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Abstract

The historical record of the SERT II spacecraft and ion thruster systems for 8 years since the February 1970 launch is reviewed. The original SERT II mission, one year duration, was planned with the spacecraft in a continuous sunlight orbit to provide continuous solar power. An extended mission, using intermittent power available from an earth shadowed orbit has been performed during the past 5 years while waiting for the orbit to change again to continuous sunlight in early 1979. Continuous thruster testing is planned in 1979. Both spacecraft and ion thruster systems are near-fully functional when the solar array is illuminated. Thruster system 2 is fully operational. Thruster system 1 continues to demonstrate relight capability, but the high-voltage-grid short remains.

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 thruster systems 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 grid short. A series of thruster turn-on tests was conducted in 1971 in an unsuccessful attempt to clear the grid short. By the end of 1971 earth shadowing of the spacecraft began, and the original SERT II mission was declared complete as no batteries existed on board to provide spacecraft power during the shadow periods. The spacecraft was placed in a storage mode.

By 1973 proposed electric propulsion missions included a need to restart a thruster many times. Therefore, the SERT II spacecraft was reactivated (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. During 1973, 112 successful restarts of each thruster were so demonstrated.[2]

The initial SERT II orbit in 1970 was a near-polar orbit with the spacecraft in continuous sunlight. The orbit plane was near perpendicular to the sun direction and the solar array was locked into the orbit plane by control moment gyros and gravity-gradient cross forces. By 1973 however, the orbit plane (and solar array direction) had precessed away from perpendicular, such that, not only was solar power lost during earth shadow periods, but the amount of solar power available during illuminated periods was also becoming marginal to operate the spacecraft. Therefore, at the end of the 1973 test period a new spacecraft orientation (spin stabilization) was proposed[3] and executed for testing in the 1974 to 1976 period.

The results of the 1974 to 1976 tests included: clearing of the high-voltage short and return to normal operation of thruster 2, multiple restarts of both thrusters, and electrical potential control of the spacecraft by the neutralizer cathode. These results were presented in previous papers.[4,5]

This paper presents: (1) ion thruster system restart data from late 1976 to the present, (2) description and results of major spacecraft attitude maneuvers to enable sufficient solar array to support thruster system operation, and (3) space degradation of the main solar array over the eight-year period since launch. Predictions of the sun angle incident on the orbit plane (and solar array) indicate that the spacecraft orbit will be sun synchronous, and continuous thruster operation will be possible in early 1979.

Spacecraft Status - 1978

An artist's drawing of the SERT II spacecraft (S/C) is shown in Fig. 1. Detailed description may be found in the literature.[1] The functional status of the spacecraft remains unchanged since last reported[5] and the reader may refer to Ref. 5 for a component-level status review. The spacecraft is able to receive commands, operate either or both ion thruster systems, send data back to ground stations or record it on a still functional on-board tape recorder. The solar array degradation is as predicted and covered in detail later in this paper. The solar illumination of the spacecraft has varied over a wide range of angles due to both orbit precession and S/C spin axis precession, yet the passive thermal control system has maintained S/C temperatures within operating limits.

Spacecraft Attitude

The S/C attitude at launch in 1970 and projected for 1980 is represented by Figs. 2(a) and (b). After launch the S/C was gravity-gradient stabilized with the solar array in the orbit plane. The orbit plane inclination was placed at 99.2° to obtain a nearly sun-synchronous orbit precession. The orbit precession, however, does not perfectly match the sun's yearly motion and the sun angle incident on the orbit plane gradually shifts (~18° per year). This shift has a 20 year period and is partly represented by Fig. 3.

After 10 years (1980) the orbit would have precessed a net value of 180° and the sun would directly illuminate the back side of the array if the S/C were in the 1970 launch position. The S/C, however, has been rotated 180° so that the sun illuminates the active side of the solar array.

Two modes of spacecraft stabilization were considered after the 180° rotation. They were gravity gradient and spinning. The gravity gradient mode was rejected because the control moment gryos can not be used for yaw-axis stabilization after the 180° rotation. Cross-axis yaw stabilization forces were believed to be too weak by themselves for yaw axis stability. Spin stabilization (about the pitch axis) analysis indicated S/C stability for spin rates greater than 0.1 revolution per minute (RPM). A value of 1 RPM was chosen as safely below any S/C structural problem and as easily obtainable by use of on-board cold gas jets. Figure 2(b) represents the spinning S/C attitude in 1980. Figures 2(a) and (b) are similar but with the S/C orbit velocity in opposite direction (when viewed from Sun). In 1970 the S/C rotated once about the pitch axis per orbit revolution. In 1980 it will rotate (spin) about the pitch axis approximately 100 times per orbit revolution.

Neither the 1980 nor the 1970 S/C orientation, however, would permit S/C operation during the 1974 to 1976 period when the sun (see Fig. 3) would illuminate the edge of the solar array and produce inadequate solar power. Therefore, the 180° S/C rotation was completed in steps. The first 60° was done in 1973 to provide a solar array, sun oriented direction, for the 1974 to 1976 period. The remaining 120° S/C rotation was performed in late 1976 (90°) and early 1977 (30°). Reference 5 pictorially described these attitude maneuvers in more detail.

Sun Angle of Incidence

Figure 4 is a plot of the actual and calculated sun angle of incidence on the S/C orbit plane. This angle is also the sun angle of incidence on the solar array when the solar array is in the orbit plane. In the 1970 to 1973 period, the solar array and orbit plane were coplaner to ±2°. In the 1978 to 1981 period, it is expected that the solar arrays also will be nearly coplaner. The spin axis (pitch axis) will be close (±5° or less) to perpendicular with the orbit plane. The precession period of the spin axis will be about 11 days for spin axis precession angles less than 10°.

The trend of sun angle of incidence with year on Fig. 4 is one of over all improvement (smaller angle) for the period of 1976 to 1980. Maxima and minima in Fig. 4 are due to seasonal variations. (Note that sun direction in Fig. 3 was for the same time each year.) When the sun angle of incidence falls below 31° there will be continuous sun on the S/C. At this angle, a S/C no longer passes into the earth's shadow if it has an altitude of the SERT II S/C (1000 km) or greater. The length of the shadow period varies with angle but is approximately 30 min. out of the 106-min. orbit period in 1977.

Presently the S/C is spinning with the plane of the solar array nearly (±4°) in the orbit plane. The solar array should remain in the orbit plane as the 20-year precession cycle steadily improves the sun angle of incidence. The angle of incidence will be near optimum when the sun synchronous orbit occurs in the 1979-1981 period, thus providing maximum power availability for thruster testing.

Solar Array Degradation

A degradation curve of the relative maximum power of the SERT II solar array with time is shown in Fig. 5. The solid line of Fig. 5 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 Fig. 5 represents the measured degradation of the solar array extrapolated through 1981. The data up to 170 days was taken from Ref. 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) and on November 29, 1977 (day 2855) when thruster 2 was operated through the maximum power point. The results are plotted on Fig. 5.

For the data point of December 4, 1975 the error band is due to two uncertainties. One uncertainty is the sun angle, 30°±5°. The other uncertainty is the maximum power drawn from the array. The telemetry updates every 15 to 60 seconds, and the actual maximum power point occurred between updates.

For the data point of November 29, 1977 the sun angle was known more precisely, 54°±0.3°, but the array temperature was less precisely known. The larger sun incidence angle resulted in a lower solar array temperature, which was below the lower limit of the telemetry. The solar array temperature, estimated from the open circuit solar array voltage of 70.3±0.9 volts, was 35.6° C.

Two important conclusions can be drawn from Fig. 5. First, the solar array degradation was less than predicted, indicating no significant contamination from ion thruster operation. Secondly, solar array power available in 1979 should be reduced by only 2-percent in relative maximum power from that measured in November 1977. This is because the degradation rate is low after eight years exposurer. If the sun/array incidence angle is zero in 1979, there will be enough power to operate thruster 2 at 80-percent throttle. The reserve power margin is small, however, and operation at lower throttle may be necessary.

Thruster System Status

A description of the SERT II thruster system has been presented elsewhere[1] and will not be repeated here. The purpose of the 1974 to 1977 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 on September 9, 1976 and November 29, 1977. The data from these tests are listed in Table 1. Both tests were similar and indicated no change in thruster performance from previous operation. Preheat and discharge only phases of the test were normal and stable. The "beam-current-on" phase was shortened due to available solar array power. In each case when high voltage was turned on to extract beam current, the flow rate was higher than the control set point of 80 ma and a larger beam current was produced. The control loop reduced the power to the flow vaporizer, but the cool-down time was too slow to limit the beam current. The beam current increased, drawing more solar array power, and within 30 seconds the power usage exceeded the solar array maximum power. After this point was reached there was a rapid drop in solar array voltage and automatic undervoltage turnoff of the thruster power conditioner. The solar array maximum power occurred at 55 volts and the power conditioner under-voltage turnoff occurred at 48 volts. The total power drawn agreed well with the predicted maximum power capability of the array. Had more power been available, the vaporizer temperature would have had time to cool down and flow control would have been established in approximately 2 minutes.

Thruster 1 was restarted 8 times in 1976 and 9 times in 1977. The restart times and other associated data are listed in Table 2 for both thrusters 1 and 2. The restarts of thruster 1 were all normal and variations in lighting times are due primarily to the initial thermal state of the thruster. For several tests the grid high voltage was applied, and the grid short was still present in thruster 1.

The thruster start tests show no heater deterioration in either thruster. The three heater resistances of each thruster remain constant within data tolerance. Each of the four propellant reservoirs continue to function normally and supply flow as required. The two neutralizer reservoirs, which contain pressure transducers, show no loss of pressurant gas due to leakage.

The starting time for the main cathode of thruster 2 has been longer in the 1974-1976 period than for prior measurements. This may be due to a lower keeper (starter) voltage caused by the lower solar array voltage, or it may indicate some deterioration of the cathode insert. The last restart on November 29, 1977, however, occurred in a normal time of only 2.1 min. As the solar array voltage (and keeper voltage) was higher for this test then for the tests of 1974-1976, it is presumed that the longer start times in the 1974-1976 period were more a result of lower keeper voltage than cathode insert deterioration.

Plans are to continue passive checking of the thrusters and spacecraft through 1978. In early 1979, when continuous solar power will be available for three months, thruster 2 will be turned on and operated continuously until orbit shadowing reoccurs in mid 1979. After the orbit shadow period passes, thruster 2 will again be operated continuously in later 1979 and into 1980 until exhaustion of its propellant supply. Figure 4 predicts 10 months of continuous power for this latter period.

Concluding Remarks

The SERT II spacecraft, designed for 1 year life, remains functional after eight 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 prevents continuous testing of the thruster, but periodic short-term check tests of the thruster verify its operational status. Maneuvers to change the spacecraft attitude were performed in August 1976, October 1976, and January 1977. These maneuvers, successful in placing the solar arrays in the plane of the orbit, combined with spin-stablization of the spacecraft will enable sufficient solar power for continuous thruster operation in early 1979.

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TABLE 1. - PERFORMANCE OF FLIGHT THRUSTER 2.

		Preheat						Propellant, no beam					
	Year	1970	1973	1974	1975	1976	1977	1970	1973	1974	1975	1976	1977
	Day	2/11	6/1	10/7	12/4	4/22	11/29	2/11	6/14	8/23	12/4	9/22	11/29
	Restart number	10	80	213	215	216	218	10	86	195	215	216	218
Main vaporizer heater	V2,v	0	0	0	0	0	0	[g]1.63	[a]1.49	1.85	1.85	(f)	1.75
	I2,a	0	0	0	0	0	0	[g]1.41	[a]1.32	1.70	1.80		1.65
Main cathode heater	V3,v	16.0	15.6	15.6	15.6	15.0	15.4	8.7	9.5	9.1	9.1		6.4
	I3,a	2.86	2.81	2.81	2.81	2.81	2.87	1.54	1.57	1.57	1.67		1.61
Main discharge	V4,v	>50	>50	>50	>50	>50	>50	39.9	39.7	40.4	40.4		40.7
	I4,a	0	0	0	0	0	0	2.0	2.3	1.7	1.7		1.8
Beam voltage	V5,v	0	0	0	0	0	0	0	0	0	0		0
Beam current	I5,a	0	0	0	0	0	0	0	0	0	0		0
Accelerator grid	V6,v	0	0	0	0	0	0	0	0	0	0		0
	I6,ma	0	0	0	0	0	0	0	0	0	0		0
Neutralizer heater	V7,v	[g]7.7	8.8	8.6	10.4	8.2	8.4	[g]7.7	[a]10.4	8.4	8.8		8.4
	I7,a	[g]2.3	2.[illegible]	2.5	3.0	2.5	2.5	[g]2.3	[a]3.0	2.4	2.4		2.5
Neutralizer keeper	V8,v	28.5	28.5	27.8	38.0	28.5	28.5	28.5	[a]32.3	28.5	28.5		28.5
	I8,a	[d]0.226	[d]0.183	[d]0.191	0.179	0.189	0.197	[d]0.199	[a]0.175	[d]0.179	[d]0.171		0.181
Spacecraft voltage	v	-6	(f)	-3	(f)	(f)	(f)	-9	(f)	-4	(f)		(f)
Neutralizer emission	a	0	0	0	0	0	0	0	0	0	0		0
Main cathode keeper	V10,v	[d]>416	[d]363	[d]371	[d]411	[d]363	[d]386	12.3	9.9	10.8	11.3		10.5
	I10,a	0	0	0	0	0	0	[b]0.280	[b]0.273	[b]0.273	[b]0.271		[b]0.279
Solar array	v	70	62	65	77	63	67	68	61	60	59	61	65

		30% beam					80% beam			Telemetry uncertainty (rss)
	Year	1970	1974	1975	1976	1977	1970	1974	1975	
	Day	2/11	9/10	12/4	9/22	11/29	2/11	9/11	12/4	
	Restart number	10	198	215	216	218	10	200	215	
Main vaporizer heater	V2,v	[g]1.63	1.70	1.70	[c]0.19	[a]2.67	1.70	1.85	1.85	±0.07
	I2,a	[g]1.51	1.77	1.70	[a]0.09	[a]2.97	1.70	1.95	1.95	±0.08
Main cathode heater	V3,v	7.9	8.7	8.7	6.1	6.1	8.3	8.7	8.2	±0.35
	I3,a	1.54	1.57	1.57	1.61	1.61	1.54	1.57	1.57	±0.05
Main discharge	V4,v	42.2	42.4	42.4	39.8	(f)	41.5	41.4	41.5	±0.2
	I4,a	0.7	0.6	0.56	[a]2.47	(f)	1.2	1.1	1.1	±0.05
Beam voltage	V5,v	[d]3490	[d]2960	[d]2900	2500	2440	[d]3160	[d]2630	[d]2500	±65
Beam current	I5,a	[d]0.088	[d]0.083	[d]0.083	[a]0.172	[d]0.119	[d]0.203	[d]0.198	[d]0.198	±0.005
Accelerator grid	V6,v	[d]-1730	[d]-1480	[d]-1430	[d]1100	(f)	[d]-1640	[d]-1330	[d]-1230	±50
	I6,ma	1.1	0.9	0.8	0.5	(f)	1.4	1.4	1.3	±0.1
Neutralizer heater	V7,v	[g]6.6	8.1	7.7	7.1	7.1	[g]6.4	7.5	7.0	±0.25
	I7,a	[g]2.0	2.3	1.9	[a]2.6	[a]2.7	[g]1.9	2.2	2.1	±0.05
Neutralizer keeper	V8,v	27.8	27.8	27.8	28.5	29.2	[c]24.0	[c]27.8	27.8	±0.7
	I8,a	[d]0.215	[d]0.175	[d]0.175	0.181	0.185	[d]0.206	[d]0.167	0.163	±0.004
Spacecraft voltage	v	-17	-8	(f)	(f)	(f)	-17	(f)	(f)	±2
Neutralizer emission	a	0.087	0.080	0.080	(f)	(f)	0.201	0.195	0.195	±0.006
Main cathode keeper	V10,v	20.4	20.0	20.0	13.8	15.7	13.9	13.1	13.1	±0.5
	I10,a	[b]0.272	[b]0.264	[b]0.260	[b]0.257	[b]0.256	[b]0.272	[b]0.260	[b]0.259	[b]±0.003
Solar array voltage	v	68	59	56	[h]50	[h]49	63	52	[h]50	±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]Value estimated from V5.

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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	$4.2^{+0.0}_{-0.6}$	$0.3^{+0.7}_{-0.1}$	3855	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)
	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)
	160	9/15/76	2.09	2.10	1.00	2.82	14.5	5.2	2.90	10.6	3.7	$6.5^{+0.0}_{-0.4}$	$3.0^{+0.0}_{-0.5}$	3891	(a)
	167	12/14/76	2.70	2.74	1.01	2.88	15.7	5.5	2.90	10.6	3.7	$5.8^{+0.0}_{-0.6}$	$7.2^{+0.0}_{-0.5}$	3894	(a)
	172	7/27/77	2.79	2.74	.98	2.82	(a)	(a)	2.90	10.6	3.7	$6.6^{+0.0}_{-0.4}$	$7.5^{+0.0}_{-0.3}$	3896	(a)
	176	11/22/77	2.89	2.74	.95	2.82	14.9	5.3	2.90	10.6	3.7	$5.8^{+0.0}_{-0.4}$	$3.1^{+0.0}_{-0.1}$	3897	(a)
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	12/21/60	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	.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
	216	9/22/76	2.97	2.70	.91	2.86	15.0	5.3	2.92	10.2	3.5	$6.2^{+0.0}_{-0.4}$	[b]$41.0^{+0.0}_{-0.4}$	2178	30
	218	11/29/77	2.97	2.70	.91	2.86	15.4	5.4	2.92	10.0	3.4	$6.4^{+0.0}_{-0.4}$	$2.1^{+0.0}_{-0.3}$	2279	33

[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.

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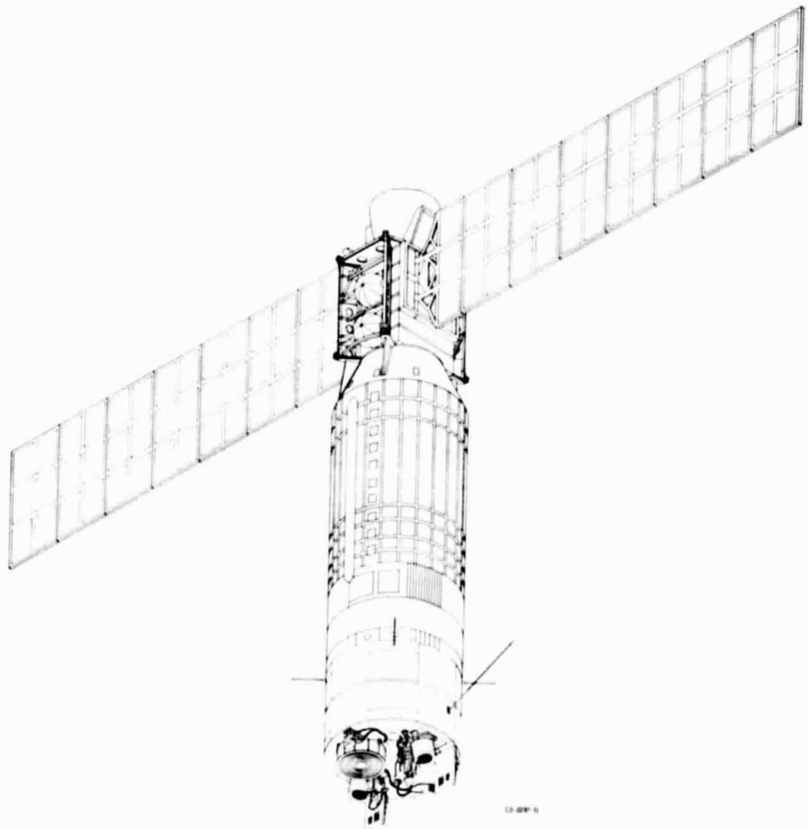
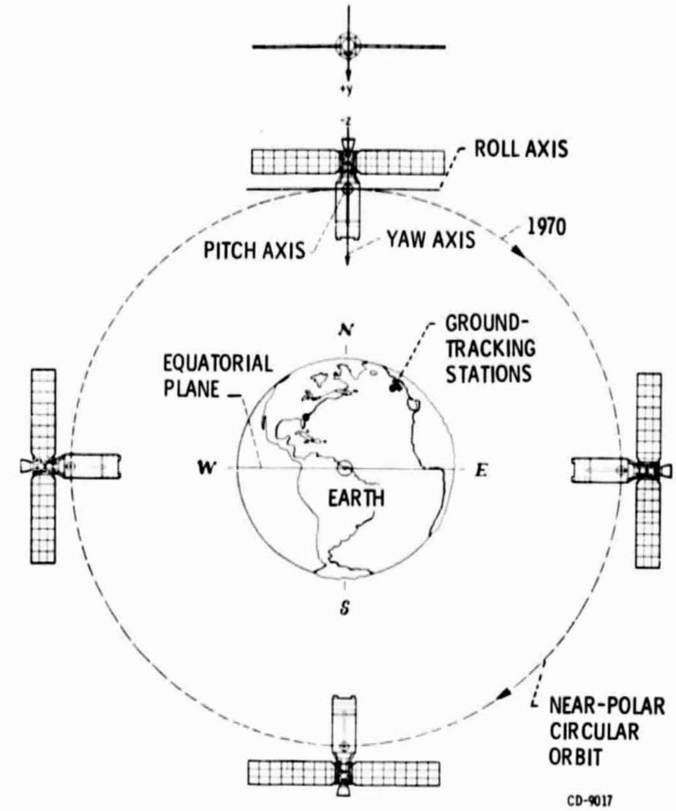
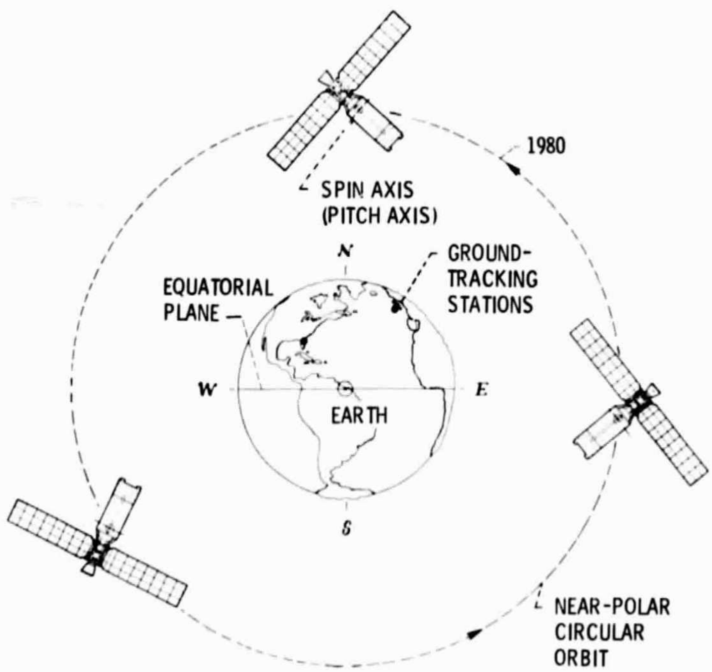


Figure 1. - SERT II spacecraft in orbit (artist's conception).



(a) 1970 LAUNCH, GRAVITY-GRADIENT STABILIZED POSITION.



(b) 1980, SPIN-STABILIZED POSITION. CD-9017

Figure 2. - SERT II vehicle coordinate system in orbit viewed from Sun.

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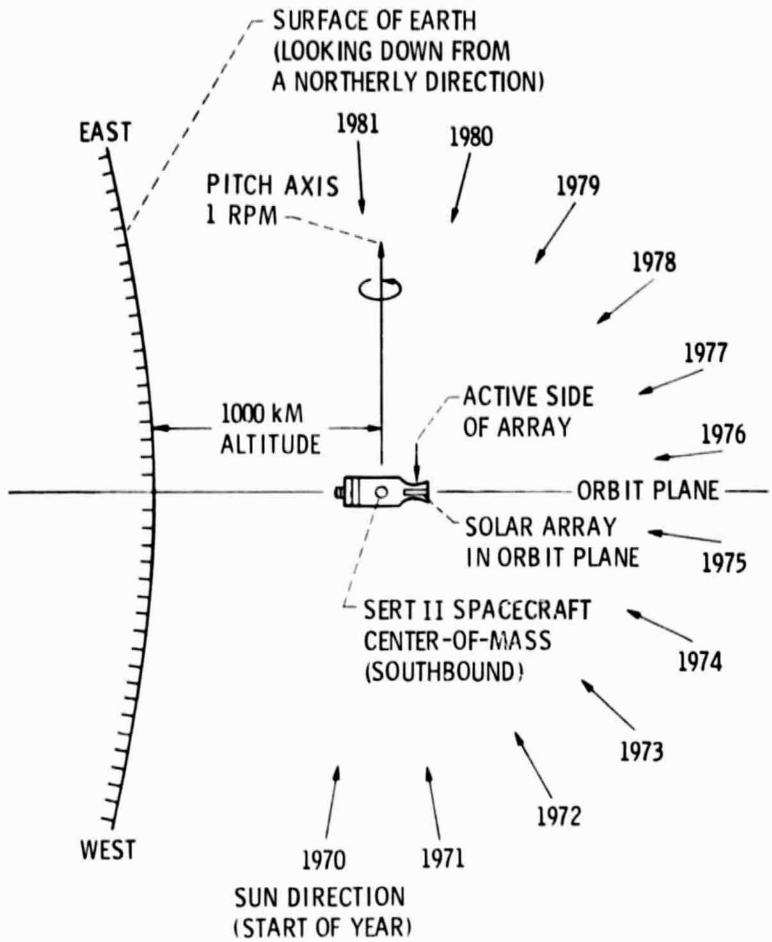

Figure 3. - SERT II spacecraft attitude position after August 1976, October 1976, and January 1977 positioning maneuvers.

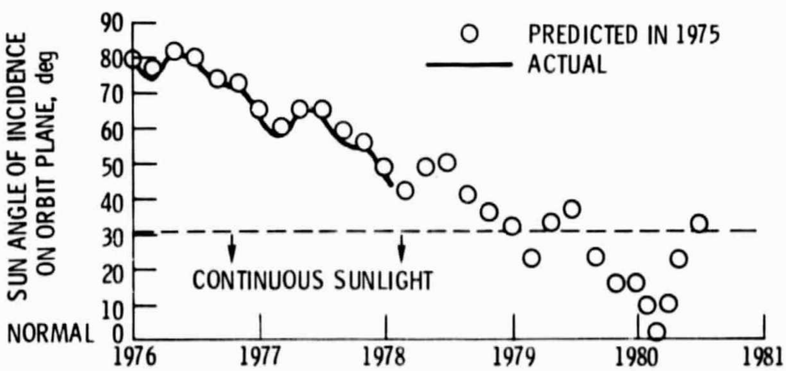

Figure 4. - Sun angle on SERT II orbit plane.

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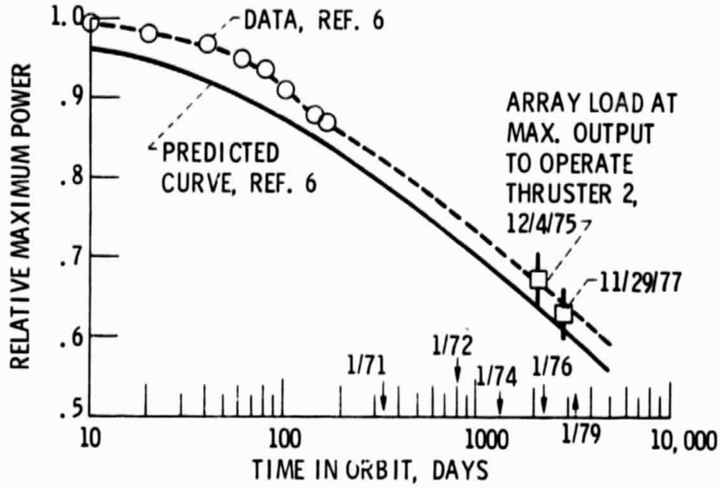

Figure 5. - SERT II spacecraft main solar array degradation. (B. O. L. max power, 1425 watts at 25^{0} C.)