Beginning of Mission Flight Data on the Transit RTG

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Theme

THE TRANSIT RTG (Radioisotope Thermoelectric Generator) was launched aboard a Scout missile on Sept. 2, 1972, into a nearly circular polar orbit (~425 naut miles), to provide the primary power for a Navy Navigational Satellite with a design lifetime of five years. Electrical and thermal data were obtained on the RTG during ascent and for the first month in space and are presented in this paper.

Temperature drop across the insulation is a nominal 264°C with an orbital spread of ±3°C, which compares exactly to laboratory data at the same operating conditions and verifies integrity of the multifoil insulation in space.

Table 1 Transit RTG instrumentation

	Nominal Value	Resolution
12 RTG panel voltages	0.48 v	0.0024 v
12 RTG panel temperatures (6 hot cap and 6 cold cap)	753°/280°F (401°/138°C)	4°F (2°C)
1 RTG voltage at regulator	5.60 v	0.07 v
1 RTG current	6.25 amp	0.04 amp
1 RTG satellite support structure temperature	70°F (22°C)	4°F
2 RTG top cover structure temperature	80°F (28°C)	4°F

Contents

Flight data was obtained on the TRANSIT RTG during the first month in orbit, and was analyzed to verify the operational status and establish beginning of mission (BOM) performance characteristics.[1] This was conducted in accordance with a pre-flight data analysis plan and required the reduction of data from approximately 150 orbits. Loss of spacecraft telemetry after approximately one month in orbit prevented further detailed analysis of RTG performance. However, continued normal operation of the spacecraft has attested to the adequacy of the RTG as a stable, dependable power source after over a year in orbit.

Data from the RTG was analyzed during launch, and before and after boom deployment, which occurred six days after launch. A description of the design features of the TRANSIT RTG are given in Ref. 2.

RTG Electrical Circuit and Telemetry Measurements: The objective of telemetry data on the RTG was to verify operation of the converter in space by establishing BOM performance and to evaluate electrical and thermal characteristics of the system as a function of time. Table 1 summarizes those telemetry channels of primary interest to RTG performance and indicates nominal values actually experienced and resolution accuracy.

Launch Phase Data: Telemetry data on the RTG was obtained during the first 760 sec of the launch ascent phase. The rise in converter temperature followed that predicted in that the temperature rose extremely fast after approximately two minutes when the shroud was jettisoned and the multifoil insulation was exposed to space vacuum.

Equilibrium conditions for the generator were obtained between the first and second orbits. After the first orbit, the generator was producing 31 w, which is about 13% below the equilibrium value.

Initial Orbital Data: The performance of the TRANSIT RTG in space closely duplicated that in the laboratory, producing up to 36 w (el) at hot cap temperatures of 400°C and a nuclear heat source power input of approximately 855 w. Orbital flight data has verified that integrity of the multifoil insulation and element bonds was maintained during the launch ascent into orbit. Data over the first month of operation has further

Table 2 Predicted and measured RTG performance in orbit

Performance parameter	Predicted	Performance in orbit: Average[a]	Day pass	Night pass	Complete orbit
RTG power at the regulator, watts (e)	36.2±0.5	35.6±0.5	34.6±0.1	35.1±0.3	34.95
RTG power at the output terminals, watts (e)	...	...	35.1±0.1	35.6±0.3	35.53
Average hot cap temperature, °C	400±4	401±2	400.7±0.7	400.2±0.6	400.9±0.3
Average cold cap temperature, °C	139±4	137±4	139.2±0.6	135.7±1.5	137.1±0.6
Voltage at RTG terminals, volts	5.6±0.2	5.7±0.1	...	...	5.672
Current at RTG terminals, amps	6.5±0.2	6.25±0.2	...	...	6.263
Normalized RTG power ($\Delta T = 265$°C), watts (e)	37.3	35.9	36.1	35.7	35.85

[a] Average of day and night passes over the APL Tracking Station for the first two weeks in orbit.

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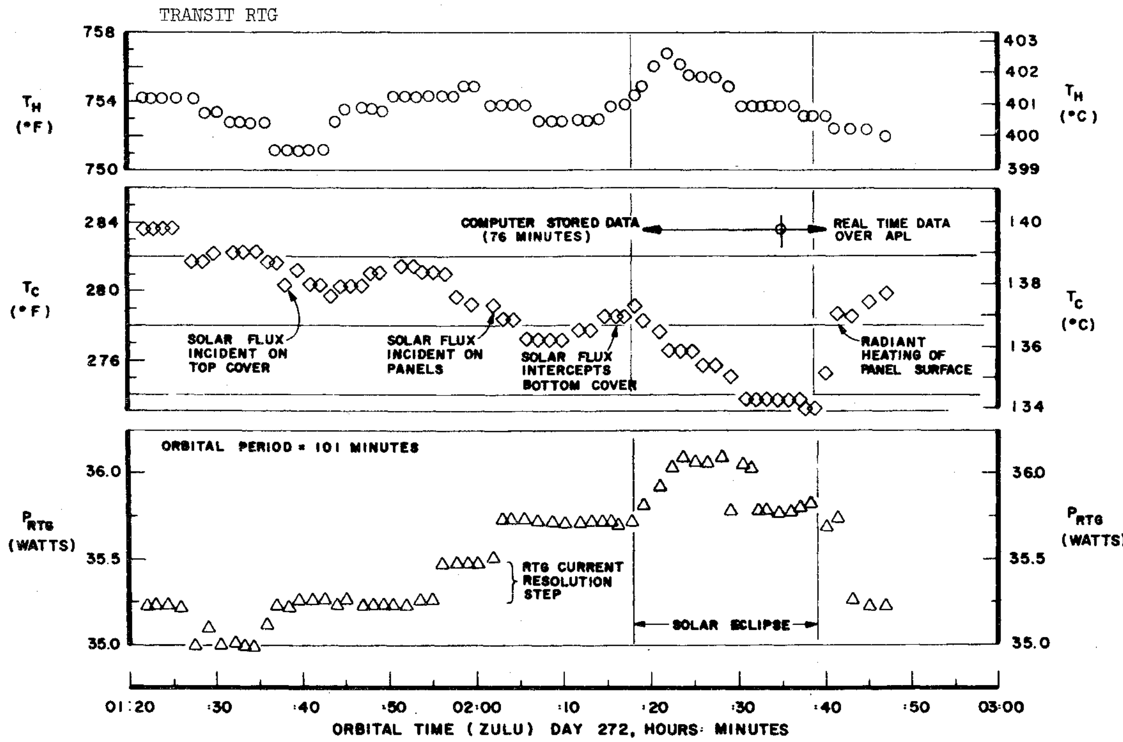

Fig. 1 RTG performance and diagnostic data for one Earth orbit (425 naut miles altitude).

demonstrated the stability of the thermoelectrics in the space and nuclear heat source environments. The following sections present performance data obtained during the first few weeks of orbit and discuss observed trends and correlations with laboratory data and predictions.

Performance Data Summary: An over-all summary of the space performance data obtained on the RTG during the first 20 days in orbit is presented in Table 2 and compared to predictions based on laboratory data. The agreement between the two sets of numbers is very close, considering the expected and actual spread in the values. The slightly higher temperature than predicted is due to a higher load voltage than expected, which was caused by uncertainties in the circuit voltage drops noted below. The 0.6 (el) difference in power is due partly to transient orbital effects caused by going in and out of the sun and by variations in altitude due to the elliptical orbit. Other contributing factors include: 1) fuel decay, 2) air operation effects, and 3) changes in spacecraft orientation and temperature.

Nominal power output of the generator as measured at the power terminals was 35.6 ± 0.5 w (el), while its power input to the spacecraft regulator was 35.0 ± 0.5 w. This 0.6 watt power difference is due to electrical power losses in a magnetic compensation loop, shunt resistor, and leads.

Table 2 compares average RTG performance data during day and night passes over the APL tracking station. This data was obtained during the 25th–30th day in orbit, and represent results of the last telemetry data received from the spacecraft.

Complete Orbit Data: Near the end of the first month in space, the satellites on-board experimental computer was programed to store RTG data during a complete orbit and transmit the data for an entire orbital cycle on command. This data provided the first accurate evaluation of the *average* RTG performance in orbit, and of the transient thermal response due to cyclic exposure to solar heating.

Averaged RTG data for the orbit is presented in Table 2 and a plot of the reduced data as a function of time is shown in Fig. 1. Changes in temperature and power data shown in Fig. 1 can be correlated with RTG position with respect to the sun vector.

Thermal performance of the RTG was evaluated to verify the insulation integrity, radiator surface properties, operating conditions, and the magnitude and changes in solar and earth IR radiation. The primary RTG thermal instrumentation included twelve 2-mil iron constantan thermocouples spot-welded to hot and cold caps of alternate *N* and *P* couples in the center of six of the twelve thermoelectric panels. Typical panel temperature distributions were extremely constant, with a maximum spread of ± 6°F (± 3°C) on the hot side and cold side at night. Thermal control is provided by 6 mil thick silicon dioxide second surface mirrors on the panel cold side and a white thermal control paint designated Z-93 on the structural components.

Conclusions: The beginning of mission performance of the TRANSIT RTG in space has demonstrated with confidence that the unit is operating at the nominal electrical power output expected. RTG power at the terminals is 35.6 w with a spread of approximately ± 0.5 w to include night and day pass extremes.

The on-board computer supplied orbital data provides a greater understanding of the in-orbit thermal perturbations on the RTG and the effect of these on power output. The averaged orbital power was found to be ~ 0.4 w greater than the real time data obtained during daytime passes over APL.

Performance of individual panels is identical with a standard deviation for all panels of $\pm 0.8\%$ and a minimum panel performance of 1.3% below the mean. The panel output characteristics have verified that there are no open elements as a result of the launch environment, and that the long prelaunch hold period (~ 15 months) did not degrade the thermoelectric elements.

Average element hot cap temperatures are within 1°C of the design value of 400°C and cold cap temperature variations between 133° and 139° are consistent with laboratory simulation data with external radiation heat input.

References

[1] Bradshaw, G. B., "TRANSIT RTG Beginning of Mission Flight Data Analysis," Rept. Gulf-GA-12347 (Draft), Oct. 26, 1972, Gulf General Atomic Corp., San Diego, Calif.

[2] Bradshaw, G. B., Postula, F. D., and Hagis, W., "Description and Status of the TRANSIT Thermoelectric Converter," paper presented at the 8th Intersociety Energy Conversion Engineering Conference, Sept. 1972, Philadelphia, Pa.