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STATUS OF SERT II THRUSTERS AND SPACECRAFT - 1976

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STATUS OF SERT II THRUSTERS AND SPACECRAFT - 1976

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Abstract

The historical record of the SERT II ion thrusters and spacecraft performance for 6 1/2 years since the February 1970 launch is reviewed. The most recent ion thruster operation test shows no changes since 1974. Thruster 2 is fully operational with no performance degradation. Thruster 1 has a high voltage grid short, but continues to demonstrate cathode and discharge relight capability. Spacecraft orbit and dynamic analysis indicates a stable, sun-synchronous spacecraft orientation by 1979. An attitude adjustment maneuver was performed in August 1976 to achieve this orientation and provide sufficient continuous solar power for thruster operation in 1979.

Introduction

The SERT II spacecraft was launched in February 1970 with a goal of demonstrating long-term operation of an ion thruster in space. The spacecraft contained two 15-cm diameter mercury electron bombardment ion thrusters designed to operate at a nominal 1 kilowatt power level. In 1970 thruster 1 was operated for 5 1/2 months and then thruster 2 was operated for 3 months.(1) In each case, thruster operation was terminated by a high-voltage short. A series of thruster turn-on tests were conducted in 1971 in an attempt to clear the short. These tests were unsuccessful and the spacecraft was placed in a storage mode.

By 1973 proposed electric propulsion missions included a need to restart thruster many times. Therefore, the stored SERT II spacecraft was activated (even though well beyond its one year design life) to demonstrate both multiple restart capability and the integrity of active thruster components, propellant feed system, power processor, and other spacecraft ancillary equipment after long-term space storage. Although the original SERT II spacecraft and thrusters were not designed for automatic cathode restarting, it was possible to manually command both the ignition of the cathodes and the subsequent turnoff. Such procedures were limited to real time while the spacecraft passed over a ground tracking station. During 1973, 112 successful restarts of each thruster were so demonstrated.(2) The 1973 test program ended, based on priorities for the ground-support equipment.

The 1970 launch, initial sun-synchronous, polar orbit of the SERT II spacecraft had processed such that in 1973 the sun angle was oblique and only marginal power was available to operate the cathodes. Inadequate spacecraft power was predicted for 1974. Therefore, at the end of the 1973 test program a new spacecraft orientation was proposed(3) and executed for testing in the 1974 to 1976 period. In August 1974 the SERT II spacecraft was again reactivated for thruster testing. The results of these 1974 tests, which included clearing of the high-voltage short from thruster 2, return to normal operation of thruster 2, multiple restarts of both thrusters, and electrical potential control of the spacecraft by the neutralizer cathode, were presented in a previous paper.(4)

STAR category 20

This paper presents thruster testing from 1975, updates spacecraft status(5), and described spacecraft maneuvers necessary to achieve solar power through 1980. In 1979 the spacecraft orbit should be sun-synchronous and continuous thruster operation may be possible.

Results of 1975 Thruster Tests

A description of the SERT II thruster system has been presented elsewhere(1) and will not be repeated here. The purpose of the 1975 thruster tests was to verify the operational status of each thruster system. This was done as part of an overall program in which yearly check testing of each thruster system has been performed.

Thruster 2 was successfully operated in a planned thruster restart on December 4, 1975. Thruster preheat and discharge ignition were normal. After discharge stabilization, the thruster was operated at 83 ma beam current (30 percent beam) for 5 minutes. The thruster was then commanded to the 200 ma beam set point (80 percent beam) where it operated normally for 4 minutes. With 3 minutes remaining in the pass time, the command to operate at 250 ma beam (100 percent beam) was sent. As anticipated with the additional load, the solar array voltage dropped below its system cut off level, and the thruster was turned off automatically. The array total power drawn before turn off was 710 watts (at 50.4 V). The total power demand at 250 ma beam (100 percent thrust) would have been between 860 and 880 watts (at 48 V).

Table I presents the thruster 2 system operating currents and voltages for the 1975 test as well as corresponding data for prior years. The 1976 testing was not complete at the time (aug. 1976) of this writing. All data of Table I falls within normally expected ranges. Differences between tests were caused by telemetry uncertainty, insufficient time to come to thermal equilibrium, and change of power supply output with change in solar array voltage. Note in Table I the changes in solar array voltage with year. From 1973 to 1975 the sun angle became less direct and the voltage (with heavy array load) was usually lower each year. The exception is for the preheat part of testing. At preheat, the array power load was low, and the array voltage was primarily influenced by the array temperature. The lower temperature each year, due to less direct sun, resulted in a higher open circuit voltage.

Table II presents SERT II thruster heat currents to light the cathode discharges for 1975 and earlier flight tests. The heater values are those just before cathode lighting. (After lighting, control loops adjusted the heater currents.) All heater values are constant within accuracy and indicate no heater degradation. The restart times for thruster 1 are somewhat quicker than average. Thruster 2 restart times are longer than average but still much shorter than the nominal 1 hour of the original SERT II starting time requirement.

Thruster 1 was operated three times during

November-December 1975 and the discharges lighted normally. The high-voltage short still, however remained. The table below summarizes the operating times and restarts of each SERT II flight thruster system as of August 31, 1976:

Thruster	Propellant flow, hr	Number of restarts
1	3890	159
2	2177	215

Both SERT II flight thruster systems continued to function as they did approximately 1 year ago. The power processor units continue to function without problems or drift of any controlled parameter. The propellant feed system functions normally with no gas leakage nor change in porous-tungsten vaporizer flow transmission. No electric insulators in the thrusters show measurable electrical leakage.

Spacecraft Status - 1976

An artist's drawing of the SERT II spacecraft (S/C) is shown in figure 1. Detailed description may be found in the literature.(1) The S/C orbit and S/C attitude after launch (1970) is represented in figure 2. In 1973 the S/C was spin stabilized,(3) and continues today in that mode. The basic S/C is an Agena vehicle with a fold out solar array mounted off an aft rack and two ion thrusters mounted on a forward deck. The solar array, when deployed, was perpendicular to the pitch axis (as defined in fig. 2) and in the roll-yaw axis plane.

Table III summarizes the status of the SERT II S/C as of August 1976, 6 1/2 years after launch. All major subsystems remain functional. This includes the solar array, command receive and telemetry systems, control moment gyros, horizon scanners, a cold-gas attitude adjustment system, and the S/C passive thermal control surfaces. Certain components with known short lifetimes, a few temperature sensors, and some secondary experiments are not functional. For example, all S/C batteries are well beyond shelf lifetimes and are dead, and one of two on-board tape recorders has failed. No changes in the S/C functional status have occurred since reference 5 summarized the status 2 years ago, and the reader is directed to this document for a complete description of the S/C performance.

Solar-Array Degradation

A degradation curve of the relative maximum power of the SERT II solar array with time is shown in figure 3. The solid line of figure 3 represents the array manufacturer's prediction for the array degradation due to normal space environment in the 1000-km high, near-polar, SERT II orbit. The dashed line of figure 3 represents the measured degradation of the solar array extrapolated through 1979. The data up to 170 days was taken from reference 6. These data were computed from test cells located within the main array. The telemetry ranges of these test cells were set to read a high relative maximum power range which occurred early in S/C life (first year). As the array degraded below 0.8 of maximum power, the telemetry output of these test cells went below the measurable range. Therefore, the only way to measure maximum array power after the first year, was to load the main array to its maximum power. This was done on December 4, 1975 (day 2130) when thruster 2 was tested, and the estimate of relative maximum power is plotted on figure 3. The error band is due to two uncertainties. One uncertainty is the sun angle, 30° ±5°. The other uncertainty is the maximum power point which was extrapolated from the last thruster operating point. The thruster system increase in power, which collapsed the array, occurred between telemetry updating and could not be sensed before the S/C shutdown.

Two important conclusions can be drawn from figure 3. First, the solar array degradation was less than normal indicating no significant contamination from ion thruster operation. Secondly, solar array power available in 1979 should be reduced by only a 5-percent additional loss in relative maximum power. If direct sun is incident on the arrays in 1979 there will be enough power to operate thruster 2 at 100-percent throttle. The reserve power margin is small, however, and operation at 80-percent throttle or less may be necessary. As will be shown in the next section, the sun line will not be direct (0° angle of incidence) in 1979, but probably will be 10° to 30° depending upon the exact attitude achieved after a 1978 S/C maneuver.

Reflector Erosion Experiment (REX)

REX is a SERT II secondary experiment to measure micrometeroid or other erosion-producing flux existing at the altitude (1000 km) of the SERT II spacecraft. The REX consists of two, thin, aluminum-coated disks facing in the same direction as the solar array. The disks have a completely open view factor of space in the sun direction or forward hemisphere. In the rearward hemisphere they are enclosed by a cup or mounting box which gives them a known, controlled thermal environment. Erosion of the thin aluminum coating on the disk will change the thermal emittance (ε) and the solar absorptance (α). Such changes have been calibrated in the laboratory as a function of the erosion flux.(7) Changes in α or ε result in a change in the equilibrium disk temperature which can be measured by the SERT II telemetry system. The disk temperature also changes with changes in the sun angle of incidence.

The result of the REX experiment was that for 3 years and 8 months there was no indicated change in α or ε of either disk. This result indicated a low erosion flux level (as predicted by some experimenters) at SERT II altitudes.

Calculating the estimated low limit of this erosion efflux is beyond the scope of this paper, but may be attempted through the procedures of reference 7. After 3 years and 8 months, the SERT II spacecraft was spin stabilized and accurate REX data was no longer obtainable. At this time the sun angle of incidence on REX changed and could not be determined with an accuracy necessary to make the REX α and ε estimates meaningful. Before spin stabilization the REX disk was in the orbit plane which could be determined accurately from spacecraft tracking. To summarize the REX results, micrometeroid and other erosion flux were sensed over a sufficiently long (3 yr, 8 mo) period that a negligibly low flux was found to exist. (A 1-yr exposure time of the disk was considered sufficient to detect medium flux levels possibly present.(7)

A secondary use of the REX is as a sun sensor when the S/C is in a spin-stabilized position. (No sun sensor instrument was included on the SERT II S/C.) If the assumption is made that the α and ϵ of the REX disks remain unchanged with time, then the REX equilibrium temperature data can be worked backward to predict a sun angle of incidence. Equation (B3) of reference 7 was used with the REX temperature to calculate sun angles for the period after September 1973. The results of some of these sun angle measurements are described in the next section.

Spacecraft Cyclic Data

Figure 4 presents SERT S/C data that was taken from day 134 to day 230 of 1976. The data accuracy and trends will be described first, and later the reason for the approximate 28-day cyclic pattern will be explained.

The solar array sun line angle of figure 4 goes through a minimum of 30° to 35° each cycle. (Smaller angle is more direct sun.) The width of these curves, about 7 days, represents sun illumination of the solar array and time of available power to operate the S/C. REX thermal analysis errors become large above 60° angle and data for angles <60° are disregarded. Telemetry count uncertainty results in an error band of ±8° for angles near 10°, ±5° for angles near 30°, and ±3° for angles near 50°.

The other curves of figure 4, PC21 and SUN8, are taken from direct temperature sensors on the S/C. SUN8 measured the S/C skin temperature on the side of the S/C near the ion thruster end. A line tangent to SUN8 location is parallel to the plane of the solar arrays. The PC21 temperature sensor is located on the radiation plate of thruster 2 power conditions. This sensor is located 170° azimuthally counterclockwise from the SUN8 sensor, viewing the S/C from the earth in the orientation of figure 2. The telemetry count uncertainty is about ±1° C for SUN8 and ±2° C for PC21. SUN8 and PC21 temperatures are plotted once per day when data was available. Gaps in the data occurred when there was no communication with the S/C due to insufficient array power to operate the S/C telemetry system. SUN8 and PC21 cyclic temperatures indicate that the solar array is sometimes facing the sun (peak in SUN8) and sometimes facing away from the sun (peak in PC21), with a nearly sinusoidal change inbetween. When the array faces directly away from the sun it receives enough illumination from earth able to power the S/C. At some array positions inbetween, the array views neither the sun nor the earth and no communication is possible from the S/C.

Spacecraft Orbit and Dynamic Motion

Figure 2 shows a conventional view to illustrate the SERT II S/C in a gravity-gradient, sun-synchronous orbit. Sun-synchronous phasing, however, is not exact and if the position of the orbit plane is observed each year, it is seen to slowly (about 19° per yr) turn away from sun. At the 1000 km altitude of the SERT II S/C, S/C shadowing occurs when the orbit plane has turned 30° or more from a perpendicular sun position. Shadowing began in 1972 and will last until approximately January 1979. The relative motion of the sun and the S/C orbit over 11 years is sketched in figure 5(a) and repeated in figures 5(b), (c), and (d).

In figure 5(a) the S/C is in the same orbit and attitude as shown in figure 2, but the direction of viewing has been changed. For figure 5, the viewer is approximately above the north pole looking down on earth and the S/C is approximately over the equator. (The curvature of the earth and S/C altitude are to scale, but the S/C is greatly enlarged.) The orbit plane remains fixed in time and is always perpendicular to the figure page. The relative position of the sun direction at the start of each year is shown. The S/C was in the position shown in figure 5(a) from launch to September 1973. At that time figure 5(a) indicates the relatively shallow sun angle on the active side of the array, and that the angle would continue to become more shallow with time, such that in 1975 there would be insufficient array illumination to operate the S/C.

Therefore, in September 1973 a S/C maneuver, shown by figure 5(b), was performed to increase array illumination.(3) First the S/C was tilted out of the orbit plane by using cold gas jets to turn the roll axis by 60°. This maneuver pointed the active array side toward the sun. Then additional cold gas jets were used to spin-stabilize the S/C about the pitch axis. The S/C spin rate is about 0.5 rpm.

The S/C, however, will not remain in the position as shown in figure 5(b). A natural combination of gradity-gradient type forces acting on the spinning S/C will cause the S/C spin axis to precess in a coning motion(8) as shown in figure 5(c). The period of this precession is about 28 days and depends on the S/C spin rate and the coning angle. The cone angle remains fixed at the initial tilt and the axis of the precession cone is perpendicular to the orbit plane.(8) The S/C position shown in figure 5(c) is 14 days after that shown in figure 5(b). In figure 5(c) the active side of the array faces the earth and corresponds to a time when the PC21 temperature data is at maximum. The S/C position of figure 5(b) corresponds to the time when SUN8 temperature reads maximum and when maximum array power is available.

If nothing were done to the S/C position shown in figure 5(b) or (c) (1973-76 period), the sun direction would continually move away from the array, and there would be insufficient power to operate the S/C. The array was approximately facing the direction of the January 1974 sun for the 1973-76 period, and by 1977, S/C operation would be marginal. To achieve an improved sun angle on the array, two additional maneuvers shown in figure 5(d) were necessary.(8) The first maneuver, conducted in August 1976, was to rotate the S/C roll axis approximately 90° to change the precession cone to the other side of the orbit plane as shown in figure 5(d). This was done to achieve sufficient power to operate the S/C in 1977 and 1978. At this position the cone precession period is approximately 8 days.

To achieve the best array direction for continuous thruster operation after January 1979, will require a second tilt of the S/C roll axis to a position where the precession cone angle is near 0° (shown on fig. 5(d)). At this final attitude the corresponding continuous sun angle of incidence will be approximately 35° at the start of 1979 and will improve with time. In the fall of 1980 the sun should be perpendicular to the solar array (0° angle of incidence).

Future Objectives and Plans

The SERT II spacecraft is existing and functioning in space. The following objectives can be met using this spacecraft in a low-cost program over the next 3 to 4 years:

1. Verify the SERT II thruster design technology which is the basis for the design of present 8- and 30-cm thrusters.
    (a) Increase demonstrated thruster lifetime in a space operation, and verify that no further problems exist in space operation of a thruster other than those which caused the initial SERT II thruster failure.
    (b) Demonstrate long-term space storage, multiple restart, and operational capability of a functional thruster after 7 to 11 years exposure to the zero-G, thermal, vacuum, and radiation environment of space.
    (c) Demonstrate space lifetime of mercury propellant feed systems; materials compatibility with mercury; and the integrity of the porous-tungsten vaporizer design.
    (d) Verify the function of all closed-loop control parameters for long-term thruster space operation. Also included in this objective is the demonstrated integrity of the insulator shields to prevent electrical leakage.
    (e) Demonstrate hollow-cathode lifetime and restart ability in a space thruster.
    (f) Demonstrate the long-term space operation of the thruster power processing unit (PPU). The SERT II PPU is similar in design concept to the 8-cm PPU.
2. Demonstrate the absence of detrimental thruster-spacecraft interactions with continued thruster operation. (No change in α/ε of spacecraft thermal surfaces.)
3. Obtain long-term solar array degradation data in space environment. The thruster system can be operated in a stepwise fashion to produce a solar array load curve at periodic intervals.
4. Complete initial SERT II objective. (6-months operation of one thruster.)
5. Maintain an existing electric propulsion spacecraft in functional order for future (presently undefined) spacecraft diagnostic tests.

Plans are to check test each SERT II thruster system once per year to demonstrate space storage and relighting, while waiting for continuous sunlight array power in 1979. In 1979 thruster 2 can be turned on and tested continuously at the highest throttle level commensurate with available solar power. Power estimates for 1979 indicate that 80-percent throttle may be the highest level. The propellant reserve in thruster system 2 tanks should permit 5000 hours of operation at 80-percent throttle or 4000 hours at 100-percent throttle. (The propellant reserve of thruster system 1 is estimated at 2100 hours at 100-percent throttle, but the grid short precludes full thruster operation.) Periods of continuous solar power are estimated to begin in 1979 and last through 1981.

Concluding Remarks

The SERT II spacecraft, designed for 1 year life, remains functional after 6 1/2 years in space. One of two ion thrusters on board is fully operational with 4000 hours of propellant reserve. Present earth shadowing of the spacecraft solar arrays prevent continuous testing of the thruster, but periodic short-term check tests of the thruster verify its operational status. A maneuver to change the spacecraft attitude was performed in August 1976 to provide spacecraft solar array power in 1977 and 1978. A further attitude change maneuver can be performed in 1978 to improve the sun direction on the solar array, so that continuous thruster testing will be possible in 1979 when the spacecraft returns to a continuous sun orbit.

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Table 1. - Performance of Flight Thruster 2

		Preheat					Propellant, no beam					30% beam				80% beam				Telemetry uncertainty (rss)
	Year Day Restart number	1970 2/11 10	1973 6/1 80	1974 12/7 213	1975 12/4 215	1976 (Oct)	1970 2/11 10	1973 6/14 86	1974 8/23 195	1975 12/4 215	1976 (Oct)	1970 2/11 10	1974 9/10 198	1975 12/4 215	1976 (Oct)	1970 2/11 10	1974 9/11 200	1975 12/4 215	1976 (Oct)	
Main vaporizer heater	V2,v I2,a	0 0	0 0	0 0	0 0	(h)	[g]1.63 [g]1.41	[a]1.49 [a]1.32	1.85 1.70	1.85 1.80	(h)	[g]1.63 [g]1.51	1.70 1.77	1.70 1.70	(h)	1.70 1.70	1.85 1.95	1.85 1.95	(h)	±0.07 ±0.08
Main cathode heater	V3,v I3,a	16.0 2.86	15.6 2.81	15.6 2.81	15.6 2.81		8.7 1.54	9.5 1.57	9.1 1.57	9.1 1.67		7.9 1.54	8.7 1.57	8.7 1.57		8.3 1.54	8.7 1.57	8.2 1.57		±0.35 ±0.05
Main discharge	V4,v I4,a	>50 0	>50 0	>50 0	>50 0		39.9 2.0	39.7 2.3	40.4 1.7	40.4 1.7		42.2 0.7	42.4 0.6	42.4 0.56		41.5 1.2	41.4 1.1	41.5 1.1		±0.2 ±0.05
Beam voltage Beam current	V5,v I5,a	0 0	0 0	0 0	0 0		0 0	0 0	0 0	0 0		[d]3490 [d]0.088	[d]2960 [d]0.083	[d]2900 [d]0.083		[d]3160 [d]0.203	[d]2630 [d]0.198	[d]2500 [d]0.198		±65 ±0.005
Accelerator grid	V6,v I6,ma	0 0	0 0	0 0	0 0		0 0	0 0	0 0	0 0		[d]-1730 1.1	[d]-1480 0.9	[d]-1430 0.8		[d]-1640 1.4	[d]-1330 1.4	[d]-1280 1.3		±50 ±0.1
Neutralizer heater	V7,v I7,a	[g]7.7 [g]2.3	8.8 2.6	8.6 2.5	10.4 3.0		[g]7.7 [g]2.3	[a]10.4 [a]3.0	8.4 2.4	8.8 2.4		[g]6.6 [g]2.0	8.1 2.3	7.7 1.9		[g]6.4 [g]1.9	7.5 2.2	7.0 2.1		±0.25 ±0.05
Neutralizer keeper	V8,v I8,a	28.5 [d]0.226	28.5 [d]0.183	27.8 [d]0.191	38.0 0.179		28.5 [d]0.199	[a]32.3 [a]0.175	28.5 [d]0.179	28.5 [d]0.171		27.8 [d]0.215	27.8 [d]0.175	27.8 [d]0.175		[c]24.0 [d]0.206	[c]27.8 [d]0.167	27.8 0.163		±0.7 ±0.004
Spacecraft voltage	v	-6	(f)	-3	(f)		-9	(f)	-4	(f)		-17	-8	(f)		-17	(f)	(f)		±2
Neutralizer emission	a	0	0	0	0		0	0	0	0		0.087	0.080	0.080		0.201	0.195	0.195		±0.006
Main cathode keeper	V10,v I10,a	[d]>416 0	[d]363 0	[d]371 0	[d]411 0		12.3 [b]0.289	9.9 [b]0.282	10.8 [b]0.282	11.3 [b]0.285		20.4 [b]0.282	20.0 [b]0.272	20.0 [b]0.270		13.9 [b]0.283	13.1 [b]0.272	13.1 [b]0.271		±0.5 [b]±0.003
Solar array voltage	v	70	62	65	77		68	61	60	59		68	59	56		63	52	50.4		±1.0

[a] Value changing in response to control signal.
[b] I10 value estimated from V10 value and power supply response characteristic curve.
[c] V8 values due to different set points.
[d] Difference in values due to different solar array voltages input to power processor.
[f] Data unavailable.
[g] Heater power lower due to higher thermal background.
[h] Data unavailable at time of writing.

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Table 2. - Representative Heater Values(c) and Cathode Starting Times

Thruster	Start number	Date	Main vaporizer			Main cathode			Neutralizer cathode			Cathode start time		Total cathode, on time,[d] hr	Neutralizer reservoir temperature, °C
			I2, A	V2, V	V2/I2, Ω	I3, A	V3, V	V3/I3, Ω	I7, A	V7, V	V7/I7, Ω	Neutralizer cathode, min	Main cathode, min		
1	1	12/9/69	2.80	(a)	(a)	2.80	>15	>5.3	2.78	(a)	(a)	$8.5^{+0.0}_{-0.0}$	$0.3^{+0.0}_{-0.0}$	———	(a)
	4	12/28/69	2.81	(a)	(a)	2.92	15.7	5.4	2.79	9.9	3.6	$6.2^{+0.0}_{-0.0}$	$0.4^{+0.0}_{-0.0}$	———	(a)
	5	2/14/70	2.81	2.74	0.98	2.88	15.7	5.5	2.90	10.3	3.6	$3.3^{+0.4}_{-0.6}$	$0.3^{+0.7}_{-0.0}$	0	(a)
	6	3/8/70	2.89	(a)	(a)	2.88	15.3	5.3	2.90	10.6	3.7	$4.2^{+0.1}_{-0.6}$	$0.3^{+0.7}_{-0.0}$	508	83
	7	5/21/70	(a)	2.67	(a)	2.88	15.3	5.3	2.90	10.8	3.7	$4.3^{+0.4}_{-0.6}$	$0.7^{+0.3}_{-0.1}$	2283	78
	14	10/26/70	2.89	2.60	.90	2.88	14.1	4.9	2.90	10.8	3.7	$4.2^{+0.4}_{-0.6}$	[b]$4.4^{+0.7}_{-0.3}$	3794	47
	20	2/11/71	2.89	2.67	.93	2.88	15.7	5.5	2.90	10.3	3.6	$4.2^{+0.0}_{-0.6}$	$0.3^{+0.7}_{-0.1}$	3835	83
	32	1/21/72	(a)	(a)	(a)	2.88	15.7	5.5	2.79	10.1	3.6	$6.2^{+0.0}_{-0.6}$	(a)	3868	29
	33	5/25/73	2.81	2.74	.97	2.82	15.3	5.4	2.90	10.6	3.7	$6.6^{+0.4}_{-0.4}$	[b]$6.4^{+0.4}_{-0.3}$	3869	(a)
	145	8/19/74	2.89	2.74	.95	2.82	15.3	5.4	2.90	10.8	3.7	$6.3^{+0.4}_{-0.6}$	$7.4^{+0.4}_{-0.3}$	3885	(a)
	149	9/30/74	2.81	2.74	.98	2.82	15.7	5.6	2.90	10.6	3.7	$6.6^{+0.0}_{-0.4}$	$6.0^{+0.0}_{-0.5}$	3887	(a)
	156	10/9/74	2.81	2.74	.98	2.82	15.7	5.6	2.90	10.3	3.6	$6.8^{+0.0}_{-0.6}$	$9.5^{+0.0}_{-0.5}$	3889	(a)
	157	11/14/75	2.89	2.74	.95	2.82	15.3	5.4	2.90	10.6	3.7	$6.4^{+0.0}_{-0.4}$	$3.8^{+0.0}_{-0.5}$	3890	(a)
	(e)	10/76													
2	1	11/29/69	2.89	(a)	(a)	2.78	>15	>5.4	2.94	(a)	(a)	$10.0^{+0.0}_{-0.0}$	$1.0^{+0.0}_{-0.0}$	———	(a)
	4	12/21/69	2.90	(a)	(a)	2.77	16.0	5.8	2.86	(a)	(a)	$6.3^{+0.0}_{-0.0}$	$1.0^{+0.0}_{-0.0}$	———	(a)
	10	2/11/70	2.88	2.77	0.96	2.86	16.0	5.6	2.97	10.2	3.4	$3.2^{+0.2}_{-0.6}$	$0.4^{+0.9}_{-0.3}$	0	97
	11	7/24/70	2.97	2.70	.91	2.86	16.0	5.6	2.97	10.2	3.4	$3.2^{+0.1}_{-0.4}$	$0.9^{+0.9}_{-0.4}$	38	97
	12	9/2/70	2.97	2.70	.91	2.81	15.6	5.6	2.97	10.4	3.5	$3.7^{+0.1}_{-0.6}$	$0.9^{+0.9}_{-0.4}$	934	65
	53	11/13/70	2.97	2.70	.91	2.81	15.6	5.6	2.97	10.4	3.5	$2.8^{+0.1}_{-0.6}$	$0.9^{+0.9}_{-0.4}$	2094	69
	67	2/26/71	2.97	2.70	.91	2.86	16.0	5.6	2.97	10.4	3.5	$2.7^{+0.1}_{-0.6}$	$0.4^{+0.9}_{-0.3}$	2126	115
	76	1/21/72	(a)	(a)	(a)	2.86	16.0	5.6	2.97	10.4	3.5	$5.3^{+0.3}_{-0.6}$	(a)	2149	33
	126	7/17/73	2.97	2.70	.91	2.81	16.0	5.7	2.97	10.4	3.5	$5.2^{+0.0}_{-0.4}$	[b]$8.2^{+0.0}_{-0.4}$	2162	22
	189	8/19/74	2.97	2.70	.91	2.81	15.6	5.6	2.97	10.4	3.5	$5.4^{+0.0}_{-0.2}$	$10.5^{+0.1}_{-0.1}$	2166	43
	203	9/12/74	2.97	2.70	.91	2.81	15.6	5.6	2.97	10.2	3.4	$6.1^{+0.0}_{-0.4}$	$22.5^{+0.0}_{-0.0}$	2169	40
	211	10/2/74	2.97	2.70	.91	2.81	15.6	5.6	2.97	10.2	3.4	$6.8^{+0.0}_{-0.6}$	$12.7^{+0.0}_{-0.4}$	2175	35
	215	12/4/75	2.97	2.70	.91	2.81	15.6	5.6	2.97	10.4	3.5	$7.4^{+0.0}_{-0.6}$	$29.3^{+0.1}_{-0.4}$	2177	37
	(e)	10/76													

[a] Data not taken or unavailable.
[b] No preheat used.
[c] Quantizing and calibration error, ±3%, root-sum-square.
[d] Includes heating time in space only; ground time, thruster 1 - 83 hr, thruster 2 - 91 hr.
[e] Data not taken at time of writing.

Table 3. - SERT II Spacecraft Functional Status Summary

Component	Status
Command receive system	Fully functional
Telemetry system	Functional, except for subcommutator 2, which is intermittent
Solar array	Degradation less than predicted
Passive thermal control system	Maintains S/C operational in all attitudes experienced; no degradation of thermal surfaces.
Horizon scanners	Fully operational after 500 hours of use
Control moment gyros	Fully functional
Cold gas attitude adjustment system	Fully functional, about half of gas supply remains
On-board batteries	Dead
On-board tape recorder	One of two recorders functional
Primary experiment:	
Thruster 1	H.V. grid short, other components normal
Thruster 2	Fully functional
Secondary experiments:	
S/C potential probe	Filament burnout at normal life
Beam probe 1	Filament intact, probe does not sweep
Beam probe 2	Fully functional
MESA (accelerometer)	Sensor float not able to be suspended
REX (erosion experiment)	Fully functional
RFI beam measurement	Open fuse in power system
Surface contamination exp.	All sensors reading

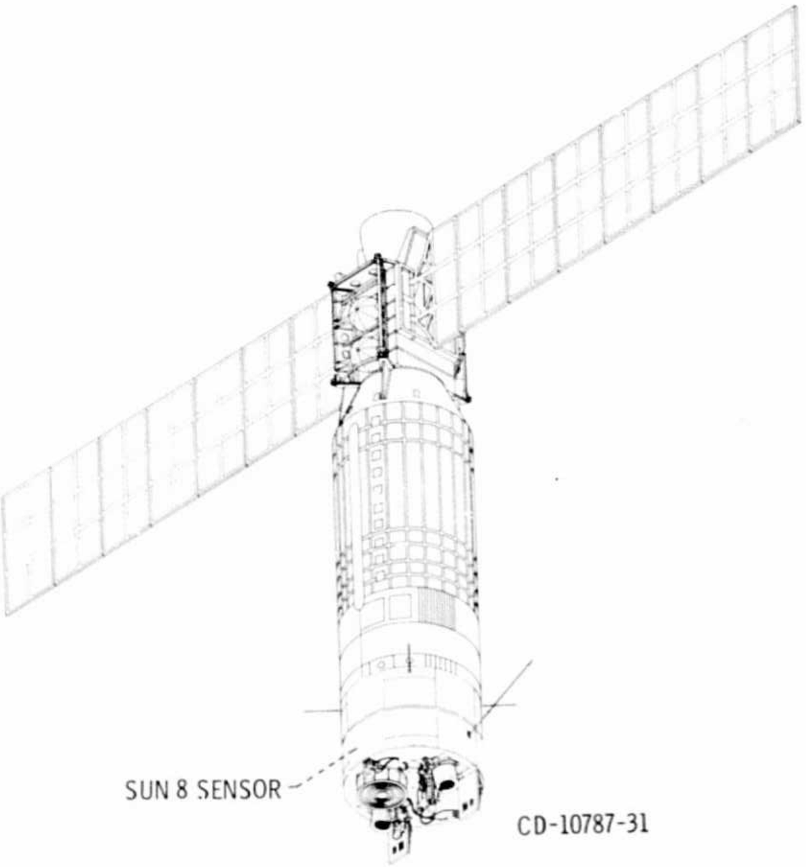


Figure 1. - SERT II spacecraft in orbit (artist's conception).

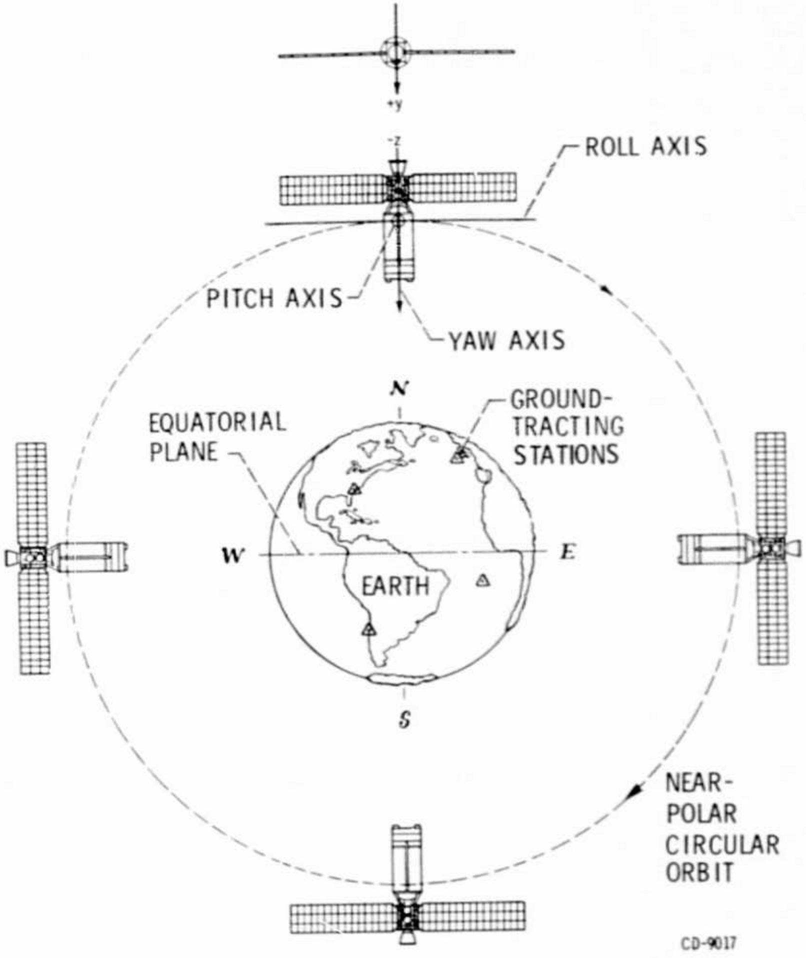


Figure 2. - SERT II vehicle coordinate system in orbit viewed from Sun for spring launch and sunset orbit injection.

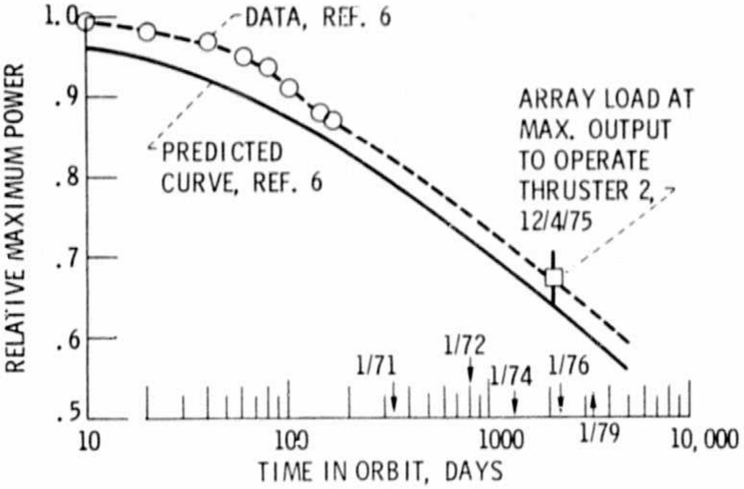
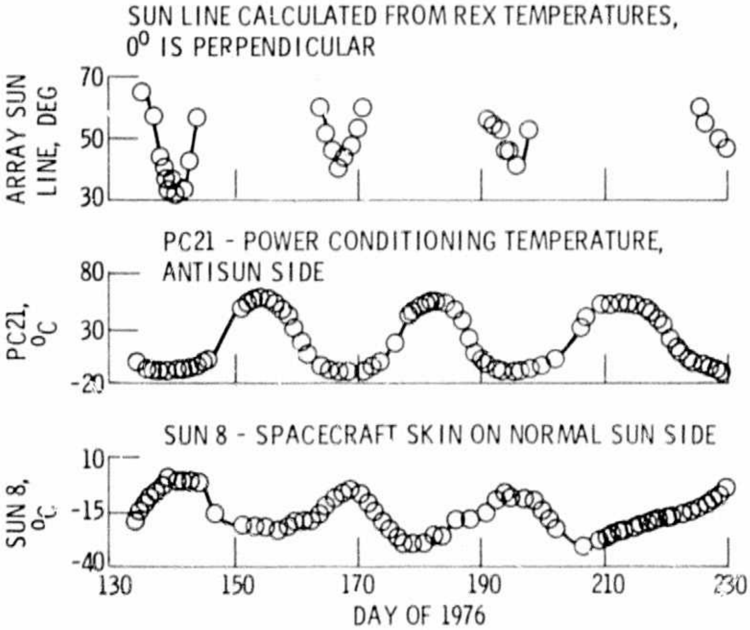


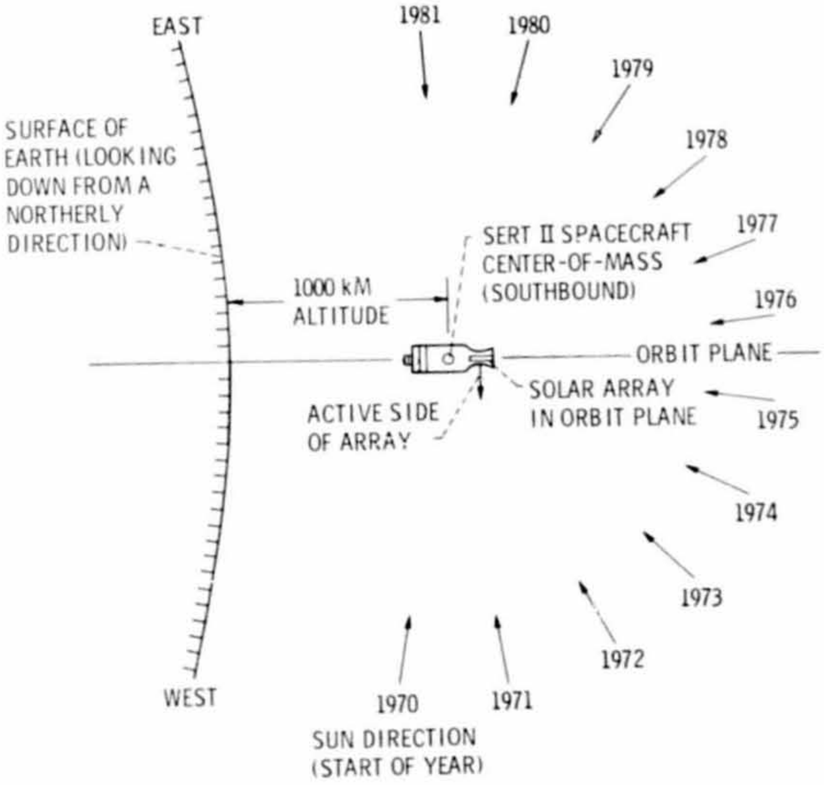
Figure 3. - SERT II spacecraft main solar array degradation. (B. O. L. max power, 1425 watts at 25^0 C.)


SUN LINE CALCULATED FROM REX TEMPERATURES, 0^0 IS PERPENDICULAR

PC21 - POWER CONDITIONING TEMPERATURE, ANTISUN SIDE

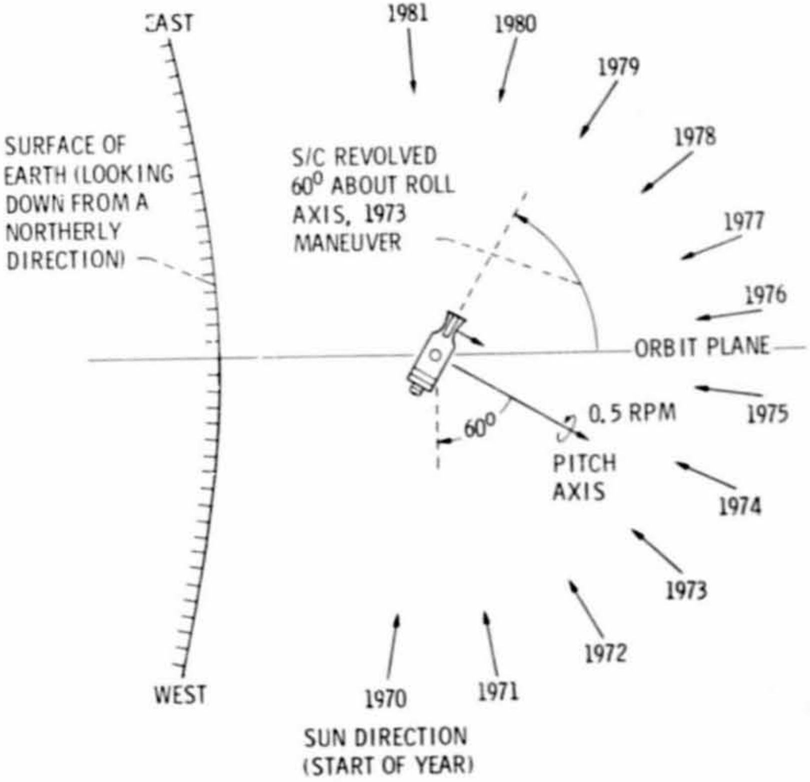
SUN 8 - SPACECRAFT SKIN ON NORMAL SUN SIDE

Figure 4. - Periodic change of sun on SERT II spacecraft.



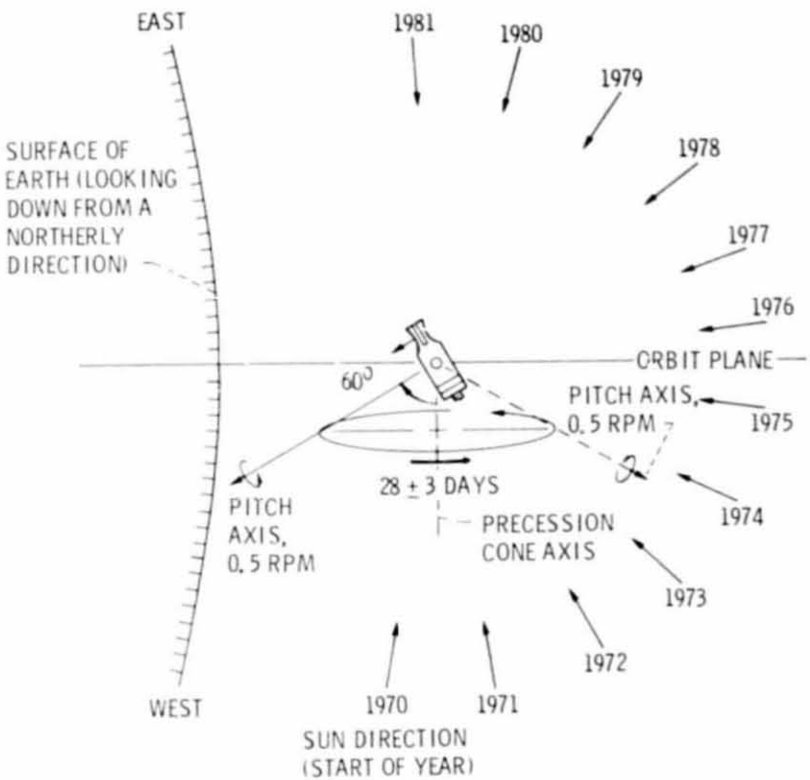
(a) Gravity gradient S/C position at launch, 1970-72.

Figure 5. - SERT II spacecraft (S/C) attitude position at various times.



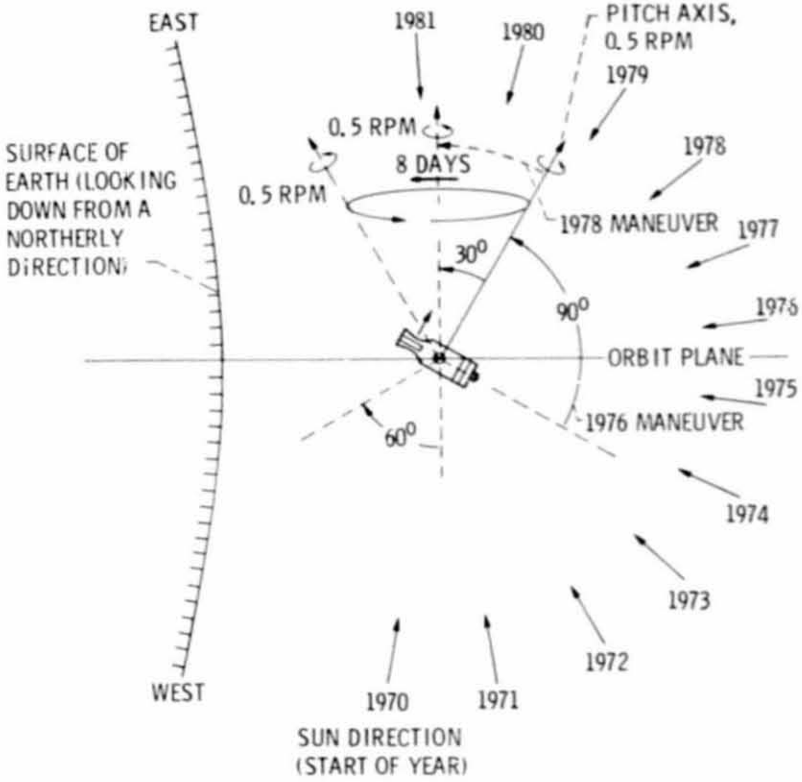
(b) Spin-stabilized position, 197[illegible]

Figure 5. - Continued.



(c) 1973 to 1976 position, S/C shown 14 days after fig. 5(b).

Figure 5. - Continued.



(d) Positions after 1976 and 1978 (planned) maneuvers.

Figure 5. - Concluded.