optimization of the SEI. Another person indicated that the researchers used advanced spectroscopic techniques and novel artificial degradation method and attempted to suggest pathways for improved SEIs. One reviewer commented that the data and analysis from the diagnostic tool is efficiently being used to correlate the results from the experimental data provided by ANL. They point out that continuous interaction with both groups can provide good progress into understanding the use of new materials and changes. One person asked whether the non-uniformity the researchers indicated was incorporated into the ANL model, and if not they asked if this is possible to do. The last reviewer had detailed comments, stating that the results from this project indicate that the surfaces of the electrodes change with time. They acknowledge that the workers developed an argon-ion sputtering technique to simulate the aging process on carbon. It is not clear that this approach is useful relative to the actual formation process that occurs in the cells. They felt that this approach may lead to a better understanding of how the impedance of a cell changes based on damage to the carbon anode material; however, the utility of this approach is not clear relative to the formation process. The reviewer concluded by stating that the work on the cathode seems to be of limited value.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

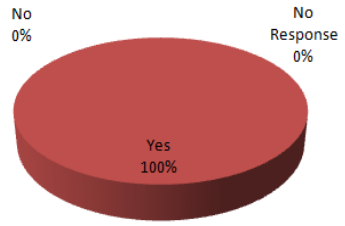
Reactions to this question were mixed. One person stated that the resources should be kept on same level. Another agreed, stating that the resources seem adequate to the work done and planned. Another person also felt that the work performed seems to be making good use of the funds and seems to be done in correlation to other experimental work. One reviewer felt that the program seems to be adequately staffed, but added that it needs "real" cells from ANL. The final reviewer remarked that the funding for this project is excessive relative to the utility of the results.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

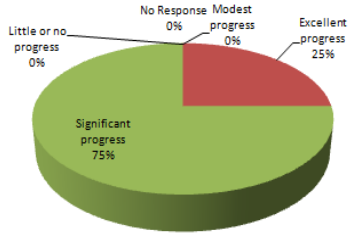
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Diagnostics at LBNL

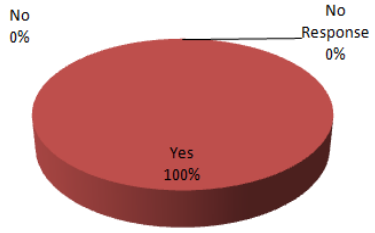
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



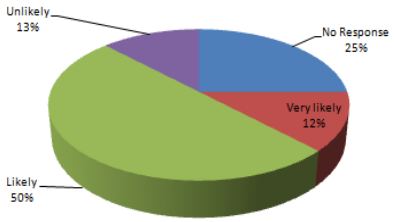
Question 3: Characterize the technical accomplishments and progress toward goals.



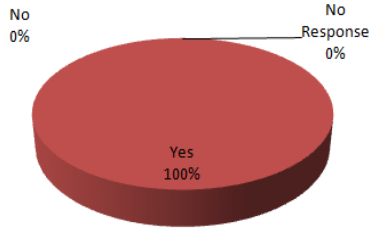
Question 2a: Are the goals of the project technically achievable?



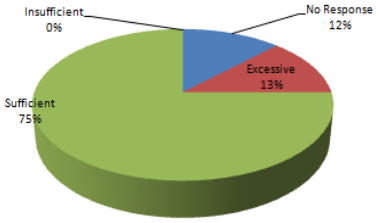
Question 4: How likely is the project team to move technologies into the marketplace?



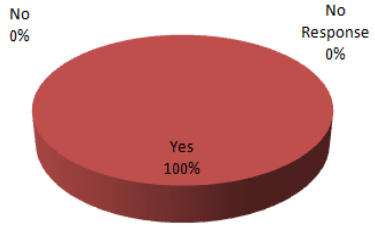
Question 2b: Have the technical barriers been identified and addressed?



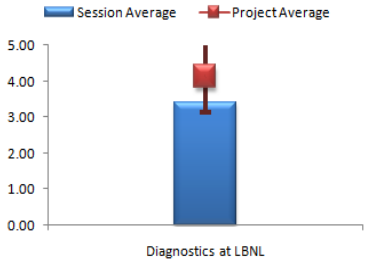
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Gen 3 Cell Model (Dennis Dees, of Argonne National Laboratory)

Reviewer Sample Size
This project had a total of 7 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
One reviewer stated that it supports lithium battery improvement, while another person commented that Dees' work will lead to a better understanding and more rapid development of batteries for HEVs and PHEVs, thus reducing oil consumption. Another reviewer indicated that we need a fundamentals-based model like this more than a data-fitting model to understand what is going on inside the battery. One final reviewer stated modeling should be an integral part to designing cells, predicting their behavior, and then verifying whether the model works or not by testing real cells.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
The first respondent simply commented "good," while another wrote that Dees' work is useful because of his in-depth contributions toward understanding the mechanisms that occur in lithium cells. Also, his work on the four-probe method should help users better understand the results from their experiments using this device. Another reviewer suggested that the project should include studies of cells produced by a significant mass-producer of consumer cells in its scope. One final reviewer remarked that the model is following adequately the cell development from Gen2 to Gen3. This reviewer asks: is it possible to extend the use of the electrochemical models to cell chemistries different from Gen-type?

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
One reviewer indicated that Dennis does very high quality work, and this reviewer is confident that his work will lead to a good resolution of these issues. Another person stated there is a good use of complementary experimental data to validate the model, and also a good use of the model for hypothesis testing to increase fundamental understanding. One other reviewer commented that Dees' careful work is an asset and will lead to a better understanding of the degradation mechanisms, which will lead to better cells that last longer. Adding to this, one reviewer commented that there is very nice coordination with experimental work. There is also a good use of four-probe DC data to supplement the modeling effort, along with a very realistic appreciation of what the data can and also cannot tell us. There is good progress overall. One person remarked that the modeling seems useful in a mechanistic way and addresses an important part of cell stability – the cell impedance as a function of storage, cycling, and duty cycle. It would be best applied to commercial well-manufactured cells for validation, however, because of the noted problems with cells made especially for ANL. One final reviewer noted that the results are only preliminary on Gen3 and require more test work. This reviewer asks: can the model be validated by enlarging testing work in the rest of the battery program? Is there any relation to thermal behavior and correlation with models developed at NREL?

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.
The first reviewer indicated that a good solution to these issues will be of interest to developers, while another respondent commented that the group is addressing and explaining key problems. One other person stated that, if the modeling is validated, it could find a number of uses in commercial cells. Another reviewer wrote that Dees' work is being used widely to help developers understand the

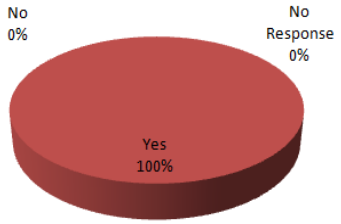
degradation mechanisms in lithium cells. One respondent wrote that the key value from this project is to publish papers disseminating the lessons learned, both in terms of modeling techniques and methodologies, and the best way to use experimental data to validate the proposed mechanisms in the model. The PI is doing a good job of publishing papers and should do more. One person stated that the use of the electrochemical model is of general value, but its transfer to the market cannot be directly considered. One final reviewer remarked that the technology transfer to the marketplace may be unlikely as long as the main focus of the project is on the Gen 3 chemistry only.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?
One reviewer commented that the group is doing very well with what they have, while another person stated that the work seems well organized even if no clear indication about resources and uses are described. One individual added that Dees' work is funded in an adequate manner. The final reviewer suggested that the resources for the project may be excessive given that the scope is limited to only the Gen 3 chemistry.

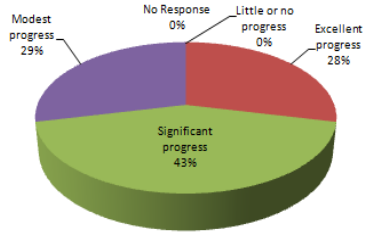
Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Gen 3 Cell Model

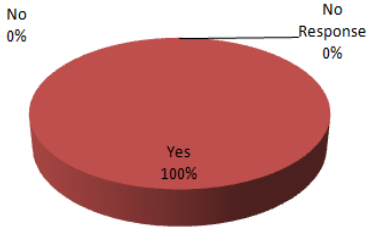
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



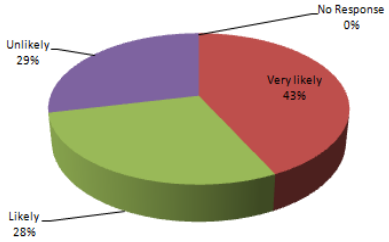
Question 3: Characterize the technical accomplishments and progress toward goals.



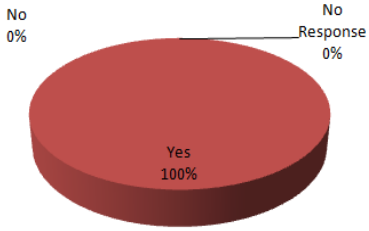
Question 2a: Are the goals of the project technically achievable?



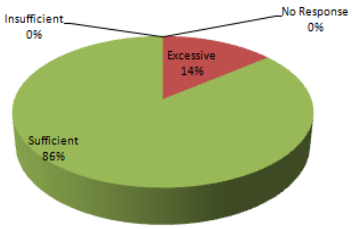
Question 4: How likely is the project team to move technologies into the marketplace?



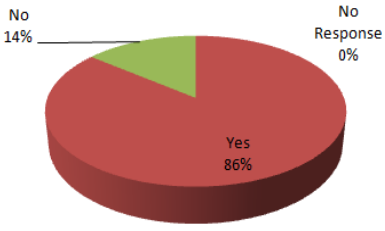
Question 2b: Have the technical barriers been identified and addressed?



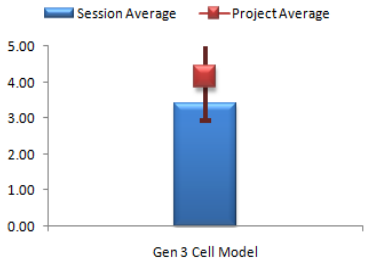
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Gen 3 Cell Status (Gary Henriksen, of Argonne National Laboratory)

Reviewer Sample Size
This project had a total of 9 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
One reviewer indicated that the research is designed to illuminate work on batteries for PHEV, while another person added that the project focuses on the fundamental lithium batteries objectives in the DOE program. One respondent stated that building cells with the materials studied is critical for final validation of those materials selected. Another reviewer remarked that this project is critical understanding and knowledge generation. One other reviewer indicated that Henriksen's Gen-3 cell studies may lead to more rapid development of lithium ion cells for HEVs and PHEVs, which will result in the reduction of oil consumption. To contrast, one final reviewer noted that the formulations and materials selected for Gen3 cells are not state-of-the-art, and one of the materials is no longer manufactured.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
The first reviewer commented that there is good cooperation and working relationships with suppliers and customers. There is a nice plan in place overall. Another reviewer indicated that Henriksen is well aware of the need to deploy the results of their work. He and his coworkers are helping battery developers by testing their cells and sharing the results of the tests with the battery manufacturers. One individual wrote that the cell fabrication and testing is an intermediate step in identifying scientific and technological solutions for more application-oriented lithium batteries. Another reviewer commented that the strategy seems sound, but the group needs to secure excellent cell manufacturing to enable sound conclusions. Multiple reviewers commented on the decision to make in-house 18650, with one reviewer remarking that this will significantly reduce the chances of success. It takes time to learn how to adjust critical parameters for electrode making and cell assembly, a skill set that the national laboratories do not have. It would have been better to stay with developers for this build. Another reviewer added that the goal of developing the capability at ANL to make 18650 cells could potentially be a huge resource sink with little benefit. There are many factors that affect the performance of cylindrical cells. It is of limited value for DOE to invest the resources needed to learn those manufacturing techniques; therefore, the results of studies with these cells would be subject to the quality of manufacturing. DOE's resources would be better spent focusing on fundamental mechanisms that affect all battery developers. One final reviewer wrote that, to develop state of the art formulations, you need much larger sample runs of combinatorial compositions that are statistically significant as well as a high throughput testing capability. The labs should partner with industry to work on a much more significant effort to work on larger and more statistically significant analysis. This should include high throughput formulation studies carried out by industry and testing and analysis carried out by the National Labs. The labs do not have the knowhow on state of the art formulation development. The compositions studies are useless. Formulation is what cell manufacturers do for a living. It is also unreasonable to assume a national lab can assemble state of the art cells by hand or with semi-automated equipment with the small cell assembly setup as Mr. Hendriksen is proposing ANL procures. Industry should work on combinatorial formulation studies and National Labs should work on analysis, testing, and validation. This reviewer closed by remarking that the calendar life test data is unreliable since reproducible, high volume, and high quality cells produced by a real pilot production line were not used in the study.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

One reviewer wrote that the project shows a reasonable approach without significant risk or drawbacks in completing testing work, while another person commented that the overview shows the PIs have made some important progress. One other respondent noted that Henriksen's project is focused on improving safety and other attributes of lithium cells. One reviewer stated that the team has clearly worked very hard and moved quickly – but is it moving in the right direction? To follow up on this question, one reviewer adds that it appears that most of the work is of routine type and does not lead to any specific meaningful recommendation for future work that will lead to addressing DOE's main objective mentioned above. Another respondent felt that there is no new technology here and little results from the testing. One reviewer stated that the progress of this project is fundamentally limited by the lack of interaction and cooperation with a significant mass-producer of Li-ion cells, while one other person wrote that the presence of leaking cells from a major part of the effort from one of the suppliers indicates a setback in the effort. This reviewer adds that results from such cells are suspect and unreliable.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

Responses to this prompt were mixed overall. The first response stated that material studies have a reasonable chance of marketability if sound cell results can be obtained. One reviewer said Henriksen's contributions to improve safety may lead to useful results. Another respondent commented that this is mostly routine analytical work. One person felt that the chemistries used should be also referred to more conventional, commercial formulations to improve transferability. One reviewer indicated that some of the work is proprietary to the developers worked with. This limits the bigger deployment to multiple companies and significantly reduces the ability to transfer to market. This reviewer added that DOE will need to strike a balance in proprietary projects and non-proprietary, which is not an easy balance to make. Another response suggested that National Labs should be focused on fundamental research and not competing with industry. Having the National Labs assembling full size cells is not a good use of their skill set, and the labs should work with U.S. cell manufacturers (EnerDel, A123, JCS, etc) to have cells assembled for them. One final reviewer asked: with the recent plethora of high power li-ion cells for power tools, is there anything to learn by looking (small effort only) at these? For example, this reviewer indicates that manufacturers often have proprietary electrolyte additives for safety and cycle-life that can be gleaned by analysis on these cells. Overall this is a good plan, but very U.S.-centric.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

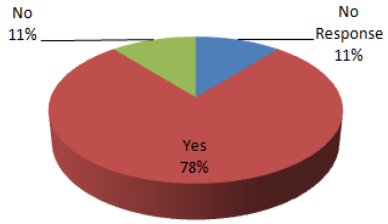
One reviewer commented that the new dry room should be very helpful. Another person felt that funding for this project is sufficient. However, funding should be reduced for those projects that are not making significant progress. Other comments were less positive. One reviewer stated the evaluation still remains difficult due to the limited description of planning and resources, while another indicated that it is unreasonable for ANL to do cell assembly. Adding to this, one individual noted that the funding for the dry room and equipments is not sufficient to build good cells, as far as the equipments go It will likely fail due to variance in the cells' build, and false negatives and positives will be obtained. Another person stated that manufacturing of quality 18650 cells requires substantial resource investment beyond what is considered in the scope of this project.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

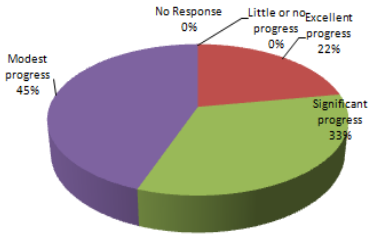
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Gen 3 Cell Status

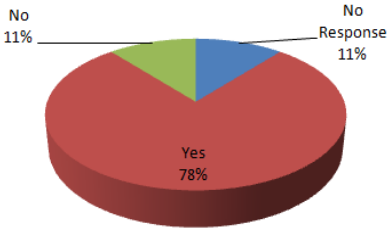
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



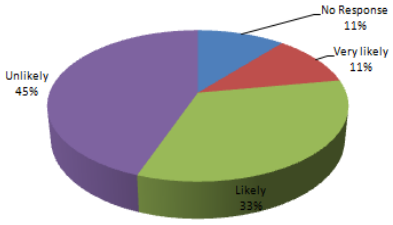
Question 3: Characterize the technical accomplishments and progress toward goals.



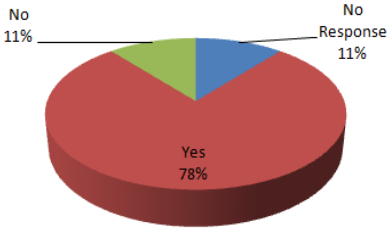
Question 2a: Are the goals of the project technically achievable?



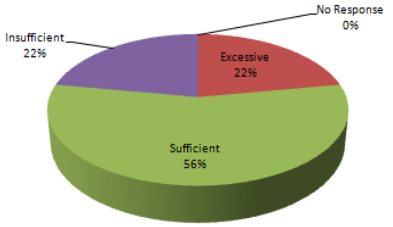
Question 4: How likely is the project team to move technologies into the marketplace?



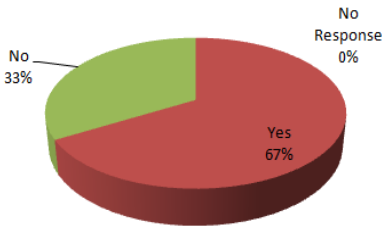
Question 2b: Have the technical barriers been identified and addressed?



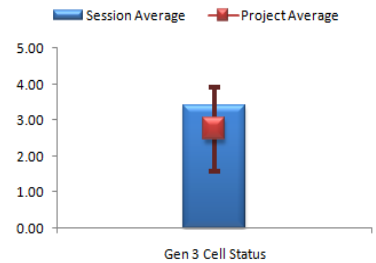
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Gen 3 Cell Testing (J. Christopherson, of Idaho National Laboratory)

Reviewer Sample Size
This project had a total of 7 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
All responses in this section were generally positive. One reviewer stated this project supports lithium battery development in the DOE program, while another (similarly) noted that the project serves as a support activity to overall DOE objectives. One other person commented that the goal of the program is to understand the life-limiting mechanisms and enhance battery lifetimes, which is in line with the objectives of the DOE program. Another added that studies of full cells using the identified materials are critical to the success of the program. One reviewer wrote that life testing and modeling is critical for implementation – this reviewer cannot wait to get real life testing even in final product, let alone in R&D cycles. One final reviewer remarked that the testing of cells being carried out at INL will help develop cells for HEVs and PHEVs, and thus reduce oil use.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
The first respondent indicated that the project scope is to carry out testing on cells developed at ANL, with no significant technical barriers. Another reviewer stated INL's testing program will lead to a better understanding of the degradation in lithium cells.

One other person said the project plans were to conduct accelerated aging on cells made by battery manufacturers (materials were provided to them for cell manufacturing), conduct tests on more samples, perform diagnostic analysis on torn-down cells that had undergone cycling, and use statistical methods for analysis of results. One reviewer commented "good," adding that this is straightforward testing and appears to be well performed. However, the researchers have not had success due to bad cells. The methodology used for the measurements are good; however, since no baseline is available from the manufacturers there is no way to assess the failed cells. If that baseline was available some additional knowledge could have been gained on the cell builds. The goals are therefore not fully achievable with the strategy chosen. One final reviewer asked: why even bother evaluating cells from a set that has leakers – even the non-leaking cells are highly suspect. This reviewer added it is always important to run a control – look for differences in cells and testing.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
One reviewer indicated that testing is an integral part of the program if li-ion batteries are going to make it into applications. Another person commented that, as a support activity, the project has provided timely and well-documented life cycle observations of Gen-3 cells. One person noted the results are online with planning. Some more comparison and evaluation of the cells' degradation with respect to the previous generation would be of value. Another person commented that they do not trust the data as presented, and that the program needs a lot more work. One other person remarked the analysis of the data obtained in this project seems to be very thin. The experimental design was not clearly stated. The use of fewer replicates will reduce the value of this work. One reviewer noted that Gen-3 cells with and without an electrolyte additive were tested. The methods used for accelerated aging are good, but the use of different manufacturers is not a good idea. This will not provide a good comparison as different manufactures have different methods of coating, calendaring and formation.

The PI needs to zone in on one manufacturer and the present experience may provide the basis for selection of one such company. The high temperature tests are good but the temperature needs to be below the decomposition of the electrolyte. The cell leakage eliminates the use of that manufacturer for future work. Another response stated that the studies on degradation show very rapid degradation. This is a failure and no real conclusions can be drawn based on leaking cells and fast degradation. No baseline cell established with the cell manufacturers, which hinders the ability to study if the fast degradation seems is due to the materials or due to the actual cell build itself.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

Responses to this prompt were generally negative. The first response stated that there are no direct market implications, while another reviewer commented that this is not new technology. Accelerated aging tests under high loads and using high temperatures is a common method. Another person stated that the results from these tests are inconclusive. One reviewer stated there are no good cell data, due to leaking cells and fast degradation, while another reviewer added that data reproducibility is questionable; using suspect cells is no good – better to get no data than misleading data.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

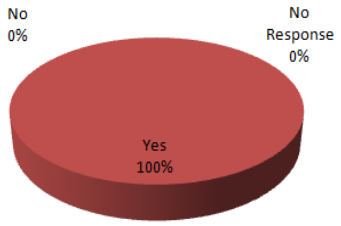
One reviewer commented that there is good work for the funding provided. Good data is provided by this group and this lab is an excellent resource for testing. Another person stated that the effort is not described but there is no evidence of problems. One respondent did not agree with the decision to keep testing at a small scale to cover a wider range of chemistries – you need to have valid data especially at early stages of R&D where you are going to make major decisions on which chemistry to pursue. This needs more resources to do valid testing. This is not a reflection on the PI – they are doing what they can, not what needs to get done! The final reviewer indicated that the results from this project seem to be limited to data that was gathered without much prior planning concerning the analysis of the data.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

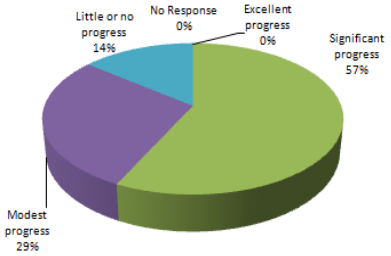
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Gen 3 Cell Testing

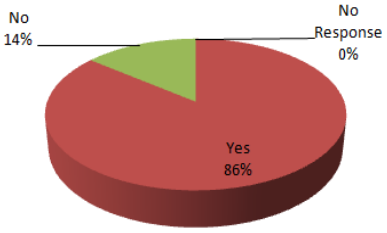
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



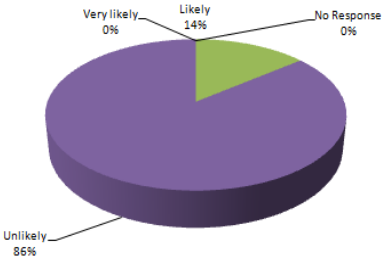
Question 3: Characterize the technical accomplishments and progress toward goals.



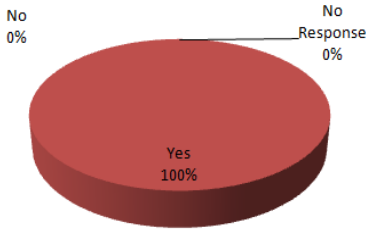
Question 2a: Are the goals of the project technically achievable?



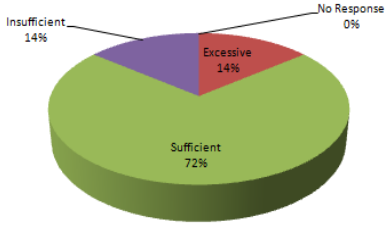
Question 4: How likely is the project team to move technologies into the marketplace?



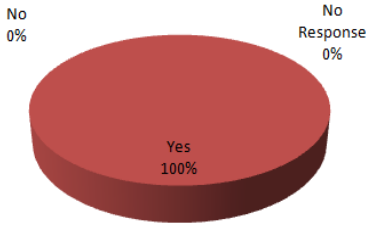
Question 2b: Have the technical barriers been identified and addressed?



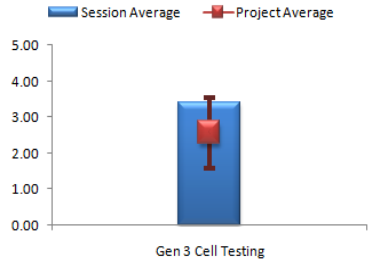
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Life Validation Testing Protocol Development (V. Battaglia, of Lawrence Berkeley National Laboratory)

Reviewer Sample Size
This project had a total of 6 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
One reviewer commented that calendar-life prediction is very important. Another stated that the development of test protocol is important to verify the achievement of the DOE objective regarding lithium battery performance. Similarly, one other reviewer wrote that making cells with optimum performance is in line with the long life requirement for the DOE PHEV program. One reviewer stated Battaglia et al.'s work will lead to better batteries and allow the realization of HEVs and PHEVs. This work will, in turn, help to reduce oil consumption. One final reviewer indicated that similar methodologies have been developed and have been widely employed for some time within the industry for the general process and methodology addressed in this work. However, understanding the general methodology may be useful for new developers who may be entering the market in the future.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
The first reviewer commented that this is a good plan to attack this important but daunting task. Another person wrote that the life test protocol and life estimation software and manual development are part of an integrated effort combining proper expertise and experimental activities in various labs. One other respondent stated that the project goals are to understand the role component and to get the best electrode configuration and use this information in a full cell by making improvements based on the studies on individual components. One final reviewer added that Thomas' contributions to this effort will provide confidence in the results published by this group because of his background and knowledge of model development based on statistical analysis. However, the group should strive to use physics-based models because the utility of their empirical models is limited to the data set used to develop the model. It is surprising that Thomas' methodology has not apparently been used by Bloom et al. to analyze Bloom et al.'s data. Perhaps this has been done and not published yet.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
One reviewer stated this is a very challenging task but the researchers are doing a good job in advancing this technology. Another individual commented that the results so far achieved are very interesting with very good progress in the way of a reliable statistical tool for life prediction. More evidence of the validation work should be presented with the level of confidence for the various chemistries and accelerating factors. One person remarked that the effect of battery models on the predicted life should be better clarified and analyzed. Another reviewer noted that the first step in the team plan is to study the component materials using diagnostic and characterization methods. Then the materials are studied using half-cells and then completed cells. In the meantime, modeling programs based on structure of the electrodes as well as system level modeling is carried out and the information fed back to optimize materials and systems used. It is a good method of optimizing but this reviewer did not see the difference between this work and the work carried out in the basic research area. There needs to be a demarcation between the two projects, and they need to make the best use of the funding obtained. One other reviewer commented that progress is too slow in this project. The lack of using a physics-based model is unacceptable. The results from the mechanism studies seem to be ignored by these empirical model developers. The final reviewer indicated that the

presenter wrote "by studying electrode formulations, different electrode designs, and newly developed materials, battery developers, automakers, and the DOE will have an increased knowledge of the limits of classes of technologies." The above is a very general statement, and no specific recommendation is found in the talk. This reviewer added that progress is very slow.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

The first reviewer indicated that this research has direct relevance to the market, adding that there is a currently no solid model to estimate and validate life. One reviewer wrote that the TVLT software tool, after complete validation and extension, may have a market application for battery developers and users. Another person commented that good progress has been made but no new technology was presented. One reviewer noted that this group may develop tools that will be useful to battery developers; however, the basic tools developed have been available from MATLAB for many years. One final reviewer wrote that this work has long way to go before it can be applied to any meaningful life verification of batteries.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

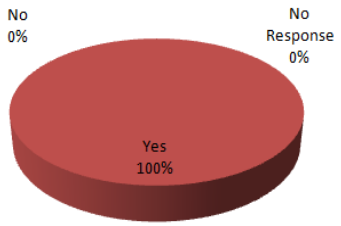
One reviewer commented that the involvement of multiple labs is an excellent approach in tackling this important issue, while another person added to this, stating that the integration of various National Labs is a way to optimize resources. To contrast, one respondent stated that the group could do more for the funding obtained. One final reviewer felt that funding for this project is excessive relative to the results presented. This reviewer added that these workers do not seem to be aware of other work in this area such as the SAFT model.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

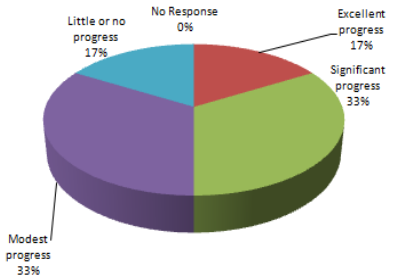
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Life Validation Testing Protocol Development

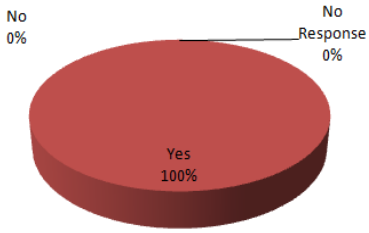
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



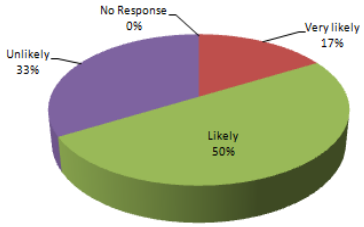
Question 3: Characterize the technical accomplishments and progress toward goals.



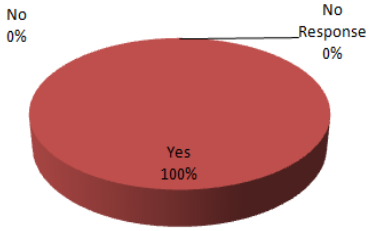
Question 2a: Are the goals of the project technically achievable?



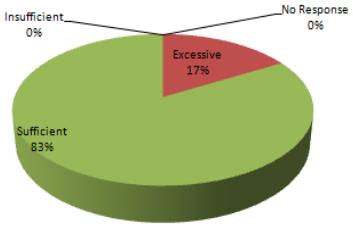
Question 4: How likely is the project team to move technologies into the marketplace?



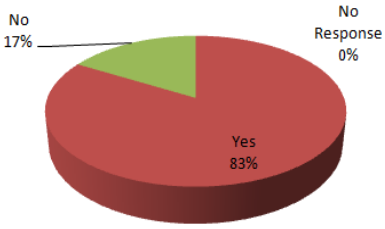
Question 2b: Have the technical barriers been identified and addressed?



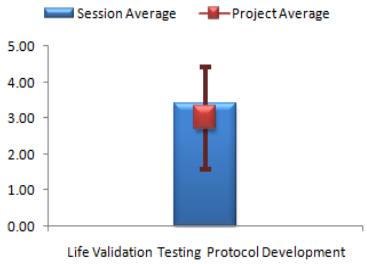
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Life Validation Testing Protocol Development (I. Bloom, of Argonne National Laboratory)

Reviewer Sample Size
This project had a total of 5 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
One reviewer commented that the development of test protocol is important to verify the achievements of the DOE objective on lithium battery performances. Another person indicated that the project provides an independent evaluation of non-DOE work to determine how DOE can use this information in their program. One other reviewer noted that Battaglia et al.'s work will lead to better batteries and allow the realization of HEVs and PHEVs. This work will help reduce oil consumption. One reviewer said similar methodologies have been developed and have been widely employed for some time within the industry for the general process and methodology addressed in this work. However, understanding of the general methodology may be useful for new developers who may be entering the market in the future.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
The first reviewer wrote that the life test protocol and life estimation software and manual development are part of an integrated effort combining proper expertise and experimental activities in various labs. Another respondent stated that the project plan was to use the FreedomCar test protocols and accelerated aging test protocols to study and to project life and also provide support for the update and validation the manual used for PHEV testing. One reviewer commented that Thomas' contributions to this effort will provide confidence in the results published by this group because of his background and knowledge of model development based on statistical analysis. However, the group should strive to use physics-based models because the utility of their empirical models is limited to the data set used to develop the model. It is surprising that Thomas' methodology has not apparently been used by Bloom et al. to analyze Bloom et al.'s data. Perhaps this has been done and not published yet. In contrast, one other reviewer felt that the current state of accuracy of the methodology is not clear from the presentations. In order for the methodology to be significantly deployed and/or accepted, demonstration and documentation of the accuracy of the model may be necessary and should be possible. The reviewer added that there appear to be plans to accomplish this in the future, and obtaining cells of industry-standard reproducibility from a significant mass-producer of li-ion cells may be necessary and may require cooperation with a significant mass-producer.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
One reviewer commented that the results so far achieved are very interesting with very good progress in the way of a reliable statistical tool for life prediction. Another person stated the first part of the program to benchmark the performance of commercially available cells is a good start. Battery level testing using batteries made by other manufacturers was also carried out. The manual written by INL was validated while carrying out the above tests. The use of 40°C to 45°C for testing is very good as it will not cause ambiguous results due to very high temperatures that would cause decomposition of the electrolyte. The method used for testing is consistent. This reviewer recommends working with local and well-known battery manufacturers. One reviewer stated that more evidence of the validation work should be presented with the level of confidence for the various chemistries and accelerating factors. Similarly, one individual though that the effect of battery models on the predicted life should

be better clarified and analyzed. One final reviewer indicated that progress is too slow in this project. The lack of using a physics-based model is unacceptable. The results from the mechanism studies seem to be ignored by these empirical model developers.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

The first respondent remarked that the TVLT software tool, after complete validation and extension, may have a market application for battery developers and users. One reviewer noted that the method of testing is not new. However, this reviewer added that the manual that is being written in collaboration with INL may have great technology transfer as well as marketing prospects. One respondent commented that this group may develop tools that will be useful to battery developers; however, this reviewer added that the basic tools developed have been available from MATLAB for many years.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

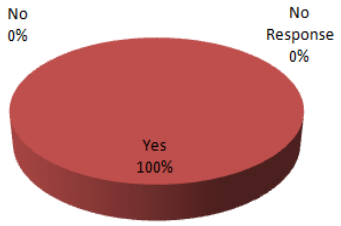
One reviewer stated that the integration of various National Labs is a way to optimize resources. One other person stated there is good work for the funding obtained. One final reviewer felt that funding for this project is excessive relative to the results presented. This reviewer added that these workers do not seem to be aware of other work in this area such as the SAFT model.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

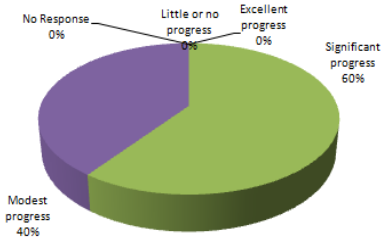
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Life Validation Testing Protocol Development

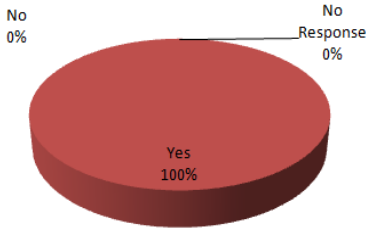
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



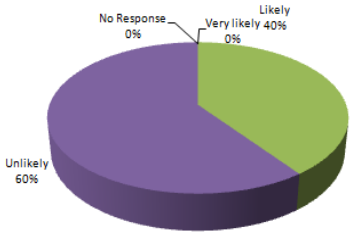
Question 3: Characterize the technical accomplishments and progress toward goals.



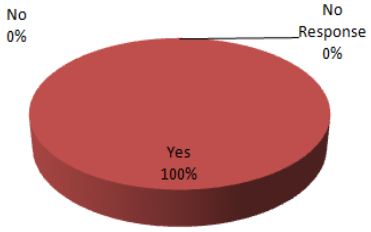
Question 2a: Are the goals of the project technically achievable?



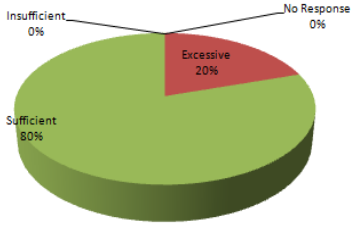
Question 4: How likely is the project team to move technologies into the marketplace?



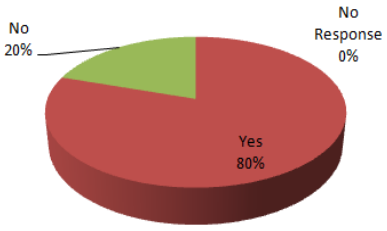
Question 2b: Have the technical barriers been identified and addressed?



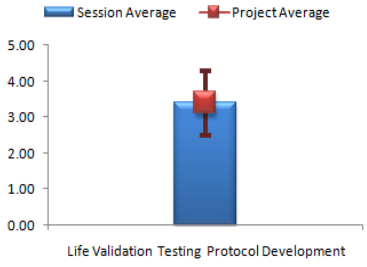
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Life Validation Testing Protocol Development (J. Christopherson, of Idaho National Laboratory)

Reviewer Sample Size
This project had a total of 8 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
One reviewer simply commented that the group is doing good work, while another stated that calendar-life estimation is an invaluable tool for the application of lithium-ion batteries. One other reviewer noted that the development of a test protocol is important to verify the achievements of the DOE objective on lithium battery performance. One reviewer noted that Battaglia et al.'s work will lead to better batteries and allow the realization of HEVs and PHEVs, which will in turn help reduce oil consumption. Another person remarked that there is a good cycle process in place. The group is working to develop a model, validate the model, check the results, check assumptions, make changes and go through the cycle again. The group plays an important role in a program where a technology's readiness for transition to production is being studied. One reviewer stated similar methodologies have been developed and have been widely employed for some time within the industry for the general process and methodology addressed in this work. However, understanding of the general methodology may be useful for new developers who may be entering the market in the future.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
The first respondent indicated that the life test protocol and life estimation SW and manual development are part of an integrated effort combining proper expertise and experimental activities in various labs. Another reviewer stated that the matrix assumed for the model is good and a lot more comprehensive than in previous years. This is a good effort to work on completed cells rather than just materials. One person remarked that Thomas' contributions to this effort will provide confidence in the results published by this group because of his background and knowledge of model development based on statistical analysis. However, the group should strive to use physics-based models because the utility of their empirical models is limited to the data set used to develop the model. It is surprising that Thomas' methodology has not apparently been used by Bloom et al. to analyze Bloom et al.'s data. This reviewer adds that perhaps this has been done and not published yet. One response stated that this seems a good plan, though it was hard to follow in such a short presentation. The battery sample size still seems very small to this reviewer. One other reviewer indicated that he or she would answer "maybe" to the above questions. This task is ambitious in scope. The task is certainly very important - we need to find a way to forecast cell life from limited data and to develop accelerated life testing methodologies. The problem, of course, is that it will take time to know whether the forecasting and acceleration methods work. Since degradation mechanisms are chemistry-specific, this task would be of most use if they looked at multiple cell chemistries, rather than focusing on Gen-2 or Gen-3. The last reviewer felt that the current state of accuracy of the methodology is not clear from the presentations. In order for the methodology to be significantly deployed and/or accepted, demonstration and documentation of the accuracy of the model may be necessary and should be possible. There appear to be plans to accomplish this in the future, and obtaining cells of industry standard reproducibility from a significant mass-producer of li-ion cells may be necessary and may require cooperation with a significant mass-producer.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

One reviewer thinks that a good foundation has already been established and further validation and refinements are necessary to make this model robust. Another person added good work, and indicated that the group needs to have more variations in SOCs as well as depth of discharges (DoD). The DoD also affects long term cycle life. The group also needs to collect DoD information with respect to temperature. One other respondent stated that the results achieved so far are very interesting with very good progress in the way of a reliable statistical tool for life prediction. More evidence of the validation work should be presented with the level of confidence for the various chemistries and accelerating factors. The effect of battery models on the predicted life should be better clarified and analyzed. One reviewer remarked that, in the talk a large number of things have been proposed to be done, but this does not come to any specific conclusion or accomplishment so far. Lessons learned are proposed to be incorporated in the revision of the TVLT manual, but the overall progress is slow. Another respondent wrote that this task is doing a good job of trying to get a handle on a very difficult problem. It is important that the PIs keep their statistical models grounded in physics, by staying in communication with the other tasks in the DOE programs that are trying to understand the physical mechanisms that affect life. One reviewer added that it was hard to judge actual progress from the talk. The work seems well-designed and poised to generate useful data, but this reviewer could not judge the value returned to date. One final reviewer stated that progress is too slow in this project. The lack of using a physics-based model is unacceptable. The results from the mechanism studies seem to be ignored by these empirical model developers.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

The first reviewer indicated that developers will immensely benefit from this work, while another reviewer added that the plan seems good and developers want and need this sort of information, so transfer should be easy – there is a lot of pull from customers. One person suggested that the TVLT software tool, after complete validation and extension, may have a market application for battery developers and users. Another commented: good work on actual cells compared to work on models. The changes made have been evaluated and introduced into future models and validated again. To contrast, one reviewer remarked that this group may develop tools that will be useful to battery developers; however, the basic tools developed have been available from MATLAB for many years. One final reviewer stated that his or her main concern with this task is, who is it benefiting? This comment applies to many aspects of the DOE's programs and not just this particular task. The U.S. National Labs publish lots of information about batteries from developers in the USABC program. In general, these publications are of highest value to the Asian competitors of the U.S. companies. In contrast, while Asian (Japanese, Korean, and Chinese) governments are funding battery development at a much higher level of investment, those governments do not publish the results to the rest of the world. It would be of more use to U.S. battery companies if the U.S. National Labs tested and reverse-engineered batteries from the leading Asian companies (Panasonic, Sanyo, Samsung, etc.) and published those results. The U.S. DOE labs provide a valuable test resource to U.S. battery companies, but that resource's value would be maximized if the test results were kept confidential for the U.S. companies, or at least published only upon approval from the companies.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

One reviewer commented that this is appropriately a multi-lab effort, while another noted that the integration of various National Labs is a way to optimize resources. One reviewer indicated that the funding is sufficient for the work carried out. Another individual noted that this task requires lots of

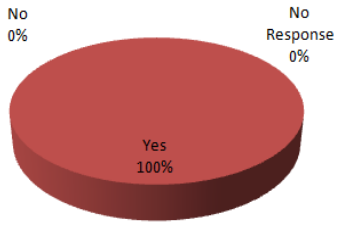
cycler channels to generate enough data to be of use. Similarly, one reviewer felt that the sample size still seems small for the amount of work required to get good data. Also, this reviewer asks, can any of the actual testing be outsourced and let the national labs focus on data interpretation? One final reviewer commented that the funding for this project is excessive relative to the results presented. The reviewer added that these workers do not seem to be aware of other work in this area such as the SAFT model.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

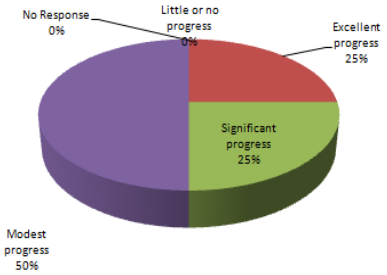
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Life Validation Testing Protocol Development

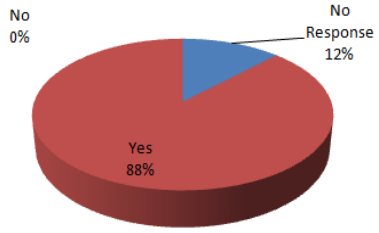
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



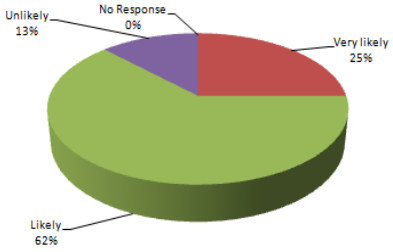
Question 3: Characterize the technical accomplishments and progress toward goals.



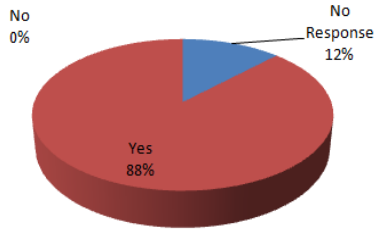
Question 2a: Are the goals of the project technically achievable?



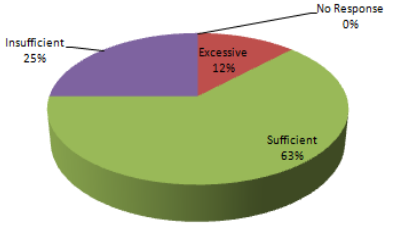
Question 4: How likely is the project team to move technologies into the marketplace?



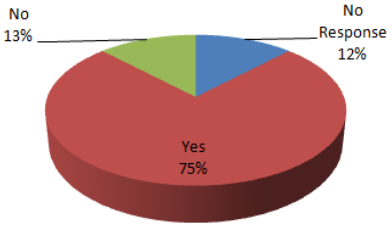
Question 2b: Have the technical barriers been identified and addressed?



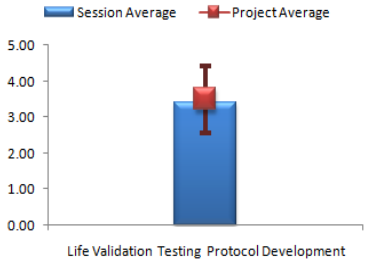
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Life Validation Testing Protocol Development (Ed Thomas, of Sandia National Laboratories)

Reviewer Sample Size
This project had a total of 6 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
One reviewer commented that the development of test protocols is important to verify the achievement of the DOE objective on lithium battery performances. Another person added that Battaglia et al.'s work will lead to better batteries and allow the realization of HEVs and PHEVs. This work will help reduce oil consumption. One respondent stated that the models developed are correlated to work performed by J. Christopherson. The model should help in understanding if the chemistry is ready for transition into the market for a 15-year life. Adding to this, one reviewer noted that similar methodologies have been developed and have been widely employed for some time within the industry for the general process and methodology addressed in this work. However, understanding of the general methodology may be useful for new developers who may be entering the market in the future. Additionally, the inclusion of specific error and variance effects as studied in this project may be useful, even in the existing industry which may already be employing similar general processes and methodology. The last person did not see the utility of empirical models as this stage of development. It does not really add to knowledge, and instead looks like mostly a fitting/extrapolation model. This reviewer would prefer to put an emphasis on Dees' fundamental model.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
The first respondent stated that the life test protocol and life estimation software and manual development are part of an integrated effort combining proper expertise and experimental activities in various labs. Another reviewer commented that the model is using or looking for practical goals such as end-of-life criteria, etc. The estimate of life based on the data provided and the uncertainty in the model provides significant data on the life of the particular chemistry studied. The model can be used by all battery users to predict battery life. One person remarked that Thomas' contributions to this effort will provide confidence in the results published by this group because of his background and knowledge of model development based on statistical analysis. However, the group should strive to use physics-based models because the utility of their empirical models is limited to the data set used to develop the model. It is surprising that Thomas' methodology has not apparently been used by Bloom et al. to analyze Bloom et al.'s data. Perhaps this has been done and not published yet. Another reviewer indicated that he or she does not trust empirical models to have anything but a very narrow range of utility. Adding to this, one final reviewer stated that the current state of accuracy of the methodology is not clear from the presentations. In order for the methodology to be significantly deployed and/or accepted, demonstration and documentation of the accuracy of the model may be necessary and should be possible. There appear to be plans to accomplish this in the future, and obtaining cells of industry-standard reproducibility from a significant mass-producer of Li-ion cells may be necessary and may require cooperation with a significant mass-producer.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
One reviewer stated that this is a good model for predicting life of battery. The new factor of memory effects is a significant factor that should be studied. It has not been studied much and not much information exists in the literature on this. Since several combinations can be used, a statistical analysis should be performed to choose the factors that would most affect the life such as effect of

thermal environments and high SOC on cycle and calendar life at various stages of the initial life of the cell. Another person commented that the results so far achieved are very interesting with very good progress in the way of a reliable statistical tool for life prediction. More evidence of the validation work should be presented with the level of confidence for the various chemistries and accelerating factors. The effect of battery models on the predicted life should be better clarified and analyzed. Following up on this, one person indicated that the uncertainty in the life prediction appears to be high. Methodology is applied only to cells - may not be same for the packs. One respondent wrote that the work is technically fine and the PIs obviously know their stuff, but in view of the small sample sizes and cell-to-cell variability this reviewer does not think the data quality justifies such a model. Much of the variability seen may actually be from "special causes" and not reflect the random variation inherent in the design. This kind of model might be more relevant in the future once a system is better designed and once consistent data can be obtained. One final reviewer stated that progress is too slow in this project. The lack of using a physics-based model is unacceptable. This reviewer adds that the results from the mechanism studies seem to be ignored by these empirical model developers.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

The first respondent commented that the TVLT software tool, after complete validation and extension, may have a market application for battery developers and users. One other reviewer said that model validation with models used to understand experimental data is an excellent tool to better predict calendar and cycle life for batteries. In contrast, one reviewer wrote that this group may develop tools that will be useful to battery developers; however, the basic tools developed have been available from MATLAB for many years. Another respondent commented that he or she does not trust empirical models to have anything but a very narrow range of utility. As a developer, this reviewer would not value this work – he or she would prefer to just look at the data. However, the group's plans to look at memory effects etc. are good if DOE continues this work. This reviewer still thinks the 100 18650 cells for future model validation is too small a sample size.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

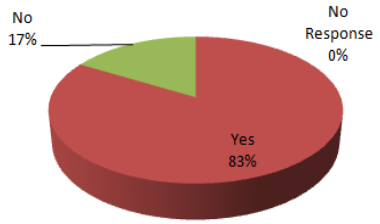
One reviewer stated that the integration of various National Labs is a way to optimize resources, while another person commented there is a good volume of work for the funding obtained. In contrast, one respondent does not see the utility of empirical models at this stage of development. This does not really add to knowledge, and instead looks like it is mostly a fitting/extrapolation model. This reviewer would prefer to put emphasis on Dees' fundamental model. One final reviewer added that funding for this project is excessive relative to the results presented. These workers do not seem to be aware of other work in this area such as the SAFT model.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

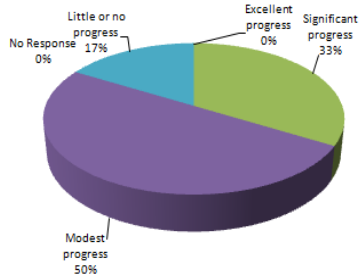
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Life Validation Testing Protocol Development

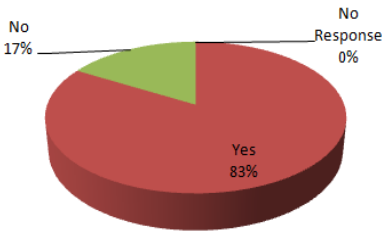
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



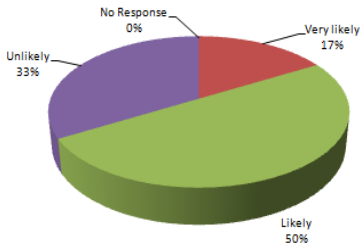
Question 3: Characterize the technical accomplishments and progress toward goals.



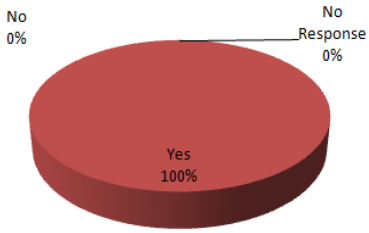
Question 2a: Are the goals of the project technically achievable?



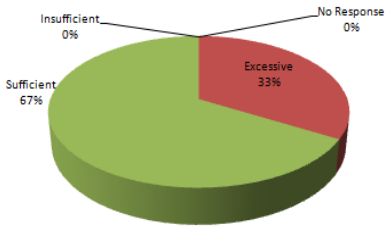
Question 4: How likely is the project team to move technologies into the marketplace?



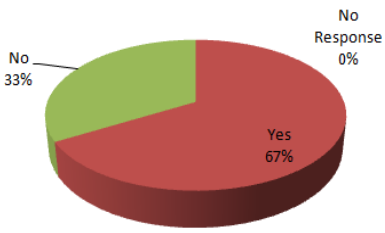
Question 2b: Have the technical barriers been identified and addressed?



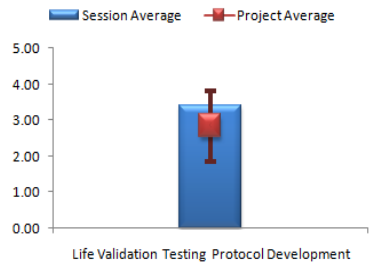
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Low-Cost Components: Development of Advanced High-Power and High-Energy Battery Materials (Khalil Amine, of Argonne National Laboratory)

Reviewer Sample Size

This project had a total of 10 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?

Multiple reviewers commented on the need for higher energy and lower cost materials for PHEVs. One person stated that this project is necessary to advance the state-of-the-art, while another reviewer noted that the project addresses the key aspects of cost reduction and increased stability of Li batteries. One response stated that low-cost components reduce the overall cost and increase the safety of batteries for HEV and PHEV. Following on this, one person wrote that Amine's work on this project will lead to less oil consumption due to the use of HEVs and PHEVs in the near future. One final reviewer indicated that this activity provides information on electrode active materials with some unique attributes and which may be of use for theoretical consideration. This reviewer added that the review of the practicality of various processing methods for some of the materials discussed in this work is useful for any potential considerations beyond theoretical.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.

The first reviewer stated that this project addresses the use of coatings for electrode materials to decrease the issues at the surface of the electrodes, while another person commented that there is a good rationale for 1/3, 1/3, 1/3 NMC material. Similarly, one respondent noted that the coating strategy is promising. The high voltage for the "1/2" materials is probably not practical, but nevertheless the material has great promise for the future also for HEV systems and not only portable systems. The co-launch of portable and HEV can give significant cost advantages, especially in beginning of HEV or PHEV launch, where material needs are small and pricing would otherwise (without the use in portable applications) be high. This is a good launch approach for the materials maker, which would stabilize the supply base for that component. The same strategy could be used for the anode materials and should be looked into; well done. Another reviewer remarked that Amine's work on the $LiC_2O_4BF_2$ additive is significant and will lead to improved anodes in lithium ion cells. His work that has produced the ANLCC cathode material will lead to rapid development of cells for HEVs and PHEVs because of the high voltage capability of this cathode material. Also, the cathode AlF_3 coating will lead to safer cells. One reviewer wrote that the approach is a following of the previous project (11286) with a clear perception of the technical barriers and adequate strategy to find solutions. It is not clear how the low cost target is addressed in the project. Another person suggested that close cooperation with a significant mass-producer of Li-ion cells or Li-ion materials would be necessary for useful deployment of this project's findings. One reviewer is not fully convinced by the work related to AlF_3 coating. If the coating is not conformal, and it is porous, eventually it will lose its protective character. However this reviewer is intrigued by the absence of power loss even though the coating is 20 nm! They need to verify this by long-term high temperature storage.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

One respondent indicated that this work showed that the AlF_3-coated on different cathodes (NMC, NCA, NM, $LiCoO_2$) have lower impedance, better cycling characteristics at high temperature, improved safety, and reduced metal ion dissolution when compared to uncoated cathodes. Another

person commented that the work related to the high energy material is outstanding. This is an exceptional result and should be of great importance to PHEV development. One individual stated that Amine's AlF_3 cathode coating provides better capacity retention with cycling. This process will probably be adopted by battery manufacturers to extend the life of their cells or to reduce the cost of cells, assuming their original cells were able to meet the life requirements. Similarly, one reviewer stated that this is good basic research to show the effect of coatings on the cathode particles. The surface studies have shown that the coatings are effective in maintaining the structure of the cathode crystals. DSC results show a delay in the onset of thermal runaway but it does not show any inhibition of thermal runaway. The charging to higher voltage may look good at this point, but safety tests on completed cells need to be carried out to determine its true safety. Collaboration with Sandia will help understand the safety of completed cells. Another reviewer stated that, as demonstrated in the investigator's other talk, this program is well thought out and reflects the many trade-offs that are involved in such work. This reviewer is not sure that ANL should be developing their own additives without first looking at what is already in use by industry, but they do appear to have been very successful. Ability to improve packing density of ANLCC is very good. AlF_3 coating quality looks very good indeed. The uneven AlF_3 coating of non-spherical particles might actually be an advantage if the thinner coating were on edge planes where lithium ions are going in and out of for some materials. (This is reported for the olivine, although not sure the olivine needs AlF_3 coating.) One person commented that the cycle tests were not compared on the same basis, C/2 vs. 1C etc., making it hard to judge the actual cycling improvements with AlF_3 coated material. The data on cobalt shows unusually low cycleability, which puts cell design in question for the cycleability; however, besides these items, this is very good work. The AlF_3 coated materials is significant progress on the nickelates. One reviewer wrote the technical results are well justified with complete characterization results, but added that the economical part of the target is not presented. The final decision will be also based on economical considerations. It is suggested to include cost analysis of the materials used and on the processes needed to introduce them. One final reviewer indicated that there is no clear route for the materials identified in this work to make their way into actual applications relevant to HEV systems. Cost aspects of any of the materials discussed or of the related processing methods is unknown based on this work. Safety improvements apparently achieved through AlF_3 coating look positive, but more evidence of abuse response in configurations closer to actual applications would be a desirable aspect of any potential future work.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

The first reviewer noted that they have already licensed the technologies, while another stated that there are already in place agreements to transfer results to the marketplace. One reviewer commented that Amine's cathode coating process will probably be adopted immediately by battery producers because the coating improves the life of the cells. This coating will also improve the safety of the cells. One other reviewer added that the materials look attractive for PHEV, but obviously needs more safety work as is already planned. The publication rate of the group is also impressive. One respondent noted that the co-existence of a cathode with portable solutions gives cheaper materials in mass production and easier to hit cost targets, especially in the beginning of development, and especially for PHEV. Another reviewer commented that there are other Universities working on similar coatings. There needs to be collaboration to optimize technology transfer and marketing. One final reviewer wrote that this task has developed interesting new materials for Li-ion batteries and is to be commended for its work on materials invention. It is very good that this task recognizes the importance of synthesis conditions to affect particle morphology which in turn affects materials performance. However, the L333 material and Ni-Mn materials appear to be ready for

commercialization – which is not the role of the national lab. This reviewer added that much of the talk sounded like a sales pitch, not a scientific presentation.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

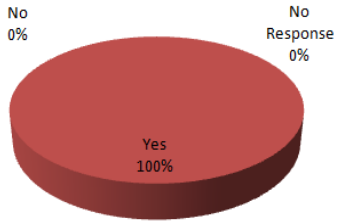
One reviewer stated that the resources seem adequate to the efforts, while another commented that there is good work for the funding obtained. Similarly, one person wrote that it appears that funding is on the right level. One other reviewer stated the group is doing very well and well positioned for follow-on work at ANL and Sandia. One respondent noted that Amine's work is producing rapidly useful results in the form of improved materials for the anodes and the cathodes in lithium ion cells. His research program should be expanded by a higher level of funding to enable him to produce even more advances in lithium ion cell technology. To contrast, the final reviewer indicated that scale-up and optimization of materials synthesis processes is not the role of the national lab. That work, if it is to be done at a national lab at all, should be funded under work-for-others contracts, not DOE.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

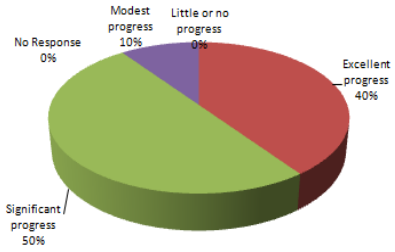
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Low-Cost Components: Development of Advanced High-Power and High-Energy Battery Materials

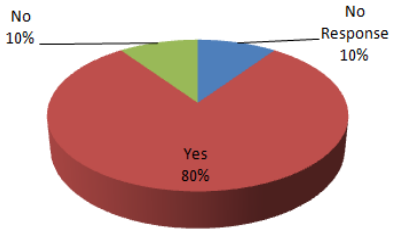
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



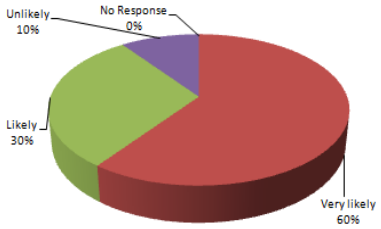
Question 3: Characterize the technical accomplishments and progress toward goals.



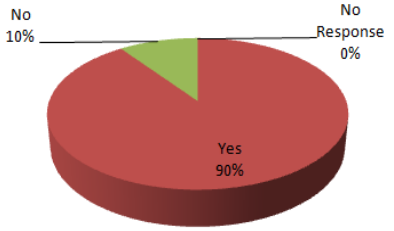
Question 2a: Are the goals of the project technically achievable?



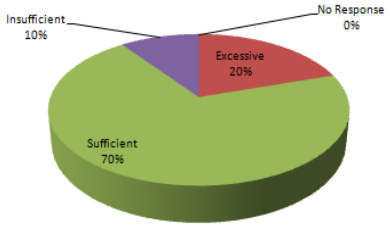
Question 4: How likely is the project team to move technologies into the marketplace?



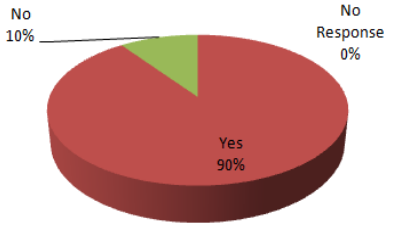
Question 2b: Have the technical barriers been identified and addressed?



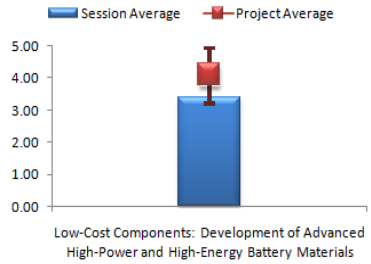
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Low-Cost Components: Screening of Advanced Battery Materials (Andrew Jansen, of Argonne National Laboratory)

Reviewer Sample Size
This project had a total of 9 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
One reviewer commented that this is an important to advance to next generation cells, while another person indicated that cost reduction is another key objective of the DOE Battery program. One other reviewer stated that new lower cost materials are critical to achieve the cost targets of the program. Similarly, one response noted that the program is still far away from its cost goals, so we need this type of work. Another commented that Jansen's work may lead to better batteries for HEVs and PHEVs, which would in turn reduce the consumption of oil. One reviewer felt that there is little transfer and communication of this valuable info to the rest of the U.S. battery community. The presentations are not enough. There should be full open access to this data for U.S. developers. One final reviewer stated that low cost material studies will help reduce the cost of batteries for the HEV and PHEV, but it is necessary to understand if the low-cost materials will provide the same performance as those in the market. Their safety also needs to be well understood before they can be used to manufacture the future cells.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
One reviewer stated that this is a good approach, if very dependent on what materials come available. Another respondent commented that Jansen's screening studies may help deploy better battery materials. Hitachi SMG anodes may be worthy of additional study. The same can be said about Hitachi's soft carbon anode material. One other person was not sure how they identify candidate materials. They are inevitably somewhat at the mercy of vendors. Having said that, ANL seems to have good contacts in the program, and they are recognized worldwide as a place to get materials validated. Thus, this reviewer thinks their evaluation program is a reasonable screening method. One reviewer response stated that the approach is consistent with the identified barriers and the available budgets. The selection of commercial materials will require a better approach: raw material costs must be considered in terms of cost-effective materials able to reduce specific and life cycle cell costs. In addition, the materials used in other battery subprograms should be considered in the overall evaluation. One final reviewer felt that, with the choice of new low cost materials in the market, this goal is very achievable. Continuing investigation of the materials from different suppliers is good work. At some point, a decision will have to be made to choose one and make improvements for that particular system.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
One reviewer commented that these are good studies and necessary to be abreast of new technologies, while another respondent stated that the technical progress is adequate to the type of experimental survey. More correlation to cell and battery development in the battery program would be advisable. Economical analysis must support technical work. One other person indicated that some of the results look pretty promising. The level of screening is adequate for a first look before going into the more costly and extensive studies on safety, etc... Impact of packing density is recognized as an issue. This makes the cells bigger and indirectly heavier (more electrolyte, packaging). One person remarked

that Jansen's project has shown that some materials from ConocoPhillips, for example, may meet the needs of HEVs and PHEVs battery manufacturers. One reviewer stated that there is a good approach, but added that the researchers need to zone in on a system -cathode / anode and electrolyte that will keep down the cost and provide the required performance for both cycle as well as calendar life. Another response indicated that the data acquisition appears to be OK, but the project may want to focus a little bit on sub-optimizing electrode formulation. A low conductive Mn-phosphate for instance will require a bit more carbon. This could help put the theoretically promising materials in better light, something that can stimulate more developments and optimization from the material's manufacturer. One final reviewer remarked that the project provides an independent evaluation of electrode materials. The same information should already be widely available to significant developers of mass-produced li-ion cells, and the activity of this project may be completely redundant on this basis.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

The first reviewer stated that, although technology transfer is not possible under this work, the study may provide insight into a choice of components that would be better suited for the HEV and PHEV applications and could be of marketable quality. Another respondent commented that there is some possibility that this work might have a minor influence on material selection to a developer who was not yet in the marketplace but who might be entering the market at some point in the future. One response indicated that the technology transfer is mainly internal to the program and to material developers. Analysis of the impact on DOE Battery Program cells/chemistries may give more value to the activities. Adding to this, one reviewer felt that the collaboration is not open enough, adding that there is no price ($/kg) reference. One person remarked that deployment is not in nature of this work. One respondent wrote that the technology is coming from the outside, but if any of these get incorporated into the main program it will accelerate implementation. This is generally to be viewed as a low LOS program to cover our bases and an insurance policy. One final reviewer stated that Jansen's results may be used by ConocoPhillips, e.g., to convince battery manufacturers that they have anode material worthy of evaluation. The Mn olivine material does not have the needed capacity and should not be tested any further.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

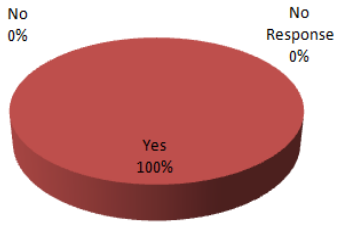
One reviewer stated that adequate studies are being carried out for the funding level, while another commented that funding for this project is sufficient. One other reviewer indicated that the work done is appropriate for the funding received, and this reviewer challenged the PI with finding more materials and stimulate discussions with material's maker on regular basis. One response commented that the resources seem adequate in view of the limited list of available materials that meet the cost requirements. Again, this should be viewed as a low level activity to give vendors a chance to bring new materials to the program. But care must be exercised in deciding which materials to evaluate so as not to divert too much effort from the main program thrust. The program seems to have a good balance. One person remarked that the cost analysis should integrate the technical one. The final reviewer added that, although the quality level of the work in this project is adequate, the basic focus of this project seems unnecessary.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

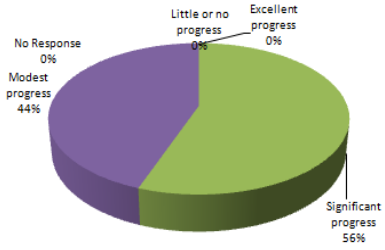
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Low-Cost Components: Screening of Advanced Battery Materials

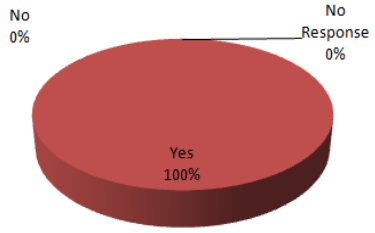
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



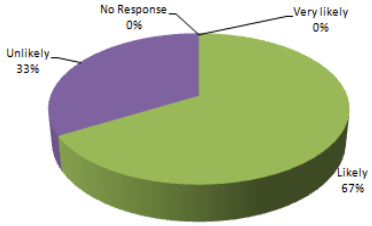
Question 3: Characterize the technical accomplishments and progress toward goals.



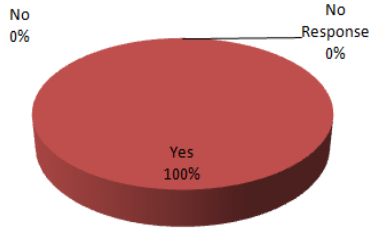
Question 2a: Are the goals of the project technically achievable?



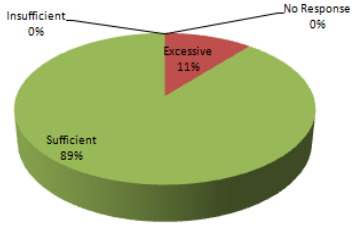
Question 4: How likely is the project team to move technologies into the marketplace?



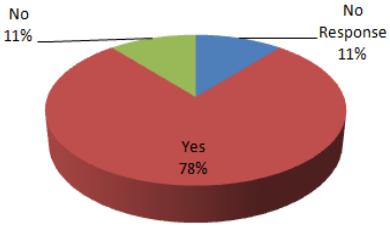
Question 2b: Have the technical barriers been identified and addressed?



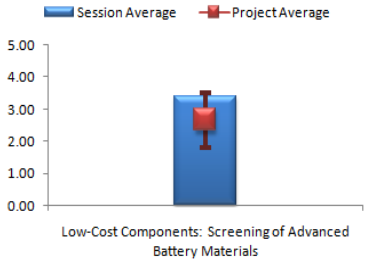
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Low-Temperature Performance Characterization (Andrew Jansen, of Argonne National Laboratory)

Reviewer Sample Size
This project had a total of 8 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
One reviewer noted that low-temperature performance is very important for vehicles, while another added that the low temperature studies are functional to reaching DOE targets for lithium batteries. One respondent noted that low temperature power performance is still the performance metric that dictates battery size, weight, and cost (also safety is easier the smaller the battery can be made). Another reviewer added that Jansen's work on low temperature use of lithium-ion cells may lead to reduced oil use if he can improve the performance of these cells at low temperatures, which would speed up the development of lithium-ion cells for HEVs and PHEVs. Another person stated that improvement in our understanding of low temperature performance limitations or phenomena may aid the achievement of improvements in low temperature performance by developers, and in turn, this may lead to the ability to reducing the size of li-ion battery pack systems, which may sometimes be oversized relative to room temperature power capability in order to better approach low temperature engine crank requirements in HEV applications. The last response remarked that low temperature studies are critical as this information is needed to not only understand limiting mechanisms, but also to understand issues related to performance in low temperature environments. This reviewer added that the group needs to better define what the low-temperature goal is and what the needs of the HEV and PHEV markets are.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
The first respondent stated that the strategy is very simple: screen major components to identify performances at low temperature and find alternatives. The technical barriers identification will be the result of the project. One reviewer added that this work showed that surface modifications do not have a significant effect on low temperature performance. One other respondent commented that the experimental data was explained well with theoretical equations. The increased power characteristics with increased surface area have been studied well. In contrast, one reviewer asked: what are the goals anyway? This reviewer was confused by the general task of improving low-temperature performance, adding that they should instead highlight the USABC targets (0°C, -10°C, -20°C etc.). One other reviewer asked: can't the Dees modeling help guide this work more? The author gave a fairly long list of things to examine. This reviewer thinks the model should help prioritize Andy's work, even though it cannot provide the "answer." One final reviewer added that Jansen's work has shown that it is unlikely that lithium ion cells will be able to provide low-temperature service without increasing significantly the surface area of the active materials.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
One reviewer noted that this task has done an excellent job of carefully designing experiments, analyzing the results, and creatively thinking about what to do next. While no "magic bullet" has been found, this task has done an excellent job of laying out the real hurdles in trying to improve the important problem of low-temperature performance. The work should also include other times besides ten-second impedance, such as one- and sixty-second, as these times are also of interest for HEVs and PHEVs. Another respondent commented that this work has showed that surface

modification of graphite and soft carbon does not affect the low temperature performance. Also, it showed the impedance response at low temperature is dominated by Butler-Volmer kinetics and not diffusion. Another person commented that the researcher has done excellent work, but it is a challenging task and this reviewer is not sure we see the light as of yet. Another reviewer added to this, stating that the group has done a lot of good work to understand what the problem is or, more correctly, what it is not. This was good work, although this reviewer was not sure that the real cause of the -30°C polarization is yet known. The reviewer adds that, without this understanding, it is difficult to have confidence that any of the proposals will help overcome the problem. Another respondent stated that the results are in line with the broad characterization planned in the project but are not yet able to give clear answers for the identification of technical barriers solving the low temperature problem. Another reviewer wrote that this activity provides some useful background regarding the nature of the limitations in low temperature performance in Li-ion systems. However, there does not appear to be any strong evidence that further work in this project will result in fundamental improvements in low temperature performance. Future work should focus only on more detailed study and investigation of the root causes of low temperature performance limitations. One reviewer commented that several variables have been studied. Different carbons (with different surface area), surface modifications, etc. have been studied to determine performance improvements at low temperatures. The electrolyte plays a significant role in the transportation of the lithium-ions. Hence this should be studied in more detail. It is a good choice of future work with the low temperature ionic liquids. The aqueous system is not a good idea as it is well known that this chemistry experiences large losses in performance in the presence of humidity. Aqueous systems may require large modifications of the cathode and anode. Working on a wide temperature range electrolyte or cell is more of a challenge and may be more useful than just a low temperature operating cell. One final reviewer wrote that Jansen's work has shown that the low temperature performance of lithium ion cells may not be sufficient to meet the needs of HEVs and PHEVs. Consequently, this reviewer thinks that his study should be ended unless significant results can be obtained in the near future based on exploiting some of his proposed future work.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

Results to this prompt were mixed overall. The first reviewer stated that, if the results are good, they will find immediate application. Another person commented that technology transfer is claimed for a novel electrolyte. One other reviewer added that, if the low-temperature issues are overcome, then it will have a very high likelihood of being used in the market. This reviewer added that, low temperature electrolytes do exist, as shown by the Jet Propulsion Laboratory with the Mars rover batteries. One person was not convinced that -30°C is even a real problem. Furthermore, this reviewer suspects that solutions, even if found, will involve other trade-offs in more important areas that will preclude implementation. One final reviewer stated Jansen's work shows clearly that the commonly used materials in Li ion cells prohibit the use of these cells at low temperatures. He should document as completely as possible what the lowest temperature would be for the use of lithium ion cells in HEVs and PHEVs.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

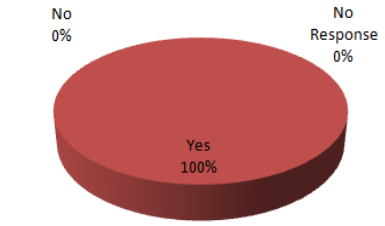
One reviewer remarked that the resources seem to be adequate to the planned work, while another added that adequate work has been carried out for the funding obtained. One other person commented on the good teamwork between Dees and Jansen. The final reviewer disagreed, stating that funding for this project is excessive based on the results obtained.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

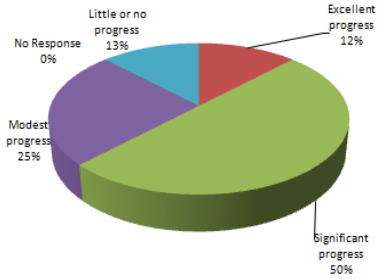
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Low-Temperature Performance Characterization

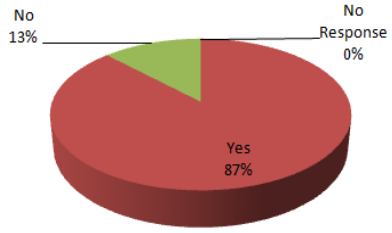
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



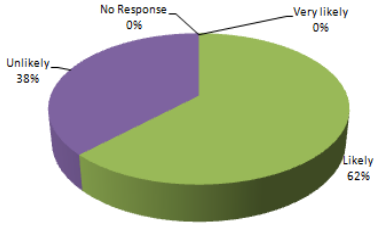
Question 3: Characterize the technical accomplishments and progress toward goals.



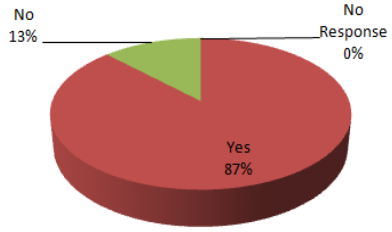
Question 2a: Are the goals of the project technically achievable?



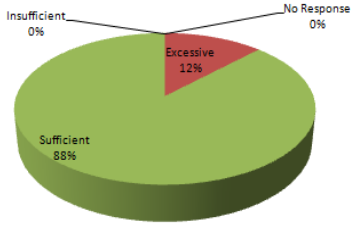
Question 4: How likely is the project team to move technologies into the marketplace?



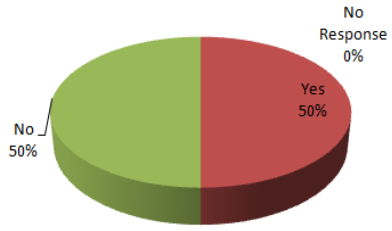
Question 2b: Have the technical barriers been identified and addressed?



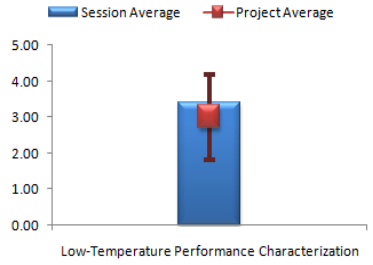
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Low-Temperature Performance: Performance Modeling (Dennis Dees, of Argonne National Laboratory)

Reviewer Sample Size
This project had a total of 7 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
Responses to this prompt were generally positive. One reviewer wrote that the work is very pertinent to the overall objective, while another respondent added that low temperature behavior of Li-ion batteries is still a key target for the DOE program. One person commented that low temperature power performance is still the performance metric that dictates battery size, weight, and cost (also, safety is easier the smaller the battery can be made). One other reviewer indicated that Dees' work on low temperature performance may lead to improvements in the lithium ion cell for use at low temperatures. If successful, this reviewer added, Dees' work may lead to the reduction of oil by using lithium ion cells at low temperatures in HEVs and PHEVs. The final reviewer noted that it does address the issues with low temperature performance of Li-ion cells, but added that the goals can be better defined to depict how low the temperatures need to be.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
The first reviewer commented that lithium metal deposition is a key problem and worthy of being well studied. One reviewer stated that the projects plans for investigating / quantifying lithium deposition at low temperatures appear to be sound and success in this area will provide useful information. Another response indicated that the approach is very sound and the PI is working very well with Andrew Jansen and the lab people. One other reviewer remarked that Dees' approach may yield results that might / will help us understand what happens at low temperatures. His approach is yielding useful information about the mechanisms that occur at low temperatures. One person indicated that his or her answers to this deployment strategy are "maybe." One final reviewer noted that the electrochemical model is good. It takes into account all the steps in the intercalation process and the limitations in obtaining 100 percent energy efficiency. The limitations of modeling are well understood. If the parameters used in the model are not reasonably close to reality, the model can either provide completely false data that can or cannot be detected. Having experimental data to correlate to the modeling helps understand if the data from the models is way off.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
One reviewer stated that Dees' results indicate that his approach may lead to a deeper understanding of the processes that occur at the anode on charge in particular. Another reviewer commented that good work is being carried out with the modeling, especially in understanding the limitations of the model and correlating it to experimental data. The calorimeter work will substantiate the results from the modeling work. Modeling the performance at low temperatures can also provide some insight into what changes need to be made with the materials or electrolyte to get better performance at low temperatures. Adding to this, one person remarked that there is a good use of modeling to show self-consistent approaches between impedance and pulse behavior of the anode - an extremely challenging task. This reviewer agrees with the presenter that impedance rise at low temperatures is the main issue, as this will invariably tend to drive the electrode into lithium plating. One reviewer stated that the progress seems to be limited and quite slow according to the presented results, while another respondent was still not fully convinced that the objective will be met.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

The first respondent stated that this project is very relevant to developers. Another reviewer noted that good modeling methods are critical to understanding as well as supporting the experimental data. Good models help in designing not only the cells but also the batteries. One reviewer commented that there was no evidence of significant technology transfer until now. Another reviewer was hoping that the understanding that a fundamental-based model provides could be used to guide the selection of experiments to try and fix the problem that Andrew Jansen is planning, as he has too many things listed to look at quickly. As discussed by another reviewer, the -30°C requirement itself really needs to be challenged more, but it is not the job of the PI's to do this. The final reviewer began by acknowledging that Dees' work is very useful. However, this reviewer adds, it is unlikely that this project will lead to higher performance at very low temperatures (-30°C). This project should be discontinued even though it may help move lithium ion cells into the HEVs and PHEVs.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

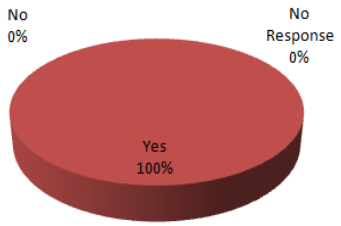
One reviewer stated that the project seems to be adequately supported and with enough resources, while another commented that the funding is sufficient for this project. One other person added that this is good work for the funding obtained. One reviewer stated the PI is extremely able and does an excellent job at leveraging the lab people.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

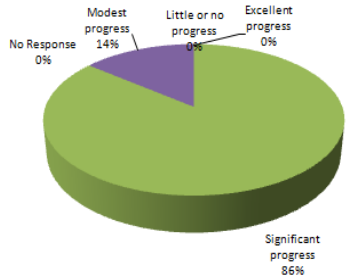
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Low-Temperature Performance: Performance Modeling

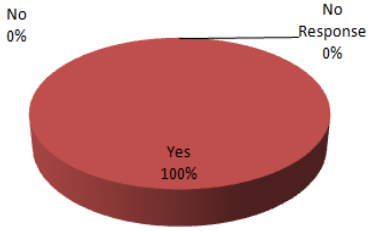
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



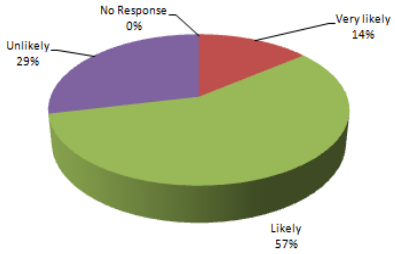
Question 3: Characterize the technical accomplishments and progress toward goals.



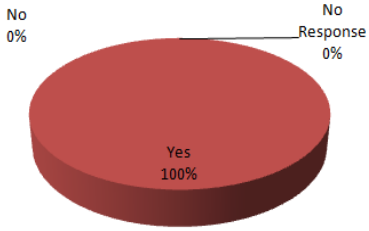
Question 2a: Are the goals of the project technically achievable?



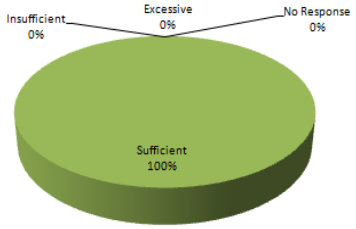
Question 4: How likely is the project team to move technologies into the marketplace?



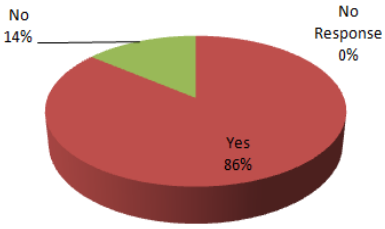
Question 2b: Have the technical barriers been identified and addressed?



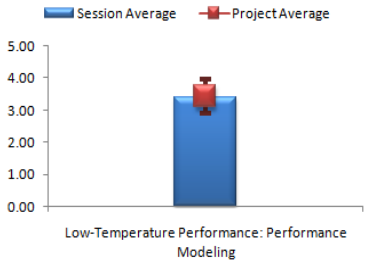
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Material-Level and Component Abuse Studies (Khalil Amine, of Argonne National Laboratory)

Reviewer Sample Size
This project had a total of 10 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
Comments to this question were generally positive. One reviewer felt that Amine's work is leading to new batteries that are being developed further in industry (e.g. EnerDel), adding that this work will lead to HEVs and PHEVs, which will reduce dependence on foreign oil. Another person remarked that it is important to know the material behavior to understand the cell behavior. One reviewer noted that screening and basic characterization of electrode materials in this work definitely supports the DOE objectives. Several comments were focused on the abuse tolerance aspect of the work. One person pointed out that abuse tolerance of materials is a key objective of the DOE battery program. Another reviewer remarked that the increase of abuse tolerance on the component level is important for the safety of li-ion batteries. They added that breakthroughs here can lead to safe high capacity materials and pathways for increasing safety and temperature tolerance in large systems. One reviewer had detailed comments, stating that the safety of this chemistry dictates the use of this chemistry in batteries for the future vehicles and that developing materials that have abuse tolerance is important. They added that the use of electrochemical shuttles under overcharge conditions is a good factor to be studied for the biggest hazard that is associated with li-ion batteries and that the industry needs to have goals on what can be tolerated. They concluded by stating that is it no fire, no venting, what types of heat generation is acceptable and so on. One reviewer pointed out that safety is critical for these large battery applications, but that this aspect is often underappreciated and did not get the emphasis it deserved in the keynote speeches, etc. The final reviewer was more critical of the work, stating that in general, much of this work is redundant with work already reported by others in the past. However, they added that investigation of specific heat generation sources/characteristics in olivine cathode li-ion cells and in titanate anode li-ion cells is of some value. They also felt that work towards specific quantification of the relative heat generation from the anode is of value.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
Comments to this question were all positive. One person simply stated that the researcher has used very sound methodologies to understand the issues underlying the electrode reactivities. Another agreed, stating that the approach is of very high level with outstanding and complete investigation able to understand abuse material capability and improve stability. One reviewer noted that the coating strategy is a good approach that has been used by a number of development companies and that it will likely work for improved reactivity. The reviewer added that the program needs to address how much of an improvement that is required to be significant for the battery developer. They felt that is a good approach to use the 18650 cells which will help qualify this on cell level. One person indicated that the researcher's plans seem good, but a key will be linkage to Sandia's testing. They were glad to see the non-flammable electrolytes continue to get attention; although the full cell results for these that they have seen are not very good. Another commented acknowledged the researcher showed good data on the heat generation with the different cathodes and anodes. They stated that it was not clear from the presentation whether an understanding of this heat generation will help in the choice of suitable materials. They pointed out that even though low surface area carbon is recommended, that

recent work is focused on nano-materials and high surface area, and that a balance may have to be found between the need for more active surface area and the heat generation encountered. The final reviewer commented that Amine's work has lead to a new anode (titanate) and may lead to a new cathode. His work has already produced valuable results and his approach consists of using the data obtained at ANL and other National Labs to develop novel approaches to solving problems (i.e., breaking through technical barriers). They concluded by observing that his work on using AlF3 to coat cathodes may lead to significant improvements in the safety of lithium ion cells.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

One reviewer noted that Dr. Amine has verified the role of cathode materials on thermal abuse (w/SNL) and concluded that, (1) oxygen released from cathodes reacts with electrolyte solvents to produce heat, and (2) spinel generate low heat compared to layered or olivine cathodes during high rate cycling. One commenter remarked that Amine has demonstrated his ability to develop material to break through technical barriers and on track to continue to do so. The reviewer felt that this work may lead to a safer $LiFePO_4$ cell for example. Another reviewer felt that the experimental work has been able to progress significantly and efficiently in identifying clear mechanisms for improving abuse stability by analyzing SEI formation and the effect of various materials (anode and electrolyte additives), reactivity between separator and cathode. They added that the researcher has proposed technological solutions to overcome overcharge (redox shuttle), even if the concept is not new and is not critically compared with previous similar solutions. They felt that some of the results need more verifications of compatibility with expected HEV and PHEV applications. One person felt that good progress has been made in determining heat produced for the different cell components. Some of the data provided is similar to that shown in 2006 such as the VC and LiBOB data. Information on the use of titanate is new and good; the redox shuttle is also a good choice for study. Another person remarked that they really like the fact that the researchers can explain their data, not just reporting results. They added that generally the PI continues to do outstanding, innovative (patented additive) and well-targeted work. In addition, the use of a wide variety of methods and techniques to answer mechanistic questions is great. They concluded by stating that the presentation was excellent and that the PI has raised awareness of anode safety aspects, especially in large packs. Another reviewer noted that the project provides some new insight into li-ion abuse response mechanisms and into some specific parameters which affect the abuse response. They added that if the project is continued, the bulk of the focus should be on advancing the understanding of li-ion abuse response mechanisms and characteristics. They felt that the development of materials-based improvements to li-ion abuse response characteristics should not be included as a part of this project if this project is continued. One person felt that the project has proceeded fine and has solid data and good theories around it. The reviewer asked whether the project has verified if there is an issue with Mn dissolution or not. If not, they felt that this should be verified, as it would be perceived as a potential showstopper. A study on this would remove doubts around this and not hinder the commercialization.

One reviewer pointed out that the researcher showed that an additive significantly reduces the self heat from SEI on the anode and increases the activation energy of reaction with electrolyte. The cells containing $Li_4Ti_5O_{12}$ was found to generate very little heat when charged and discharged at very high rates. It was demonstrated that thermal characteristics were improved with AlF_3 coated cathode materials, via surface stabilization. They were very pleased with the conclusions, describing them as excellent. Another reviewer agreed that the researcher has done a great job, commenting that he has performed cutting-edge work on understanding electrode reactivities. They felt that the studies are thorough and very well thought out. The reviewer noted some reservations about the work on redox

shuttle, stating that people have looked at these materials over the years but they all invariably are of lower rate capabilities having no relevance to HEV applications, and potentially even too low for PHEV. They concluded by stating that they were surprised that these materials are being investigated since BATT had similar programs under Tom Richardson. Two reviewers raised some questions and concerns regarding the work. One person pointed out that the PI gives an incorrect interpretation of the meaning of heat generation during charge/discharge in the calorimetry results, noting that there is a strange confusion of heat of decomposition versus heat from cell impedance. They concluded by suggesting that perhaps the PI would benefit from conversation with his modeler colleague Dr. Dees so that he can avoid making erroneous public statements. The final reviewer suggested that it would be helpful if the plots would show error bars or multiple cell replicates, to get a better sense for the statistical confidence in the difference shown between different materials. They acknowledged that DSC is an important technique, but unfortunately it is known to be poorly reproducible. They felt that it would be helpful to see what reproducibility is achieved in this work. In general, this also is an area where help from the National Labs is needed to publicize best practices for test methods. They agreed that the work on the effect of surface treatment of graphite on safety is very interesting - the investigation of fundamental mechanisms is what is most useful from the National Labs, much more useful than advocating the particular IP patented by the PI. The reviewer asked whether future work will consider anode materials produced by multiple suppliers in addition to Hitachi; for example, will the future work consider materials produced by U.S. producers of anode materials (e.g. Superior Graphite and Conoco-Phillips)?

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

Comments to this question were mostly positive. One person simply stated that the work might lead to novel/improved materials with direct relevance to developers. Another felt that there are a variety of results with potential impact on market products. One person indicated that it is not yet clear which of these safety approaches will "win" in the market place, but ANL is looking at the most promising ones. They added that even if their work will not in detail be carried forward, something based on this type of work will have to be incorporated into a viable, safe product. One reviewer reiterated that again, Amine's team has produced a material that is now used by EnerDel. They pointed out that during his work Dr. Amine keeps in mind the need to move the material from the lab to the marketplace. They concluded by stating that his redox process for protecting Li ion cells during overcharge will probably be adopted by battery manufacturers. One person commented remarked that the factors studied should be looked at closely to determine which of these will be incorporated into future cells and that the collaboration with cell manufacturers will help to take this to the next level of implementation in real cells. They pointed out that a lot of smoke was generated with complete cell disassembly during overcharge abuse of cells with olivine cathodes at NASA. They asked whether the heat generation observed in the olivines be correlated to that data; there was not much fire but a lot of smoke and gas; enough to cause cell disassembly. The final reviewer, however, felt that the portion of work in this project devoted to materials-based improvements in li-ion abuse response characteristics would be better re-directed towards better understanding the abuse response mechanisms and characteristics.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

One person noted that the effort is large with an adequate budget. Another felt that the researcher has produced good work for the funding obtained. One person noted that the researcher generated a lot of data for the money, which is nice to see. They noted that the solid collaboration with materials supplier (Hitachi Chemical) is good for the program as tailoring is allowed which allows testing of

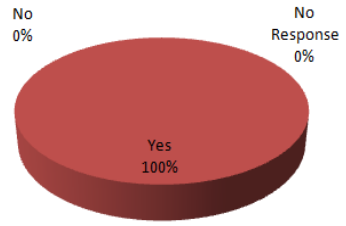
hypotheses, critical for success and guidance of efforts at materials developers, which eventually leads to better batteries. Another reviewer highlighted that the PI has accomplished a great deal since the last review and is obviously, very effective at leveraging partnerships. They added that it is a pity he cannot be cloned. The final reviewer simply stated that Dr. Amine's progress could be improved by providing more funding for his projects.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

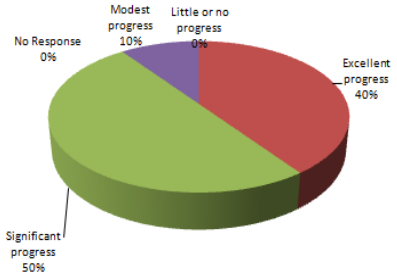
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Material-Level and Component Abuse Studies

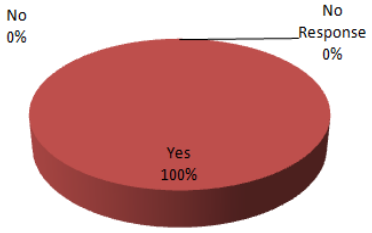
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



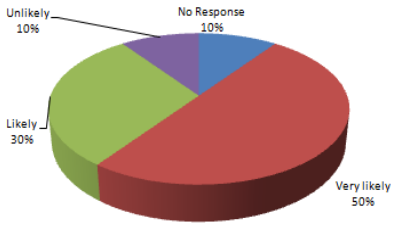
Question 3: Characterize the technical accomplishments and progress toward goals.



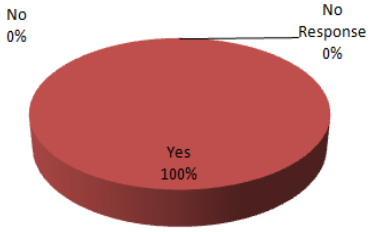
Question 2a: Are the goals of the project technically achievable?



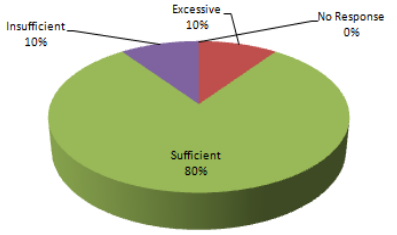
Question 4: How likely is the project team to move technologies into the marketplace?



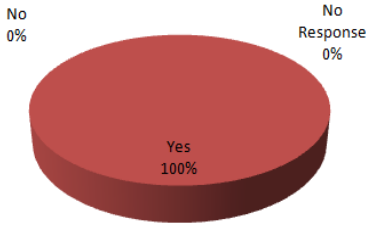
Question 2b: Have the technical barriers been identified and addressed?



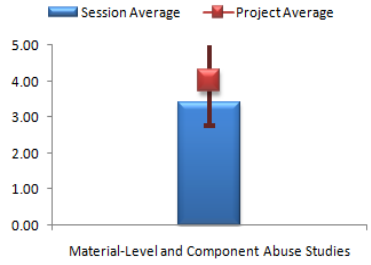
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Overview: Applied Battery Research (Gary Henriksen, of Argonne National Laboratory)

Reviewer Sample Size
This project had a total of 7 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
One reviewer stated that this program clearly supports the key objectives of battery development, while another person added that this program is comprehensive and will lead to better batteries. One response noted the studies of materials are important, and so are the various generation cells; once successful, key component choices will be available as a benchmark to the industry. The detailed published information is useful for comparative studies carried out at various efforts at battery manufacturers. The final reviewer noted this was an overview of the DOE vehicle technologies goals and the team's plans and collaborations to reach that goal.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
The first reviewer commented that there is good teamwork and strategy to meet the PHEV goals. The goals are very challenging, especially the safety and 15-year life. One reviewer, similarly, wrote that there is good management and plan going forward. Another person indicated that Henriksen's program is comprehensive and has already led to the titanate cell, which is being developed further by EnerDel. Another response noted that the program is aimed at analyzing and verifying key enabling factors of lithium batteries: improved performance in most wanted operating conditions, abuse tolerance, and reduced costs. There are areas of potential overlapping with NREL activities on thermal behavior and modeling/diagnostics, which are not included in the list of National Labs collaborations. They concluded by noting that the recommended collaboration on modeling and diagnostics was particularly interesting. Another reviewer remarked that some of the efforts are hindered by the limited availability of good cells. It is not clear that the 18650 cells to be built for the "thicker" electrodes anticipated to be used for PHEV applications, with current degradation methodologies, will be successful unless factors such as stack pressure is taken into account. If this is not addressed within the PHEV program there is risk of failure, which is why the "no" is checked. Otherwise, for all other aspects, those boxes should be checked with "yes". One final reviewer stated that focus on materials development in many projects may not be successful in the absence of significant cooperation and interaction with significant mass-production manufacturer(s) of li-ion consumer cells.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
One reviewer stated that the results show clear progress well aligned with the expected outputs and the investigations planned. One response commented that the materials development is very good, especially on the metal oxide side, while another noted that several very important findings have been identified, and the group is looking at the right materials. One other reviewer noted that the overview indicated that the team had made good progress toward achieving the PHEV goals. A very good summary of the team's involvement was provided by the speaker, and a good example was set by the Team Lead in keeping to the time limits. One reviewer suggested that the lack of significant cooperation with significant mass-production manufacturer(s) of Li-ion consumer cells may result in a lack of focus on the most pertinent and critical issues to practical implementation. One final reviewer acknowledged the data and analysis has been used to make significant contributions to cell

development. However, this reviewer adds that some projects have not made significant progress since the last review in August 2006.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

The first reviewer noted that the results are directly transferred to battery developers and market products. Another respondent commented that the presentation indicated that all the work being carried out was evaluated for technology transfer and marketing. One other reviewer wrote the project team could provide valuable input and support towards those already in the marketplace and potentially to those entities which may enter the marketplace in the future. One reviewer, similarly to those above, noted some transfers are already taking place. Another person remarked that, again, ANL's titanate work has already resulted in a potentially useful cell for HEVs and PHEVs. The last person wrote that the program has traditionally been somewhat limited by the fact that the generational cells are focusing on a few materials only. The success within this area is therefore limited by the ability of the materials supplier to supply a material that is effective for the HEV conditions. It is a good idea to now move into a variety of materials for larger benchmark studies. A well-executed statistical design of experiments for these materials will be key to success. This reviewer added that the national laboratories have the expertise to do this.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

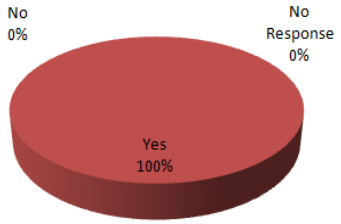
One reviewer felt that there was good work for the funding received, while another said that the funding for this program is sufficient. However, this reviewer added that funding should be reduced or eliminated for some projects due to a lack of significant progress. One other reviewer stated that the technical resources of the project are sufficient to achieve some success with a more limited and defined project focus and are insufficient to achieve success with the current project scope which is much too wide. One respondent indicated that the survey shows very large activities with little information about resources implications, which makes this evaluation difficult. The final reviewer noted that degradation is highly dependent on the mechanical stability of the electrode array. When going to high energy, trade-offs on binder and higher densities are needed (important for PHEV). This calls for optimization of these mechanical aspects, which is different from the electrochemical and chemical degradation mechanisms. Ways of measuring this mechanical degradation should be developed and resources will be needed, equipment and staff.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

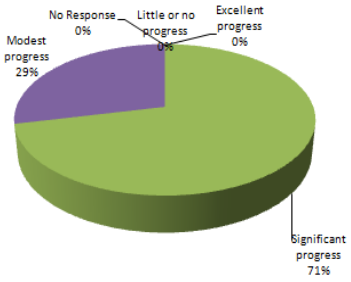
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Overview: Applied Battery Research

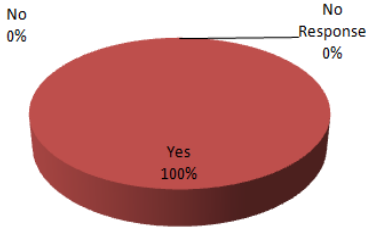
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



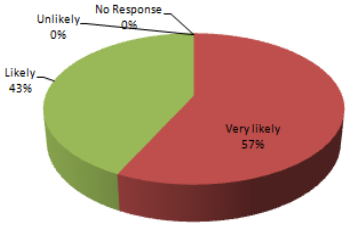
Question 3: Characterize the technical accomplishments and progress toward goals.



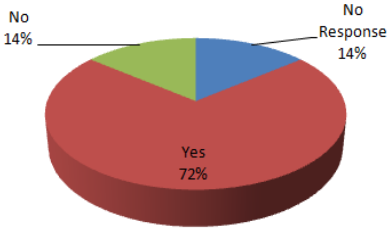
Question 2a: Are the goals of the project technically achievable?



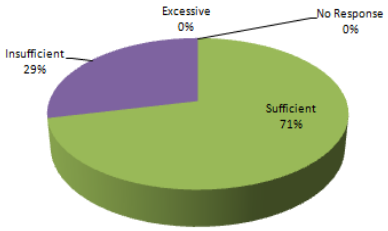
Question 4: How likely is the project team to move technologies into the marketplace?



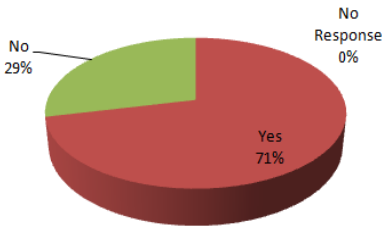
Question 2b: Have the technical barriers been identified and addressed?



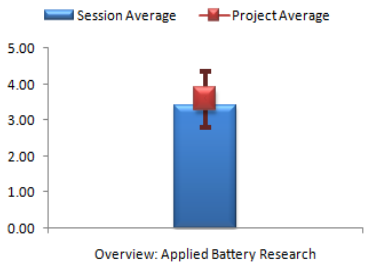
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



Plug-in Hybrid Electric Vehicle R&D on High-Energy Materials (Jack Vaughey, of Argonne National Laboratory)

Reviewer Sample Size
This project had a total of 9 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
One reviewer stated that the project has good goals – greater than 200 mAh/g for 100 cycles between 4.5 V to 2.0 V. This goal is significant and will benefit not just the vehicle technologies program but also the commercial market as well as other government agencies. Higher energy density materials will reduce the mass of the batteries. Another reviewer stated that the industry needs this for long term true EVs, and this could also be used for PHEV if safety issues and poor cycle life can be overcome – both are very difficult goals. Similarly, one person noted that this is a high risk project, which if successful would accelerate the development of lithium metal anode cells which have a much higher energy density. This project would result in the reduction of oil consumption. Another respondent stated the work on the metal oxides is very worth the exploratory nature and all comments below are therefore related to Thackarey's presentation. This reviewer added that the other programs will be hard to deliver in a reasonable time frame. Many reviewers indicated additional hesitation or concerns regarding this project. One reviewer was surprised that this became an ATD project (adding that the work on cathodes by Mike is just fine). Another response stated that this can only be a long-term project since the studies funded by DOE over the years have not led us anywhere. It has great potential but no immediate resolution in sight for the problems and should be left to the BATT program. In the same vein, one reviewer noted that similar and extensive work has already been conducted on numerous occasions in the past and over a significant time period. One final reviewer added that the project considers Li metal anode for HE PHEV Li Batteries. This reviewer felt that this seems like an old story with limited impact in the short-term.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
The first reviewer wrote that this project, if successful, may enable the use of Li/S cells, for example, in HEVs and PHEVs. This would be a significant advance. Another person stated that Thackeray has come up with a great approach to get a new high performing material, and funding should follow. This project is a little bit longer term, but well worth pursuing. Approach for activating the crystal structure is sound. Optimization of particle size and formulation will enhance the cyclability of these metal oxide materials. Opportunities also exist to limit the voltage range for performance. Lots of flexibility available and the PI is well positioned to solve these. One other reviewer commented that the goal to achieve greater than 200 mAh/g at the material level is not a difficult one. Currently, materials providing as high as 260 mAh/g have been tested and proven by University (Dr. Manthiram) as well as some government agencies (NASA - JPL). The choice of material based on theoretical capacity is a good start, but if it cannot meet the high cycle life requirement, the parameters may have to be changed to meet the goals of the program or to optimize the cyclability of the materials studied. A good work plan should be developed to indicate how that goal will be achieved. One person said that both lithium metal and new cathodes projects are high risk but worthwhile. Initial results from cathode study shows proof of concept and there has been a lot of work on protected lithium surfaces recently. However, while Thackeray is obviously well positioned to do the cathode work, this reviewer is not sure about the anode work. One reviewer remarked that the project has identified the

barriers but the strategy is not clearly specifying the final cell targets. It is not clear how these barriers and proposed solutions find space in the ongoing ATD activities, even if there are examples of present commercial development (not only HQ but also BATSCAP in France, and subsidiary Avestor in Canada). Another person commented that we probably have over 30 years of history of funding for a rechargeable lithium battery without success. Just recently, the lithium batteries installed by AT&T at UPS and made by Avestor using polymer electrolytes, etc. (with USABC funding) use very old ideas and they did not work. They are going to replace all of these batteries. This reviewer is a big proponent of this work, but it is a long-term project and should not be part of the ATD. This reviewer added that the work by Mike on cathodes is fine. The last reviewer stated that, of the lithium metal task, PHEVs need high energy, but they also need high power and acceptable safety. Li metal by itself is not a high power electrode, particularly at low temperature; any coating would most likely increase the impedance, making the situation worse. Before investing too many resources down this path, the researchers should first determine whether there is any possibility that Li metal can meet the power requirements for PHEVs, especially at low temperature. Furthermore, the safety is a high risk. Cycle life testing should include charge pulses of the magnitude to be expected during regeneration at low temperature, to determine whether the coating can prevent dendrites under those conditions. Regarding the new cathodes task: this task has identified the barriers and is likely to overcome them.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.

One reviewer noted the great performance promise, which is work well done. Another reviewer pointed to the fact that his or her comments refer to the Li anode only, adding that the cathode work is fine. Another person commented that the results are only preliminary, with limited progress due to the late start of the project. Another respondent wrote that the project has shown significant progress but it is not anywhere near to obtaining a practical high energy density product. Proof of concept at the material level is not adequate to overcome all the barriers existing to meet a goal of cyclability and greater than 200 mAh/g at the component level. Similarly, one reviewer remarked that both aspects of the research are at too early a stage to expect much progress. Cathode works looks exciting and novel. Anode works looks very difficult and also this reviewer thinks this might better be outsourced to someone like PolyPlus if possible. Alternatively, try to get coated lithium from PolyPlu's supplier, Ohara Glass. The physical dissolution of Li during deep discharge can be very challenging - the 150 mAh/g data shown is a very shallow DOD and not going to be enough for PHEV. This reviewer suggests they look at deeper DOD early in the program. The final reviewer stated that, unfortunately, the investigators have not made much progress toward developing a coating for lithium metal. Their literature survey apparently did not include a thorough review of the patent literature, where it has been shown by Steve Visco, for example, that it is possible to produce Li metal coatings for low rate cells. These investigators should attempt to reproduce the discovery made by Visco as part of their background work.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

Responses to this prompt were generally negative. The first reviewer stated that it is hard in this phase to estimate technology transfer. Another person added that the use of lithium metal anodes limits the safety of the lithium-ion cells. May need extensive testing to prove safety before marketing or technology transfer can occur. With respect to Dr. Thackeray's presentation, it is too early to think about technology transfer or marketing. One reviewer highlighted the 30 years that have already gone into funding this project, while another stated that it is unlikely that this project will be successful based on their reported work to date. One response noted there is high risk at this stage. One final reviewer commented on the low likelihood of success of these high risk approaches, adding that this

does not mean we should not fund them, but we need to ensure they have some early benchmarks and check back frequently for signs of progress or killer issues. This has to be viewed as seed money for longer-term blue sky projects. Also, protected lithium seems to be well done by PolyPlus and others – this reviewer is not sure how this group can expect to improve upon that. Maybe do a joint JV with Polyplus and /or Ohara Glass instead?

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

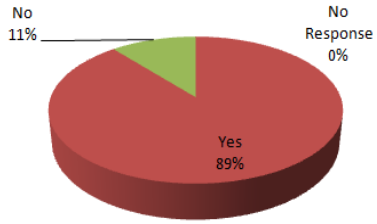
One reviewer commented that the work carried out is significant and the funding is adequate, while another person stated that this should be funded but under the BATT program. One other reviewer added that the funding should be funneled to the metal oxide program. Otherwise this reviewer suggests increasing the funding so that the metal oxide program gets done without funding limitations. In contrast, one person indicated that, although the quality level of the work in this project is adequate, this project should not be continued. Another reviewer remarked that the lack of information and the large funding planned make the evaluation hard. One respondent stated that, before substantial resources are devoted (yet again - as we know this happens about every decade) to lithium metal, serious thought should be given to questions of low-temperature power, manufacturability, and safety: the main hurdles for lithium metal. One final reviewer stated that funding for this work should be reduced unless a more thorough understanding of the existing technology in this area is established by this research group. This reviewer added that it is unfortunate that Mike Thackeray's work was lumped in with this report. It may be that Mike's work on $Li_{1.2}V_3O_8$ may lead to materials that would have value for PHEVs. His work should be and would have been scored differently from the scores given here for the lithium metal anode coating work.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

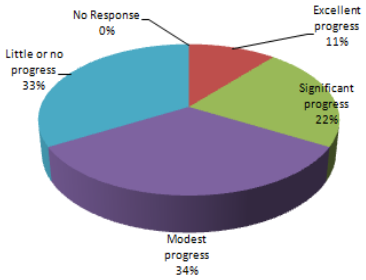
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Plug-in Hybrid Electric Vehicle R&D on High-Energy Materials

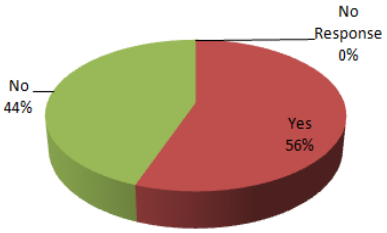
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



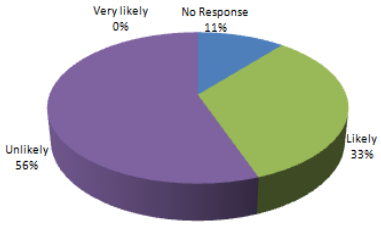
Question 3: Characterize the technical accomplishments and progress toward goals.



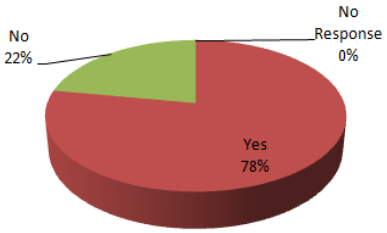
Question 2a: Are the goals of the project technically achievable?



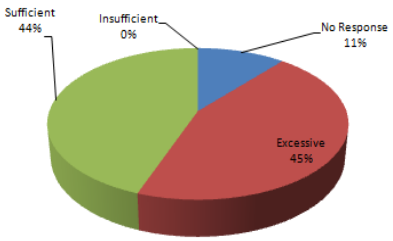
Question 4: How likely is the project team to move technologies into the marketplace?



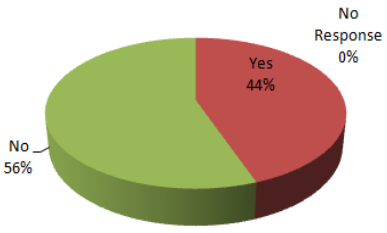
Question 2b: Have the technical barriers been identified and addressed?



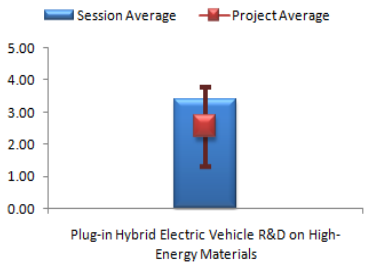
Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating



SEI Studies at ANL (D. Abraham, of Argonne National Laboratory)

Reviewer Sample Size
This project had a total of 8 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
One reviewer wrote that formation is a key step in manufacturing lithium ion cells, while another respondent stated that the project aims at the DOE objective of improving the calendar life of lithium batteries. One reviewer commented that the films are key to long life, low impedance, and maybe safety. One final reviewer indicated that this work will lead to the reduction of the use of oil because it will lead to better batteries for HEVs and PHEVs.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
The first respondent simply commented that the group has a good work plan. One reviewer indicated that the growth of the SEI layer on the negative electrode and the increase of deposits on the positive electrode are well known to have a negative impact on cell impedance during storage or cycling. The program is well designed to study these effects. One other person commented on the good results to date, and this reviewer likes the plan to do a Design of Experiments trial on formation. Another reviewer wrote that this project is focusing on understanding the protective layer that is formed on the anode during formation. Several National Labs are involved and the work is being coordinated. The results of this study may lead to an improved understanding of this process. One final reviewer stated the clear and well described approach is likely to give scientific explanation to SEI formation and electrode formation protocol, adding that the weak point is the limited number of chemistries analyzed.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
One reviewer indicated that the results are valuable and consistent with the planned activities, and that the extension to other components would be very important. Another respondent wrote that this project may lead to a better understanding of formation of cells and how that might be controlled better to extend the life of the cells. Similarly, one reviewer commented that this study contributes to the understanding of the cell performance and is quite useful. Another response stated that the ideas are quite good, but this reviewer would have loved to see more conclusive results. One respondent noted that it is difficult to show a direct relationship of the measured properties of the SEI and cathode deposits and the cell impedance, but the problems are too important to ignore. The progress is expected to be rather slow because of the difficulty of the studies. Another person wrote that this is a nice systematic XPS study – which is time consuming and difficult. A lot of very careful work has been done. This reviewer adds that binder-carbon free studies are very good as a fundamental study, especially as they seem to behave similar to real electrodes. Cycling tests seem to be a bit vague and need standardization – need to look at high voltages and high temperatures to study cycle life effects as another reviewer commented. There is some concern about the difficulty of distinguishing between simple electrolyte residues and actual surface films. The last reviewer felt that the scope of the project is too general, and work similar to much of this project has already been conducted elsewhere in the past. In particular, studies of binder/carbon-free electrodes are redundant to work conducted in the past. Inclusion of actual observations of the effects of formation parameters on SEI and/or on performance characteristics could be of value, but no information regarding this was presented.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

The first response commented that this seems to be key information, while another reviewer added that the industry seems to be a potential user of these results for improving lithium batteries. Another person wrote that this project is a comprehensive approach by several labs and should lead to new information about the formation process for lithium ion cells. However, this reviewer adds that it seems that the participants are not as familiar with prior work as they should be. One final reviewer commented that this work might lead to better general understanding. However, developers have their own processes in place, which are the results of many years of test data, and this reviewer doubts that there is any new data generated in these studies that would be of immediate interest to commercial producers.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

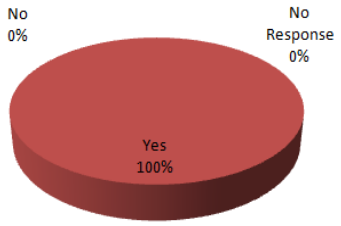
One reviewer stated that the funding for this project is sufficient, while another similarly stated that the resources roughly described seem adequate to the planned work. One person noted that the group has done a lot of work already, but adds that this is very difficult work. This reviewer suggests maybe leveraging outside resources more – i.e., people who have already been studying these films (e.g., Aurbach in Israel?).

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

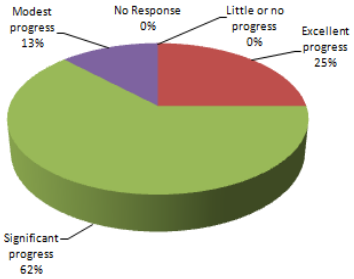
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: SEI Studies at ANL

Question 1: Does this project support the overall DOE objectives of petroleum displacement?



Question 3: Characterize the technical accomplishments and progress toward goals.



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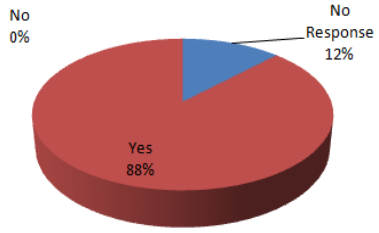
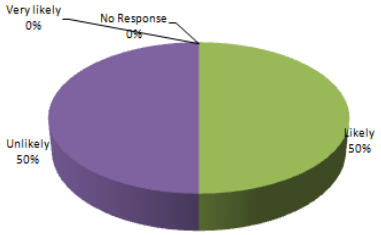


Question 4: How likely is the project team to move technologies into the marketplace?



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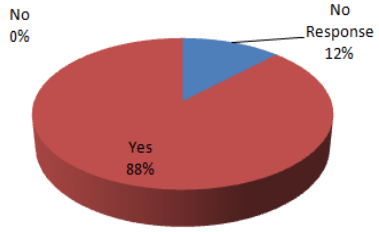
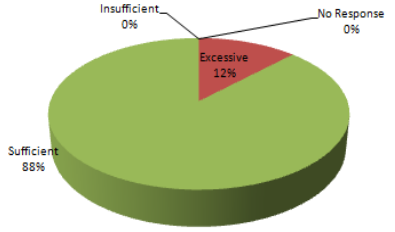


Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



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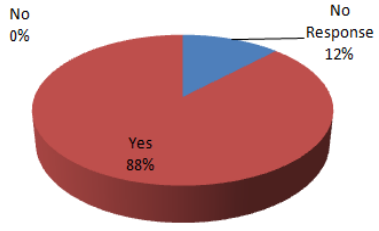

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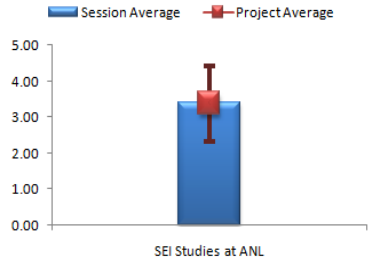


Statistical DOE at INL (Kevin Gering, of Idaho National Laboratory)

Reviewer Sample Size
This project had a total of 10 reviewers.

Question 1: Does this activity support the overall DOE objectives of petroleum displacement? Why or why not?
One reviewer noted that the project is functional to the DOE objective to increase lithium-ion cycle-life. Another person commented that the project will provide useful results that will lead to more rapid development of batteries for HEVs and PHEVs thus reducing the use of oil. Many comments were focused on cell formation. One person simply pointed out that formation is a key step in manufacturing lithium-ion cells, while another person added that it is critical to making and testing real cells and estimate lifetimes reliably. Another person commented that the formation process is extremely important for long cycle-life, calendar-life, and can allow for capacity optimization (as shown). Another person remarked that SEI formation greatly affects the life of the cells and learning more about these and how they protect will help improve life by changing components that will enhance good protection that will last with extended cycling. They concluded by mentioning that statistical analysis provides insight into which parameters need to be pursued for father life studies. The last person commented that aside from the effects on performance and life, the formation process is a significant economic aspect of li-ion battery production, and detailed DOE studies such as in this study provide insight.

Question 2: Are the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the project likely to overcome those technical barriers? Please comment on the project's strategy for deployment of technologies.
One reviewer simply acknowledged the good work plan. One person indicated that the researcher's work is of fundamental importance to obtaining a better understanding of the formation process. Another person observed that the barriers are well identified and the approach is likely to give indication to overcome barriers in an interesting fashion. One reviewer commented that statistical correlations show information already established in the lithium-ion database, namely, higher capacities obtained with higher end-of-charge voltages, higher capacities obtained with lower charge/discharge rates, etc. They added that the conclusion of higher temperatures being good for good battery performance can be misconstrued because the comparison was made between 40°C and 0°C, so they suggest that the researchers need to be more specific in this area. One person congratulated the researcher on employing a good strategy, but cautioned that the study is somewhat limited by using coin cells. They commented that this is a very nice first step in using statistical methods in a significant way and applauded DOE for selecting this particular project. Another person agreed, commenting that the researchers need to address other systems and cell sizes as described in more detail below. The final reviewer agreed, stating that it is unlikely that a full resolution of variables that are truly relevant to cylindrical lithium-ion or pouch cell lithium-ion can be determined from coin cell data. They highlighted the fact that the contact of the electrodes is quite different and gives rise to a different distribution of current on the electrodes. However, they felt that the studies can help to understand particular problems such as mass transport in electrolytes and solids in the coin cell experiments.

Question 3: Characterize your understanding of the technical accomplishments and progress toward DOE goals: please state the reasons for your assessment.
One reviewer simply commented that the researcher's systematic approach will lead to a better understanding of the formation process for Gen 3 cells. Another person commented that, although the study is limited to a very specific cell type, it provides useful information about some of the effects

of some key variables of the formation process. One person pointed out that the researcher has shown very important progress that can be used throughout the DOE program for optimized conditions. The researcher added that they would like to see a doubling or tripling of budget so that this type of methodology can be used also for electrode formulation, electrolyte composition, and formation studies. They concluded by suggesting that the scope be expanded into cyclability to look at trade off effects would also be helpful. Another reviewer indicated that overall the researchers have done outstanding work. They commented that is nice to see Design of Experiments work being done at a government lab. They acknowledged the project employs good experimental design, but having a somewhat nitpicking suggestion, they would have chosen a wider range for the number of formation cycles (such as N=2 and 5). The reviewer suggested that when doing a screening study the goal is to set the chosen levels to have a decent amount of discrimination to see if the variables are important. They concluded by noting that obviously, this cannot be taken too far, otherwise you just get into the good/bad region whereas you want to stay in the good/not-so-good range of performance. One person noted the good work plan, but they mentioned that they would have expected some concrete suggestions with respect to the "optimum" formation conditions. One person remarked that the study is nearly completed within its own barriers, but it needs to be related as far as possible to results from large lithium ion batteries. The reviewer also suggested that there needs to be an increased emphasis on standard deviations since the design is essentially statistical, rather than scientific. Another person acknowledged that the statistical analysis provides excellent data, although a lot of this information is already well-known. They added that the chosen factors should be incorporated into the studies and understood for the electrode materials and electrolyte compositions as these can vary depending on the compositions of the components. One person, however, commented that too many parameters to fit the experimental results, this fact reduces the effectiveness of this work. Another person mentioned that the large number of samples and the overall analysis of parameters affecting formation give results with a good coverage of possibilities; the weak point is due to the fact that the results are restricted to one chemistry. The last reviewer person remarked that the program is a brute-force approach to optimizing formation procedures and there does not appear to be much use of physical understanding to complement the brute-force statistical analysis. The reviewer commented that since the studies are being done with a single chemistry and electrode design, it is not clear how these results will be of general applicability to the battery industry.

Question 4: What is the likelihood that the project team will move the technologies toward or into the marketplace? Please state the reasons for your selection.

Reactions to this question were mixed. One person commented that the methods used for data analysis are very good as they correlate to what is already well known. Another person pointed out that the researcher collected a significant amount of data that has been used by him and his coworkers to make preliminary statements about the influence of various parameters in the formation process. However, they added that the analysis is limited to an empirical approach and the use of a geometric mean for the capacity is questionable. They concluded by indicating that data should be analyzed by using a physics-based model. One reviewer suggested that the project needs more resources to be useful. The reviewer added that work like this project needs to address other issues besides formation. Another reviewer argued that significant commercial producers of mass-produced li-ion cells already employ similar methods for studying formation parameter effects; however, it is possible that producers who may be entering the market at some future time would benefit from understanding this work and the general method. One person stated that only if they come out with a greatly improved formation process, the current data are not good enough for that purpose. Another person felt that until the translation of results to large cells is shown it is unlikely that the technology will be

marketable. Another reviewer remarked that the results do not seem to have their own specific market value, even if the developed methodology can be made available to other chemistry. The last reviewer highlighted that this work will increase speed to market and will assume that optimized conditions are used for the materials studied, which is critical for assessments, so that no false negatives are obtained.

Question 5: How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

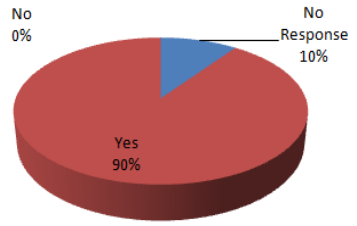
One reviewer simply stated that the funding for this project is sufficient. Another person agreed, stating that based on the quantity and quality of work, the resources seem adequate. One person mentioned that the number of cells and the test and analytical work seem consistent with the budget, even if uncertainties still remain about the overall resource use. One reviewer suggested that the inclusion of similar studies of cells produced using electrodes or materials produced by a significant mass-producer of li-ion cells would be very useful and would provide an important reference point, but would require cooperation with a significant mass-producer. One person suggested that the project funding should be increased and to have the researcher interact with all the experimentalists in a significant way with experimentalists providing the researcher with parameters they know affects performance the most and have the researcher find a cost effective way of studying those. The reviewer indicated that this is what the large manufacturers have spent a lot of time on in the past and will lead to guaranteed success. They added that some people would say that this type of research is for battery companies to perform, but the case is that if it is not done in conjunction with the materials development, the materials development will be hindered and not as effective as it could be. The last reviewer had detailed comments and highlighted that a lot more work needs to be done to address other chemistries and the additive influence and larger cells and cell types (e.g. pouch versus cylindrical). For example, gassing in pouch cells can be a real issue whereas cylindrical cells are less sensitive to this. The reviewer does not believe findings can be generalized from one system to another. They suggest that instead of running large full factorials on six variables, running a larger number of smaller experiments such as a half factorial. With six variables, the aliasing in the half factorial is pretty small and valid results can usually be obtained with far less data by leveraging the inherent replication in the Design of Experiments design. The reviewer asked whether the researchers repeated any runs to get an estimate of the replication error, or are they relying upon the replication built into the design; suggesting that it might be worth considering as a basic quality check of the data. They concluded by stating that overall, this work needs to be expanded and more resources applied.

Question 6: Summary rating: when scoring this project, consider the relevance of the work to DOE's objectives, potential impacts on DOE/VT goals, project accomplishments, likelihood of technology transfer, and sufficiency of project resources.

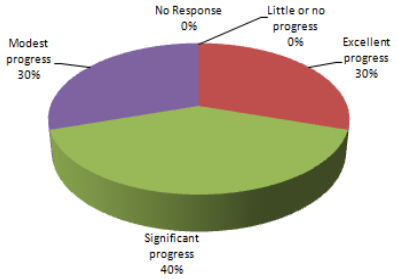
There were no expository comments for this question: refer to the graphic on the next page for this project's summary score.

Project: Statistical DOE at INL

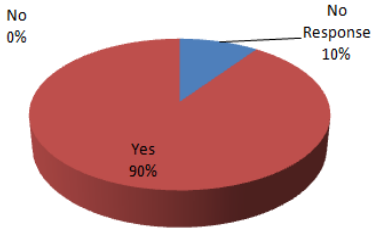
Question 1: Does this project support the overall DOE objectives of petroleum displacement?



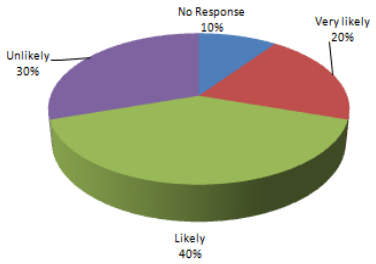
Question 3: Characterize the technical accomplishments and progress toward goals.



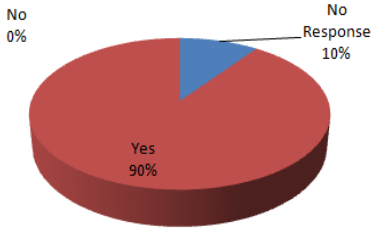
Question 2a: Are the goals of the project technically achievable?



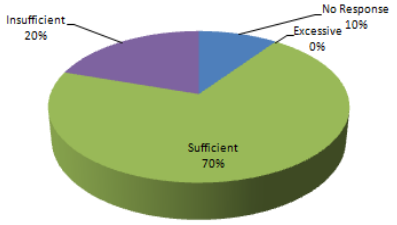
Question 4: How likely is the project team to move technologies into the marketplace?



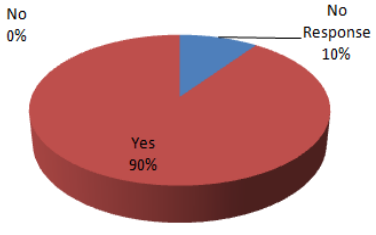
Question 2b: Have the technical barriers been identified and addressed?



Question 5: Characterize the resources available for this project to achieve the stated milestones in a timely fashion.



Question 2c: Is the proposed work likely to overcome technical barriers?



Question 6: Overall Rating