BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: ALSEP Central Station Thermal Design - Case 340

DATE: February 16, 1968

FROM: P. J. Hickson

ABSTRACT

In the past few months there has been concern as to whether the ALSEP central station thermal control system would perform adequately in lunar operation. This concern was occasioned by recent Bendix analytical predictions on lunar performance, and by the need to provide the experiment with 8 watts additional power and the need to consider a larger power regulator (40 W→55 W) so that the central station could accommodate a larger RTG power source (63 W→75 W). Inclusion of these items would tend to make the predictions worse. The author participated in meetings which examined the thermal problem on November 17 at MSC, and November 30, December 7-8, and January 8-11 at Bendix, Ann Arbor, Michigan.

This report summarizes the actions at those meetings. After a detailed examination of the prototype test data and consideration of the impact of minor hardware alterations and a new thermal control operating procedure, it was concluded that the ALSEP central station thermal design is no longer a source of great concern.

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MEMORANDUM FOR FILE

In the past few months there has been concern as to whether the ALSEP central station thermal control system would perform adequately in lunar operation. This concern was occasioned by recent Bendix analytical predictions on lunar performance, and by the need to provide the experiment with 8 watts additional power and the need to consider a larger power regulator (40 W→55 W) so that the central station could accommodate a larger RTG power source (63 W→75 W). Inclusion of these items would tend to make the predictions worse. The author participated in meetings which examined the thermal problem on November 17 at MSC, and November 30, December 7-8, and January 8-11 at Bendix, Ann Arbor, Michigan.

The meetings on November 17 and November 30 were held to define the source of concern, request additional thermal calculations and documentation and to encourage Bendix to undertake a detailed re-examination of all the constraints of the present design. The meeting on December 7-8 was a Prototype Thermal-Vacuum Test readiness review. At that meeting, it was determined that Bendix had adequate documentation and predictions prior to the test, and that the test would serve as a Thermal Design Verification Test. MSC has assigned the additional 8 watts to the experiments and determined that the present 40 watt regulator is adequate. The January 8-11 meeting was held to examine in detail the test results, which were surprisingly good, and the new analytical predictions relating to a slightly altered design with altered operating procedures ("active" rather than "passive" thermal control). Following a day devoted to the Bendix presentation, the author and R. S. Harris of MSC spent three days examining the analytical predictions and test results in detail to determine their credibility. Pertinent information on the thermal control system follows.

The prototype ALSEP central station thermal control system is totally passive and is configured to satisfy the lunar surface dust requirement laid down in September 1965.* The design consists of a 2 foot square horizontal radiator plate to which the electronics are thermally attached (Figure 1). Except for this attachment, the electronics are the thermally

*All sunlight surfaces are assumed to have 100% dust degradation.

isolated in a superinsulation bag, and the radiator plate is effectively decoupled from lunar surface thermal inputs. A sunshield, which also serves as an experiment tie-down pallet during lunar transit, is located 26 inches above the radiator plate after deployment. A V-shaped silver-coated mylar reflector connects the ends of the sunshield to the center of the radiator to prevent radiation emitted from the lunar surface from reaching the radiator. The reflectors face north and south after deployment with side curtains and awnings preventing solar radiation from reaching the radiator. The ALSEP electronics were designed assuming that the radiator temperature would be between 0°F and 125°F. The thermal design is insensitive to all lunar surface dust conditions except for insulating layers of dust on the radiator or optical layers of dust on the reflectors. About one-half of the radiator area is masked by superinsulation to provide the appropriate effective radiating area. Alterations in the mask area will change the average operating temperature of the radiator but will not change the day-to-night temperature swing.

In November the predicted temperature for the prototype model in lunar operation, but with the larger 75 W RTG and 55 W regulator, were -20°F to 167°F, a swing of 187F°. Further, while the swing was nearly the same at each point on the radiator, the radiator has a temperature distribution of ± 10F° about its mean temperature. These predictions resulted in the initial concern over thermal control.

In December the pre-test prototype A prediction for the vacuum chamber operation was -10(± 10)°F to 130(± 10)°F. The test measurements show a radiator temperature of -13(± $\frac{9}{7}$)°F to 105(± $\frac{9}{7}$)°F. The test also revealed that the predicted ΔT between the radiator and individual electronic components of 15 to 60F° were generally high by a factor of 2*. This somewhat relieves the concern about radiator hot-spots, especially in light of the fact that most electronic components are given a (short) functional test at soak temperatures of -20°F and + 158°F, and the communication components at -10°F and + 140°F. A small correction to 3 geometric radiation view (F) factors (worth -6F° on the radiator swing) and increasing

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*The 60F° estimate for ΔT applies to the Power Conditioning Units (PCU) regulating transistor which can have a power dissipation of up to 12 watts. The test gave a measured value of 37F° for this component and < 10F° for all others.

the reflector reflectivity to 0.9 (worth -4F°) still leaves the prediction 9F° high (after the test prediction is corrected to the measured test values of power, etc.: worth -9F°). The prediction below is, therefore, 9F° lower than the computer answer.

The current ALSEP, starting with the Qual A model, has the awnings removed (allowing solar radiation on the mask of the radiator only, taken as worth -15F°), a 40 watt regulator, a 63 W RTG (guaranteed), and the new day and night experiment powers (giving a PCU output power of 38/51 watts). The latest Bendix prediction of the radiator temperature swing is now 148F°. The latest MSC prediction of the temperature swing is 125F°. This is accomplished by:

1.	use of a more realistic lunar surface model than the over-conservative one permitted in the Bendix prediction (i.e., the use of realistic thermal properties for the lunar surface, including the effects of shadowing underneath the central station, has the equivalent effect of using isolating pads between the central station and an isothermal moon).	-5F°
2.	use of measured value of the flight RTG power at ∿68 watts	-8F°
3.	use of the existing command power dumps during the lunar day only (i.e., operational change to "active" thermal control* by dumping 21 watts outside the central station)	-10F°
	i.e., total decrease below the Bendix prediction of 148F° is 23F°, for a net of 125F°.	-23F°

Actually the awning removal may be worth -20F° rather than the -15F° used in the above, so that the prediction may be close to 120F°. This could go to 115F° if internal dump resistors can be added to the experiment No. 5 switches, or if one set of Power Conditioning Unit (PCU) regulator resistors can be moved inside the central station (each worth -5F° but not additive) with no schedule slip. In any case, some insurance is available in that emergency use of the ALSEP contingency heater is worth -6F° on the radiator swing but would switch

*No power is (or need be) specifically allocated for thermal control.

one experiment to standby* (i.e., degrade the total science output of ALSEP if 100% coverage of all experiments is essential).

In summary, having examined the Prototype test data and the analytical procedures used by Bendix, it is concluded that the present temperature predictions are fairly reliable (+5F° to -10F° is our estimate for each predicted temperature)** and that the ALSEP central station thermal design is no longer a source of great concern. This does not obviate the need to consider the possibility of degradation due to dust accretion caused by the LM ascent blast. As noted above, a 10% decrease in the specular reflectivity of both reflectors would increase the temperature swing of the radiator by about 4F°.

While not formally recommended, we support the following views:

1. The present analytical estimate of the power dissipated inside the central station as a function of PCU output power for an assumed total power output of the RTG is the sum of two terms: 1) the PCU power converter loss is 5 W + 7% of the PCU output power, 2) a parabola-like term for the power loss in the PCU regulator transistor which has a base value of zero and a peak of ∿9 W. This dissipated power can, thus, total about 9 to 19 watts. Only indirect data on this crucial power map is available from the Prototype test, and so detailed measurements of the PCU power map should be made as soon as possible.

2. The altered design and new operating procedures and power levels should be thermal-vacuum tested as soon as convenient. Most of the swing changes reported above were "deltas" from a nominal computer output assuming that the radiator temperature change per watt of power dissipated in the central station is

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*The ALSEP central station is provided with a 10 W contingency heater which is thermostatically switched on at -10°F and off at 0°F. If on, it can be commanded off. If the ALSEP power demands exceed the RTG output, an appropriate number of experiments are automatically switched to standby (survival) power levels by the central station.

**Not a large error on a radiating temperature of up to 600°R with complex geometry in a 50 node analysis.

+ 3F° at night and + 1 to + 1 1/2 F° in the lunar day. Hence, detailed computer calculations on the final configuration and operating powers should proceed on a priority basis and a final presentation and review be scheduled to finally clear this issue at an early date.

3. Future ALSEP's should be provided with duplicate sets of regulator resistors (of both redundant PCU's), one set inside and one outside the central station and with the command capability to switch from one set to the other as desired. This would provide ALSEP with a proportional power dump both inside and outside the central station, and thus, allow every available fraction of a watt to be used for thermal control. Possibly this might now be implemented using the experiment No. 5 switches.

4. Since the "problem" reported here was precipitated in part by additional allocations of thermal control power to two experiments, it would seem appropriate to subject the experiment thermal designs to the same careful scrutiny if for no other purpose than to avoid requests for further allocations.

5. The reliability of ALSEP should be assessed in detail for operation outside the nominal 0°F and 125°F limits.

6. The extent of degradation of ALSEP central station thermal control due to dust accretion, caused by the LM ascent blast, should be assessed in detail, especially as to the effect of off-nominal deployment from LM.

7. Removal of the present side curtains should be given appropriate (low-priority) evaluation, since it is the only low-impact hardware modification left to consider.

Paul J. Hickson

2015-PJH-kse

P. J. Hickson

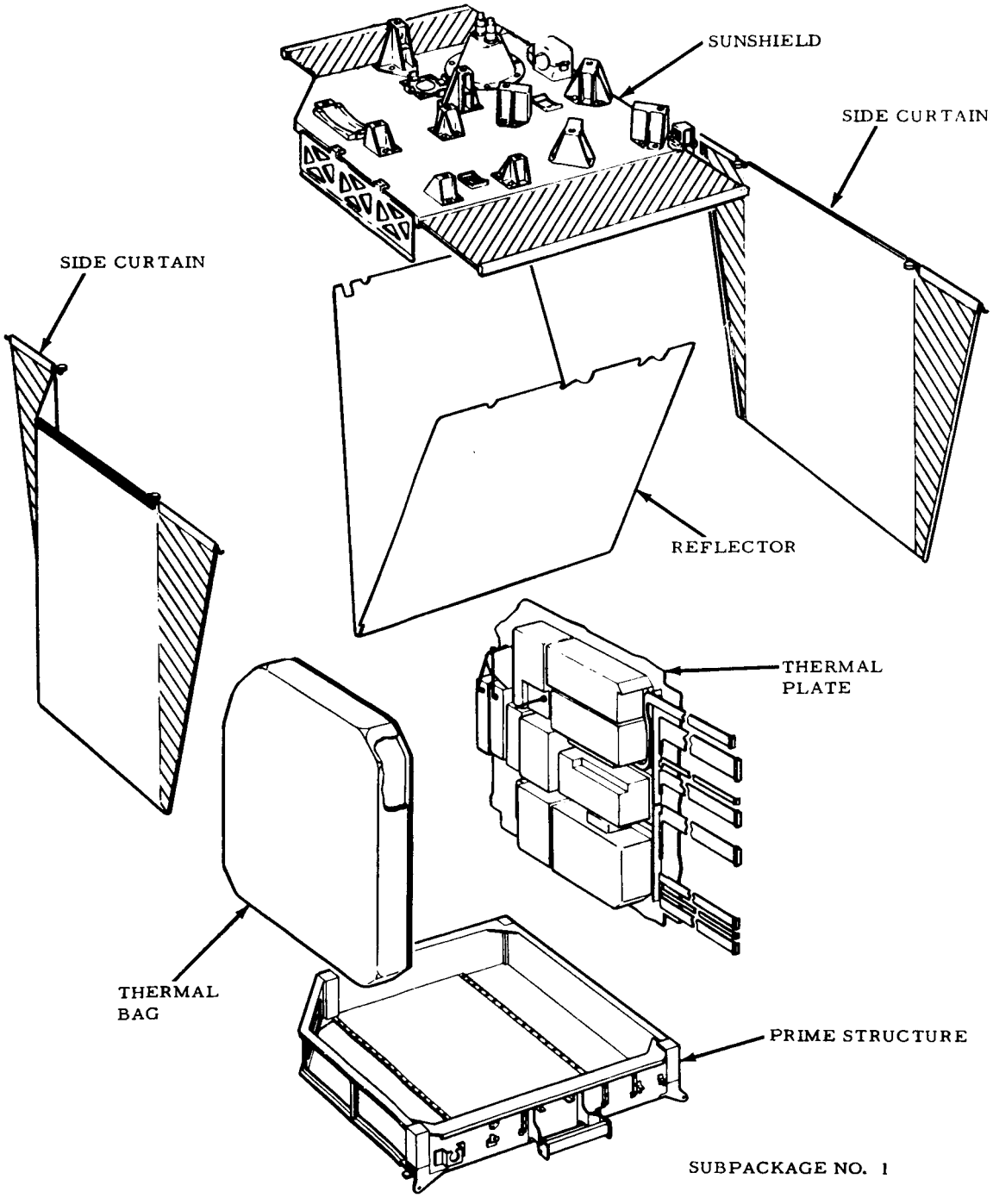

FIGURE 1 - ALSEP CENTRAL STATION, PROTOTYPE MODEL CONFIGURATION. THE QUALIFICATION AND FLIGHT MODELS HAVE THE SHADED AREAS REMOVED

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