BATTERY WORKSHOP

Cochairmen: Richard H. Sparks
TRW Defense & Space Systems

and Floyd E. Ford
NASA Goddard Space Flight Center

The battery workshop was attended by 18 people from industry and government. Review of the requirements for energy storage and the plans for battery development was vigorous, with widespread participation. The workshop followed a debate format, with the objective of recommending improvements to the development plans presented by NASA and the Air Force. The issues addressed were

(1) Significant technology deficiencies which can be identified

(2) Adequacy of current and proposed programs to resolve the technology deficiencies identified

(3) Additional tasks which should be undertaken, including benefits and timing

(4) Lowest priority items in the presently planned program, both in content and in timing

The workshop was limited to 2 hours, which necessarily restricted the depth of our review; however, a general consensus was reached by both workshop subgroups. The main theme of their conclusions was that the power system trade-off studies for large power systems (25 kW and larger) have not been adequately performed:

(1) Early 1970's battery technology is generally compared with projected 1980's fuel cell capability.

(2) Small-battery data are compared with a single large-fuel-cell-system data base.

(3) Cost trade-offs do not include redundancy and scaling factors for larger battery and fuel cell systems.

(4) Effects of bus voltage on the energy-storage-system concept have not been identified.

The consensus of the workshop was that the battery development program is underscoped because the trade-off studies have not adequately considered battery advanced technology capability and relatively low cost at the system level; hence, the priority associated with advanced battery development is too low.

The most significant technology deficiencies identified by the workshop were as follows:

(1) Battery life development goals do not meet mission-planning goals and ground rules:

(a) Low-Earth-orbit missions are being planned based on a 10-year life. Battery development goals in the present programs are 5 years. A 10-year life requirement is needed.

(b) Geosynchronous-orbit missions are being planned with lifes ranging from 7 to 15 years. Battery development goals are 10 years. A 15-year life requirement may be needed.

(2) Low-cost batteries are widely discussed; however, mission requirements are based on low-cost battery systems which include total system reliability, life, and maintenance costs. The low-cost battery concept is not totally consistent with low-cost battery system concepts:

(a) Battery costs are already relatively low; but implementation costs within the aerospace software and hardware systems are high. Implementation cost reductions cited in the workshop are

- To increase battery life to reduce replenishment costs
- To reduce battery redundancy weight and complexity to save initial costs and launch costs

(b) Batteries are small (less than 60 Ah), necessitating the use of multiple battery assemblies and control electronics for 25- to 100-kW systems. Cost data presented at the workshop show a significant cost leverage by reducing the number of components in the battery system. A 100- to 500-Ah battery size capability is needed.

(c) Parts screening costs have significant leverage on battery costs; however, without screening of parts made with commercial processes, reliability and hence maintenance cost are impacted strongly. Refined screening methods commensurate with the maintenance cost models being planned should be developed.

(d) Battery system redundancy is very costly both in weight and in electronics complexity. A low-cost, low-weight redundancy concept is not available and needs development.

(3) Deep-discharge, long-life applications for batteries are not well developed. Operating conventional batteries at deep depths of discharge (DOD) is the best single way to reduce energy-storage-system specific weight. Present nickel-cadmium battery studies are based on 15-percent DOD for 3.5- to 5-year low-Earth-orbit missions. Increasing DOD to 60 percent for a 10-year life is a major improvement which should be developed to meet the mission goals presented:

(a) Nickel-cadmium batteries can be operated at deeper depths of discharge (up to 85 percent for some applications) by using new operating methods and newly developed plate and separator processes. The nickel-cadmium battery should be developed for a 10-year life at greater than 20-percent DOD.

(b) Nickel-hydrogen batteries are being developed by the Air Force for a 1-year life at 80-percent DOD and for a 5-year life at 60-percent DOD in low Earth orbits. The capability should be improved to 60-percent DOD for 10 years, and a low-Earth-orbit flight experiment should be flown at 60-percent DOD to validate the system in space.

(4) Peak loads requiring load-leveling battery systems were shown by both Air Force and NASA mission models in 1987-1988. No technology is available to support load-leveling missions within reasonable weight constraints. This mission requirement should be immediately translated into energy-storage-system requirements for further development.

(5) Large bulk-energy-storage battery systems are not available for 100-kW and larger systems in the 1990's. Work in sodium-sulfur, advanced lithium, and large nickel-hydrogen systems needs to be done to identify potential capabilities and to develop a large bulk-energy-storage system for the larger space platforms.

Other technology deficiencies were cited by the workshop but had lower priorities than the preceding items.

During the workshop discussions, the group commented on current and proposed NASA and Air Force programs. The comments are summarized as follows:

(1) Overall funding for battery systems is too low to meet the large-power-system program goals. NASA has underestimated the potential of batteries for large space systems by using overly conservative battery performance data for system trade-off studies, thus causing a low priority to be given to advanced battery development. Emphasis on battery development should be increased.

(2) A 100-Ah cell program start in 1978 is needed; however, the scope of the planned feasibility program should be expanded to encompass a cell size range of 100 to 1000 Ah to provide a more useful data base for large-power-system designs.

(3) Very limited studies of nickel electrodes and nickel-cadmium cell designs for long life are planned and funded. A much more extensive concentration on electrochemically impregnated and other more physically stable electrodes should be initiated and directed toward 10-year life cycle service, including

(a) More fundamental studies of deep-discharge cycle phenomena

(b) More investigation of operating methods which do not overstress the electrode structure

The payoff will be for both NiCd and NiH_2 batteries. Other comments on existing programs were varied and, in general, fell within the scope of those summarized.

The workshop worked toward a summary of additional tasks needed to meet the NASA and Air Force mission objectives. Several additional tasks were identified:

(1) The first recommendation was to perform updated spacecraft system-level trade-off studies comparing existing and future battery systems, including fuel cell systems. The studies should use projected 1980-82 capability and 1985-87 capability and should determine sensitivity to different types of batteries and fuel cells. Weight, cost, redundancy, life, and control-system-complexity sensitivity variables should be included:

(a) System cost and weight trade-offs should be performed for candidate energy storage systems.

(b) System redundancy and refurbishment trade-offs should be performed for candidate energy storage systems.

The workshop noted that maintenance of heavy components in space through refurbishment may not be practical and will be very expensive.

(2) The second recommendation was to initiate development of substantially larger battery cells with active cooling provisions which can be adapted to large space systems. Development should be centered on a 250- to 500-Ah cell or battery design, scalable from 100 to 1000 Ah for system design flexibility.

(3) The third recommendation was to initiate a near-term NASA program to implement the nickel-hydrogen battery system into NASA systems studies. An early low-Earth-orbit flight experiment should be performed at deep depths of discharge (40 to 60 percent) to assess the technology capability and to determine refinements needed for larger space cell development.

(4) The fourth recommendation was to increase funding to cover a broader battery technology program for large long-life systems, including

(a) 10-year Low-Earth- and geosynchronous-orbit system life

(b) Lower system costs by eliminating system complexity:

- Fewer batteries
- Low-cost redundancy concept
- Minimum replenishment

(c) Increased monitoring of DOE technology developments to select timely technology spinouts for space applications (Lithium, sodium, and other high specific energy system developments should be monitored closely.)

(d) Investigation of technology required to support high-voltage power systems

The workshop encountered difficulty in identifying the three lowest priority technology items in the NASA plan. The work planned is narrow and needs to be widened. However, priority recommendations were developed to be offered in assisting future plans as follows:

(1) Increasing the specific energy of NiCd cells should receive much lower priority than increasing the life and utilization of stored energy at deeper depths of discharge. The largest overall system cost and weight savings for the larger space systems planned will result from doubling the battery life and increasing depth of discharge to 40 to 60 percent. Small increases in specific energy are of little overall system value.

(2) Higher priority should be placed on following DOE high-energy-density systems work, including

(a) Close surveillance

(b) Identifying early spinout for space to meet 1990-2000 goals

A low priority should be placed on starting new developments paralleling DOE work until a good basis for spinout is established.

(3) Highest priorities should be applied to long-life battery systems which can deliver a high percentage of stored energy to the power system, in contrast to short-life scientific system battery requirements. Space system cost-effectiveness models presented show that short-life energy storage systems are extremely expensive.

These workshop conclusions and recommendations were presented before the entire symposium. No disagreement was received from the floor. The workshop summaries were therefore documented in this report with minimum changes for clarification.