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INTERAGENCY ADVANCED POWER GROUP

December 15, 1993

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Dear 1~ 3~:

Enclosed is a draft copy of the presentation you gave at the recent IAPG Mechanical Working Group meeting held November 3-4 in Albuquerque, New Mexico at Phillips Laboratory.

Please review the enclosed segment of this draft, making any additions or changes you deem necessary. If you would like to make any corrections or changes to your view graph slides that you previously gave to me, please include the substitutions with your abstract changes.

In order to publish the final minutes of the Mechanical Working Group meeting, your comments must be returned no later than **December 27.** Please mail your written comments to the PIC at:

Power Information Center
c/o Horizon Data Corporation
10700 Parkridge Boulevard, #250
Reston, Virginia 22091
Attn: Dawn Skinner

If I do not receive any written comments from you by that date, the draft will be finalized for publication. **Your immediate attention to this request is greatly appreciated.** If you have any questions, please call me.

Sincerely,
POWER INFORMATION CENTER

Dawn M. Skinner
Meeting Coordinator

Enclosure

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WELCOME AND INTRODUCTIONS

Mr. Phil Colegrove, Mechanical Working Group Vice Chair, opened the meeting for Mr. Richard Shaltens who couldn't attend the meeting because of travel limitations. Dr. Inara Kuck, the host of the Mechanical Working Group meeting welcomed everyone to Phillips Laboratory and addressed the possibilities for lunch in the area. Mr. Colegrove turned the meeting over to Dr. Jerry Beam to introduce the Panel speakers.

PRESENTATIONS

Thermal Management Panel

Dr. Jerry Beam, Thermal Management Panel Chairman, identified that four topics within the Thermal Management Panel would be discussed. He then introduced Mr. Ted Swanson, the Panel Vice Chair, as the first speaker.

Mr. Ted Swanson, NASA Goddard Space Flight Center, presented the topic "*A Thermal Flight Experiment Test Program*" that is ongoing at NASA Goddard. Before addressing the program's objective, Mr. Swanson explained that the other NASA sites perform other tests. He discussed the technology needs that led to this flight experiment, stating that the analytical model and the hardware need to reveal the same information. Mr. Swanson discussed the future trends of the spacecraft design pointing out the conflict between the radiator and the instrument views. He also addressed future needs of exposure to high thermal sink temperatures for the lunar surface.

Future spacecraft will also have an increased need for cryogenic cooling. The evolution from discrete to central thermal control is also a future trend that was mentioned. Mr. Swanson displayed an overhead revealing an analogy of the enhancements of heating systems in buildings to that of spacecraft showing the two phase central thermal bus as the most recent spacecraft advancement.

Next, Mr. Swanson discussed the current efforts at NASA Goddard. He addressed a 12 year in-house development effort with Capillary Pumped Loops (CPL) and discussed the "proof of concept" experiment and the analytical model that is being validated in space. The CPLs are baselined for several spacecraft such as the Earth Observing Spacecraft (EOS). Mr. Swanson went into some detail explaining the components and capabilities of a CPL. He then explained how a CPL operates by using a schematic drawing and pointing out the flow of liquid throughout the model. Mr. Swanson addressed five points of a CPL system and then showed a model of a capillary pumped system emphasizing that there were no moving parts, hence nothing to wear out. Mr. Swanson then identified the only known facilities doing work with CPLs and then gave a history of the CPL stating that the development began in the '60s and picked up speed in the '70s. Now the applications for CPLs have gone beyond that of heat pipes. The other technical efforts at Goddard include flight experiments in both room temperature heat pipes and cryogenic heat pipes pointing out that verification tests had been completed for the testing of the CRYOTP experiment. Mr. Swanson showed a photograph of PCM and heat pipes and explained that it is flown on the shuttle in "hitch-hiker" mode with control from the ground. Next he discussed loop heat pipes and the Russian technology and he showed a schematic of heat pumps with a 2-phase bus concept explaining the high rejection temperature cooling payload. Another thrust area mentioned at NASA Goddard was work in the area of micro heat pipe/CPL and Mr. Swanson discussed the increased hot spots on the board. He also discussed water based heat pipes addressing the application for high temperature and non-toxic fluid. Mr. Swanson displayed and discussed a table denoting thermal control hardware applications for low temperature, room temperature, and high temperature devices. Lastly, Mr. Swanson discussed the plan for the thermal advanced development flight experiment program which showed the flight experiments needed in the future on a time line. At the conclusion of questions, a break was taken and then the next speaker was introduced.

Mr. Kirk Yerkes, Wright Laboratory, presented the "*Development of Actuator Thermal Management*". He stated he had just returned from getting his doctorate degree and his presentation was a summary of his work at school and at Wright Laboratory. He stated the work on actuator thermal management had pulled together in the last year. Alot of work was done with actuators, not particularly difficult, just different work. He offered ideas of future thrusts o fthe actuator development. Aircraft actuators are multi-disciplinary. The goal is to increase reliability and life by cooling things like high power electronics of motors and generators. The actuator types he discussed were EMJ, EHA, and smart actuators. Passive thermal management is the focus primarily because of the support that is needed andto help eliminate the fluid lines. In particular, we're looking at heat pipe technology and reflexive technology utilizing stuctural heat sink. Passive thermal management still has some transcient issues to resolve. The end result is increased reliability and life. He displayed a frequency response (on a graph) showing the need to diminish the peaks and the time at the peaks.

Five types of passive thermal management were discussed. Mr. Yerkes stated that the heat pipe is gravity sensitive. Key elements being looked at are the environmental body forces. Thermacore developed heat pipes for the Navy. In house studies are currently being conducted. Sunstrand is working on a 34 hp motor, with expectations of achieving 50 hp.

Arterial heat pipe performance in transcient body environments were discussed. The purpose was to test steady state transverse acceleration and transient acceleration. Mr. Yerkes discussed the Thermacore approach with flexible bellows heat pipe. He showed pictures of evaporator pads, flexible artery, and the condensor pad. He mentioned that this set up is at Wright Laboratory. A schematic was shown with a centrifuge table room and condensor room. Many pictures were shown of various segments of the heat pipe assembly. He then showed a graph of transient acceleration which showed a normal acceleration plot. Radial mounting and transverse mounting were also discussed. Steady state tests had been run from 1-10 G to verify that it would run. Mr. Yerkes showed a graph depicting transient and axial results. Currently, Mr. Yerkes has experienced coupling of the acceleration transients to the power transients, which is the key behavior pattern. Mr. Yerkes next discussed the affects of acceleration transients on maximum power transports. Reflux cooler work with a standard approach was also discussed. He showed early schematics of a scanner spar and phase change cells. Rotating thermosyphon is just getting off the ground and the operation was explained as Mr. Yerkes pointed out the centrifical forces and the cooling provisions. He then showed a schematic of a tapered wall that is being used instead of a wick structure. The different design configurations are circular, conical, and circular evaporator. One of the prime interests of this area is the ability to have it on-axis or off-axis. This increases the transport, but work still needs to be done. In summary, the serious issue that needs to be addressed is the exclusion of vibration from the duty cycles. The goal has been to develop the actuator and put it on the centrifuge. Many questions were asked concerning vibration and other issues. After all questions were answered, Dr. Jerry Beam announced another brief break.

Mr. Bob Vacek, Phillips Laboratory presented an "*Overview of Phillips Space Thermal Technologies Branch*". Mr. Vacek began by addressing the technical focus of cryogenic technologies and spacecraft thermal control stating that Phillips is market driven with high risk high payoff. Full technology life cycle development has been done by Edwards AFB and then activities have moved to Kirtland AFB. IDEAS platform for Sunstation was discussed. Becoming more involved with space experiments. Mr. Vacek showed an Organization Chart and pointed out the power and thermal technology divisions at Phillips Laboratory and then highlighted their capabilities. Mr. Vacek showed an overview of cryogenic technologies stating that this area was vastly funded. Infra red is the concentration for funding. He gave the background, objectives, and technical requirements, stating that the requirements were stringent. He compared the application and the research effort in the area of cryogenic development stating that the most important requirement is the MWIR sensor (60-65K). The LWIR sensor for cryogen storage is 35K. The VLWIR sensor for superconducting devices is 10K. The primary optics SWIR sensor is 120K. Next, Mr. Vacek discussed the five tasks of management in the program structure of cryogenic technologies. Mr. Vacek stated that there is concern with Task IV. Next Mr. Vacek highlighted an overview of spacecraft thermal control giving the background, objectives, and technical requirements of this area. Conventional space applications were shown to reach approximately 450K while heat pipes reach 600K. Mr. Vacek concluded by answering a few questions regarding heat pipes. Dr. Beam then introduced the next speaker.

Mr. Albert Bertram, Naval Surface Warfare Center (NSWC), gave a presentation on "*Materials for Thermal Management*". Mr. Bertram opened by stating that NSWC has been working in the area of thermal management for several years. This was an outgrowth of earlier work involving the development and use of Metal Matrix Composites (MMC), particularly graphite reinforced metals, in space applications. Hence, the bulk of the work in thermal management is based on materials reinforced from ultrahigh thermal conductivity graphite fibers such as the Amoco K1100 fiber. The presentation covered five areas: a manufacturing technology graphite fiber program, a robust processing program on cast graphite reinforced aluminum, a space radiator demonstration program, a high thermal conductivity carbon-carbon program, and a carbon "brick" material program.

The Manufacturing Technology program (development of low cost high thermal conductivity carbon fibers) has been terminated due to lack of funding. However, some of the work will be picked up in the Robust Processing Program. The ManTech program had four tasks. Task 1 was for fiber processing development optimization to get the fiber conductivity up and consistent and to establish reproducibility and to reduce the cost. Task 2 was to obtain data on composites incorporating the fibers into various matrices to demonstrate representative thermal and mechanical properties that could be obtained. Task 3 was to fabricate and test two specific components (namely a graphite/copper satellite radiator and Standard Electronic Modules Format E (SEM-E)). Task 4 was to perform a survey and determine other components where the incorporation of ultrahigh thermal conductivity graphite fibers could provide a beneficial payoff in the materials. In addition, this task was also to examine composites made of pitch and PAN graphite fiber combinations to see if they could be used in aircraft appications where a combination of strength and thermal conductivity were both of importance.

The Robust Processing Program is to demonstrate the performance of graphite/aluminum plates as SEM-E thermal planes and to demonstrate the producibility and robust processing capabilities of casting for Gr/Al thermal planes. The outline of the program was to demonstrate composting capability with existing tooling, standard fiber and standard processing with several vendors, downselect and demonstrate rapid processing capabilities with existing tooling but utilizing modified fiber and/oer preforms, and then produce at least 25 full-scale components meeting property requirements in a single 8 hour shift. The program is now in the process of scaling up in size and using the higher thermal conductivity fiber. Future plans are to demonstrate the robust processing capability of the program.

The Metal Matrix Composite Space Radiator Demonstration is to determine the feasibility of using advanced composites for improved thermal management in Navy Satellite systems. Ten-layer Gr/Al plates were fabricated and tested to ascertain if they could meet the specified requirements. A nickel-hydrogen battery component was then assembled and tested. The component passed the space qualification requirements for thermo-vacuum and vibration. The assembly is now awaiting an upcoming flight.

The Carbon-Carbon Composites for Thermal Management program is a Phase II SBIR contract. The purpose of this program is to optimize the thermal conductivity of the carbon-carbon composites. Methods to accomplish this include using different matrix starting materials, using different fibers, and using additives to the matirx. Materials have been fabricated and tested using both balanced and unbalanced weave fabric preforms. It has been shown that the improved matrix conductivity provides equivalent or higher thermal conductivity of the composite at lower fiber volumes.

The feasibility of the Carbon "Brick" material was shown on a Phase I SBIR contract. A Phase II SBIR proposal was recently approved. This material take green fibers of the type used to make high thermal conductivity graphite fibers directly from the spinnerette and consolidates them. The compressed material is then carbonized and graphitized using processing similar to the conditions used for the fibers. The resultant brick material can be machined into components or impregnated with epoxy or metals to enhance the properties. Mr. Bertram concluded his presentation by showing the properties of impregnated materials.

Dr. Beam announced that following the lunch break, the Aerospace Power Panel would resume. After lunch, the meeting was reconvened by Mr. Phil Colegrove, Working Group Vice Chair, who announced the opening speaker for the Aerospace Power Panel, Mr. Scott Rubertus, could not attend and stated that he would present Mr. Ruberus' material.

Mr. Phil Colegrove, Wright Patterson AFB, presented the "*C-141 Electric Starlifter*" giving the background, system layout, and electric actuator description. Mr. Colegrove identified that this program is to replace hydraulic actuators. Mr. Colegrove discussed the projected C-141 operational payoffs, specifically discussing the operational availability, sortie generation, and reliability and maintainability. Mr. Colgrove specifically addressed the increased MTBMI of the flight control system by 50%, the reduced MTTR by 50%, and the MMH per AC per year reduction of 55%. The team functions of the C-141 Electric Starlifter were explained. The program status was also given as Mr. Colegrove emphasized the hardware and software specifications that were completed, along with the completions of the software design, coding and testing. He also stated that they built actuator mock-up components. He stated that the Aileron system design is completed. He then showed a schedule for the program based on funding. Flight tests should begin around July of '94. He showed the Aileron control system pointing out the cable linking the front of plane to the back. The pilot and co-pilot operate this cable and Mr. Colegrove emphasized the difficulty of the linkages of the wheels, pullys, and cables. He showed the spoilers and actuators in each wing, emphasizing the maintenance involved. He showed many pictures such as the double actuators. Spoiling is needed to tilt the plane so it can release things out of the rear of the plane. He then showed a C-141 Electric Starlifter pointing out the key components and stated that all previous planes were to be replaced with this Integrated Action Package (IAP) system. He discussed the conventional hydraulic methods as he compared them to the electronic actuator. The new IAP utilizes a single speed motor with 115V AC from the aircraft. Mr. Colegrove concluded with the Aileron actuator characteristics and then introduced the next speaker.

Captain Shaun House, Phillips Laboratory, presented information concerning "*Battery Research*". In discussing the goals of the program, Capt. House identified a 15% decrease in power system mass, a 5% decrease in satellite mass, and an increased satellite lifetime of two times. He discussed the battery performance of energy density over the years. He highlighted the following battery programs at Phillips Laboratory: Nickel Cadmium, Nickel Hydrogen, Sodium Sulfur, and solid state. He discussed the special NiCa testing at Phillips stating that is it was a small in-house effort to demonstrate performance of Sanyo 4 AH cells under Leo conditions and compare the performance with other Sanyo NiCa batteries operationg at different temperatures. The NiH_2 testing goals are to produce more energy with more life. The objectives are demonstrate performance in orbit. He showed test results of the life testing of NiH_2 with roughly four failures from things such as separator dry out. He discussed common pressure vessle testing and showed the test schedule for this to begin in late '93. Then Capt. House discussed the NiH_2 pulse test which is a subset of Leo lifetest. Next he discussed the Sodium-Sulfur Technology (NaSTEC) Program at Phillips which includes participating members of NASA, Sandia National Laboratories, NSWC (Crane), NRL, and industry. The program is divided into three phases; two of ground testing and one of shuttle flight testing. He then gave the details of the flight test. Solid state batteries were discussed next as Capt. House explained the radical effects of testing. Advantages of using solid state batteries are that they have high energy density, they can be made in any shape, they operate at different temperatures, and lower costs are possible. Applications for solid state batteries are situations that are volume/weight limited, power supplies for micro-electronics for integrated circuits, and energy storage for distributed power systems (such as very large space station radar). The Air Force efforts are concentrated on geo satellites. The goals are 10 year life with greater than 1000 cycles at 80% DOD. He identified contractor efforts of Alliant, Harwell Labs, JPL, EIC Laboratories, emphasizing that all of the contracts are under $200K per year. Capt. House concluded with an in-house effort of life testing Canadian cells. Currently setting up with Sandia to work on electrode materials to build some small laboratory cells.

Lt. Joel Boswell, Phillips Laboratory, presented the "*Photovoltaic Programs in the Airforce*". He outlined the solar cell development, solar array development, and flight experiments. The first area of solar cells covers high efficiency solar cells and lightweight solar cells. In the area of high efficiency solar cell development, Phillips has three contracts: RTI, Spectrolab, and WSU. The goal is to develop solar cells better than the cells currently available. Specifically, the goals are to achieve 23% efficiency with a two terminal configuration and a structure of 2cm x 2cm. He gave the current status of each of the contractors. RTI has gotten the top cell that they are looking for, but the silicon cell is presenting an obstacle. Spectrolab has also been successful with the top two cells. WSU has not been successful. An SBIR program with Astropower for lightweight light-trapped thin GaAs was discussed.

Thin film cells was discussed next as he showed some thin films and explained that paneled arrays were built from these which is very labor intensive. One contract in this area is with Martin Marietta and the other is with Boeing. He discussed the two schedules of both contractors.

An advanced array program, not yet started, was discussed as Lt. Boswell stated that the program manager was looking for proposals from companies who could build solar arrays. Another program called the Inflatable Torus Solar Array Technology (ITSAT) program was mentioned. The ARPA program managed at Phillips Laboratory is targeted for smalller power levels of 300-600W per wing. Deployment tests and thermal property tests are complete. A flight demonstration is planned for May '96.

Next, Lt. Boswell described two flight experiments. The first was called PASP Plus. It is a cooperative effort with NASA. The objective is to determine voltage and performance limits of 12 advanced photovoltaic array designs operating in the natural space environments. Array modules were installed on payloads of the satellite. The testing of the payload panel and shelf was completed along with comprehensive performance testing and environmental testing. A launch of the satellite is scheduled for January of '94 and is to have a three year mission. The second program is called Space Technology Research Vehicle (STRV) which is a micro-satellite flown by the Bristish Defense Research Agency. The STRV is concerned with supplying power panels for powering satellites. Lt. Boswell stated there is an extensive list of experimental cell types that are being installed. He also stated there is cooperation with NASA Lewis. Questions were anwered regarding the use of thin films.

BUSINESS MEETING

Old Business

Mr. Phil Colegrove, Mechanical Working Group Vice Chair, announced the commencement of the business meeting. He stated that there were three action items to cover. The first was to find a replacement for Dr. Jerry Beam, Chairman of the Thermal Management Panel, who is retiring. Mr. Colegrove stated that Mr. Ted Swanson, Panel Vice Chair, had agreed to ascend as Chairman. Mr. Colegrove stated that Mr. Al Bertram of the Naval Surface Warfare Center had agreed to fill the Vice Chair position. Mr. Colegrove made a motion to approve Mr. Bertram as the Vice Chair of the Thermal Management Panel and the motion was seconded, voted on and approved.

The next action item from the last meeting was for the PIC to take the information presented from the last meeting and extract information to be put on PIC Worksheets. This was completed by the PIC, but it was Mr. Colegrove's opinion that this task should not be continued because not all of the PIC briefs will ever be briefed so relying on that method to keep the briefs updated will not work. There needs to be a better way to update the briefs.

The next meeting location was discussed. Mr. Colegrove asked for volunteers to host the meeting in six months. The members suggested that Mr. Bertram, the newly elected Panel Vice Chair, host the next meeting. As Mr. Bertram was not in the room at that time, Mr. Colegrove stated that he would get in touch with him and plan it for early May at the NSWC.

The members discussed their desire for a symposium, as the last one was so well received. Many members asked if the symposium was already a possibility and asked who needed to approve such a meeting. They expressed the value of the contacts made at the past symposium and stated that this form of networking is not available at the general meetings. The response from the PIC was that the subject of a symposium was a topic that was scheduled for the upcoming Steering Group meeting and that the decision would need to be made by those members. An action item was assigned to Mr. Shaltens to express the request of the Mechanical Working Group's desire for a symposium to the Steering Group.[1]

New Business

Mr. Colegrove asked if there was any new business to discuss or if any other items needed the Steering Group's attention. There were none and a motion was made to adjourn the meeting until the following day's session of the Terrestrial Power Panel.

Terrestrial Power Panel

Mr. Phil Colegrove, Mechanical Working Group Vice Chair, opened the second day of the

[1] Action Item.

meeting by announcing the opening of the Terrestrial Power Panel session. He introduced Mr. Scott Coombe, the Panel Vice Chair, who was also the first speaker.

Mr. Scott Coombe, US Belvoir RD&E Center, presented information on the "*Ground Based Radar Advanced Power System Development Program*". Mr. Coombe began by stating that the presentation of the Ground Based Radar (GBR) system was an update to a briefing in May and he showed overheaddrawings of the system. The GBR is part of the Theater Missile Defense (TMD) concept stating that it is analogous to Patriot except it's a larger scale, thus requiring more power. He stated the whole system requires 1.1 mega watt of power. The whole system, including a radar antenna, electronics equipment, cooling equipment, control shelter, and a prime power system, is under contract to Raytheon. Raytheon has developed two fully operational systems that can be employed for emergency situations. The current focus is the Engineering Manufacturing and Development (EMD) contract that is to be awarded in the first quarter of FY97. It will consist of 28 generator sets. Mr. Coombe discussed the TMD-GBR advanced 1.1 MW power system development by pointing out the milestones, funding profile, the requirements and the special considerations. The milestones stipulate acquiring 2 diesel engines or 2 turbine engines and downselecting with the best choice.

He discussed the transportability and the mobility of the system. Also, he discussed the power level of 1.1MW being at 8000' and sustaining temperatures of 95°. He addressed the special requirements stating that there were not any generators available in the DOD standard inventory that met the requirements. Mr. Coombe explained that the turbine engine assumed a low technical risk for mobility, while the diesel generator had low fuel consumption. There is also a requirement to standardize power. There is a large logistics impact because it's a new system and limited quantities. He next discussed the program organization stating that the user is the Air Defense Artillery School in Ft. Bliss, Texas and is managed by the Huntsville office. All of the fabrication is conducted at Ft. Belvoir RD&E Center. There is a power systems advisory group to help make the decisions which includes: Air Defense Artillery School, PM-GBR, PM-MEP, Prime Power Battalion, Belvoir, and Los Alamos National Labs.

Mr. Coombe next discussed the specifications of the advanced GBR systems, covering the diesel and the turbine alternatives. The biggest difference in the specifications involves the difference in weight. The operational weight of the diesel is 30,000 pounds and 18,000 pounds for the turbine. The diesel system is large and there has been difficulty in finding a trailer for this set to be housed. Currently, efforts have been made to modify the trailer used for the Patriot.

Mr. Coombe showed a schematic drawing of the turbine version GBR power system addressing the removable panel approach. He stated that the fuel tanks for the turbine version holds fuel to last for one hour of operation. In parralelling this version, he showed a schematic of the diesel version pointing out the semi-trailer approach.

Next, Mr. Coombe compared the major thrust of Belvoir to that of Raytheon. He showed a photograph on the overhead of the HMET. Then he showed photographs of the three prime candidates for the diesel engine contractor. Of these, he stated that the Perkins Condor engine is the best candidate. He next showed a photograph of the five current candidates for the turbine engine.

Before summarizing, Mr. Coombe displayed the management structure for the development of the GBR program which is headed by the Bullistic Misile Defense Office (BMDO). In summary, Mr. Coombe stated that the FY94 funding was significantly reduced. On a better note he stated that the program was technically on track to meet all requirements and that PM-GBR remains committed to the program.

Mr. Walter Taschek, Fort Belvoir RD&E Center, presented the next topic on "*Power Systems Assessment*". Mr. Taschek explained how his field was related to Mr. Coombe's and explained how they worked together. The goal of the system's assessment team is to analyze cooling, heating and power requirements, to assure the fielded systems are: mobile, sustainable, effective, and fuel efficient under worldwide combat conditions. They analyze heating and cooling power requirements and measure them when they can. He stated that they developed tools to measure power data during system operation of cooling and heating. This information is kept in a database that they developed. They try to pin point peak power requirements as well as average power requirements. He showed examples of HEMV systems they looked at and indicated the location of the cooling units. Showed a bigger system that is less mobile.

Mr. Taschek next discussed the impact of cooling on mobility. He used a scenario of S250 or Standard Integrated Command Post Systems (SICPS) shelter. He explained that having the same average heat load and the same shelter heat load, that the equipment heat load could be externally disipated reducing the total heat load, thereby only requiring 9,000 ECU. He then showed a graph depicting a cooling analysis which demonstrated reduced equipment load. He discussed the need for vehicle downsizing as he showed the basic system, the enhanced system, and the future system. The basic system utilizes a 2-1/2 ton truck requiring 9704 KG and by reducing the total heat load, the enhanced system can be used which utilizes an HMMWV and requires 5102 KG of power. The hope for the future is to combine the power system on board and eliminate the use of the trailers because the power requirements are only 3736 KG.

He next addressed recommendations to reduce cooling and electric power loads. If cooling loads are reduced then electric power loads can be reduced. This can be accomplished by mounting high power components outside, for example, on the hitch. Also, heat can be conducted through shelter walls through paneled heat exchangers. Another recommendation was to cool with ambient air and practice load management. The advantage of mounting high power componets outside is having 100% heat rejection and space is usually available over the cab or in wheel wells. One disadvantage is that high temperature operation is a necessity. Cooling electrical components and cooling soldiers is also necessary. Mr. Taschek also suggested conducting heat through shelter walls and dissapating heat to the outside. Cooling with ambient air was also discussed. Mr. Taschek explained that load management helps to keep the size of generators down. Using load management with critical mission power generated equipment is designed to reduce the air requirements during peak electric load.

On board APU/PPUs were discussed next, as Mr. Taschek explained that the SICPS program is ongoing. The SICPS shelter is a box on the back of the HMMWV and a tunnel that goes all the way through that was envisioned to enclose the air conditioning unit and the auxiliary power unit.

The recommended approach is to use DC systems compatible with vehical/battery system to allow emergency operation in the event of generator shut-down. System cooling requirements were shown in graph form which revealed that the ECU required the power. Only 5 kw is needed for the compressor of an engine that size. In summary, Mr. Taschek stated that mobility can be realized with on-board generators.

Mr. Larry Jackson, Fort Belvoir RD&E Center, presented information on "*Generator Prognostics and Diagnostics Equipment (PDE)*". Mr. Jackson opened his presentation by stating the purposes of the program. The generator PDE is designed to reduce power interruptions on generators particularly on generators that are unattended while operators have other duties. The PDE is to ensure that operators are aware of any degradation of performance. The PDE also provides on-line system monitoring for conditional maintenance, as opposed to time schedule maintenance that is currently used. This more efficient method of maintaining only when necessary will help reduce downtime and repair time.

The background of the generator was discussed next. Mr. Jackson explained that back in '87 Ft. Belvoir had a game plan to acquire tactical, quiet, and reliable generators. Mr. Jackson initiated a Phase I SBIR and received 25-30 proposals and found Winrock, who could produce diesel engines. In '88, the logistics R&D work began by producing software capabilities to interface with the tactical quiet generators. A Phase II SBIR with Winrock Inc. was initiated which specified the diesel engine driven generators.

The technical details were discussed next. The hardware is a microprocessor 8086 chip with a display panel with membrane pads around the screen like an ATM machine. There are a variety of different boards and sensors. The software is C++ in a DOS based environment which takes a reading every second. The cost is about $1800 per PDE with the expectation of a decrease in price as production increases. The cost can be recouped over the life of the generator since it's more reliable. Although it's difficult to link the cost savings of the reduced downtime, it is another factor that will offset the cost of the PDE. He showed a hardware block diagram, pointing out what the user sees, the display panel, and then all of the associated processing elements that are not seen.

Mr. Jackson discussed the technical details of the PDE. He stated that they had taken over the generator's controls. They were not governing the engine, just controlling all of the functions that were at the instrument panel. All the gages were consolidated into this package. Also, the indicator lights on the panel show a green light for normal operation; a yellow light that indicates a fault; and a red light that indicates a serious problem and may shut down the generator. Fault messages are displayed for the operators and there are provisions for operator override. A diagram of the PDE was shown which indicated the display screen for the messages; the warning, or indicator lights; and the membrane key pads. Many different screens were shown of what the operator might see.

Next, Mr. Jackson discussed the PDE fault detection. Faults are detected in the cooling, electrical, fuel, mechanical and lubrication systems of the engine. There is also fault detection of the generator and the PDE sensors. An example was shown of the display screen if a fault exists. Cooling system faults can be coolant sytem failure, excessive temperature, fan belt slippage, and improper cooling air flow. Electrical system faults can be low battery charge, battery charging failure, battery sulfided, voltage regulator, insufficient cranking voltage, and fan belt slippage. Fuel system faults that can be detected are poor fuel quality, failed fuel injectors, pumps, or injector line leaks, improper injection timing, fuel system not primed, low fuel level, and clogged air intake. Mechanical faults such as improper engine speed, worn or damaged rods/bearings, valve overlash, excessive head vibration, excessive temperatures, low engine power, and bad turbochargers can be detected. Mr. Jackson discussed that the lubrication system faults are more precise than before.

In summary, Mr. Jackson discussed downloading information with the PDE and stated that an RS232 interface is used. Maintenance history, fault history, and operating history of the past 24 hours is maintained. He showed a display screen of the maintenance menu and an example of the faults that are displayed. Lastly, he briefly identified the potential improvements to the system stating that control capabilities can be expanded and software can be improved with more electrical diagnostics, and remote alarms.

Mr. Colegrove, Working Group Vice Chair, announced the closing of the meeting and invited all participants to attend the tour of Phillips Laboratory that was scheduled next.