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NAVAL RESEARCH LABORATORY SATELLITES 1960-1989

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The US Navy's Naval Research Laboratory (NRL) in Washington, DC has been involved in space exploration since the V-2 rocket test at White Sands in the late 1940s. These were followed by Aerobee flights and the development of NRL's Viking sounding rocket, which grew into the Vanguard satellite launch vehicle. NRL's Vanguard programme ended in 1959 with the launch of the third successful Vanguard satellite. However, NRL has remained active in space research ever since, and recently developed and operated the Clementine space probe which mapped the Moon in 1994. In this article I explore Vanguard's successors and Clementine's antecedents, in an attempt to illuminate NRL's continuos history of 'smaller, faster, better'.

1. INTRODUCTION

The NRL satellites can be divided into several categories:

(1) Solar radiation satellites - NRL has a long history of solar physics research, motivated by the need to understand and predict the effect of solar flares on radio transmission in the ionosphere, to preserve reliable naval communications.

(2) Ionospheric propagation research - These satellites investigated radio propagation directly, to support communications satellite design.

(3) Space radar calibration - The US Navy operates the NAVSPASUR (Naval Space Surveillance) radars, a key component of the US satellite monitoring effort. NRL has launched satellites of various known sizes and shapes for calibration purposes.

(4) Navigation - The first US Navy navigation system, Transit, was developed by the Applied Physics Laboratory (APL), a university-based Navy laboratory which has also been responsible for numerous Navy satellites. The NRL Timation research satellites laid the groundwork for the follow-on, national, system of GPS (Global Positioning System) satellites.

(5) Space Technology - NRL launched a number of technology satellites, mostly to develop gravity gradient systems.

(6) Classified programmes - NRL flew a series of small classified satellites in the 1960s, and in the 1970s developed the secret but widely reported WHITE CLOUD satellite system which used radio interferometry to locate naval vessels by their radio emissions.

(7) Experiments on NASA and USAF host satellites - These include the HEAO A-1 X-ray sky survey on HEAO-1, the SOLWIND coronagraph on P78-1, and the NRL-701 LASSII ionospheric experiment on CRRES.

1.1 Launch Programmes

Most of NRL's satellites were launched as part of two launch programmes. The first consisted of NRL secondary payloads on Thor Ablestar rockets whose primary payload was APL's Transit navigation satellites. On 22 June, 1960, Solar Radiation 1 was ejected from the Transit 2A satellite using a spring, to become the first secondary payload or subsatellite in orbit. Later on most of the Transit subsatellites were APL rather than NRL payloads, with the exception of the August 1965 launch. In 1962 NRL launched Composite 1, a payload on a Thor Ablestar consisting of a cluster of small satellites. This rocket failed to reach orbit, but it was followed by a series of launches using Thor Agena rockets to orbit similar clusters. The NRL launches held the record for many years for the number of payloads orbited in a single launch (an Air Force Space Test Program launch later exceeded them). The missions seem to have used leftover rockets; the sixth was the last time the Thor Agena D rocket was used for a space launch in its original form without strapon solid rockets. Non-NRL payloads are included in the launch table in italics. The small NRL satellites were usually spherical, and are reminiscent of the Vanguard payloads.

2. THE SOLRAD SERIES

The Solar Radiation satellites were known variously as SR, SOLRAD, or (mysteriously) GREB. They monitored the X-ray emission from the Sun. When the Sun's million-degree corona flares, the X-ray emission can increase manyfold, and the energetic X-ray photons ionise the Earth's upper atmosphere, affecting communications and increasing radiation levels in low orbit. Lower in the Sun's atmosphere, hydrogen at several tens of thousand degrees emits ultraviolet radiation with a characteristic wavelength of 1215 Angstroms, the Lyman-alpha line. The SR satellites would monitor variations in the Sun's radiation output over a long period of time, allowing scientists to look for correlations with disturbances in the Earth's atmosphere. The first SR satellite carried an X-ray sensor operating in the 2-8 Angstrom band and a Lyman-alpha ultraviolet detector; it operated from June 1960 until April 1961, and showed that an August 1960 solar storm which caused a shortwave radio communications fadeout coincided with a large, rapid increase in solar X-ray flux. SR 1 was followed by a rapid series of similar payloads. SR 2 failed to reach orbit; SR 3 made it up, but failed to separate from a University of Iowa payload. Nevertheless it operated from June

1961 to November 1961. Its two X-ray sensors covered the 2-8 and 8-15 A bands. SR 4A and SR 4B were both lost in launch accidents, while SR 5 was never launched. SR 6A flew in June 1963 but was stranded in an elliptical orbit when the Ablestar upper stage failed to restart, and reentered after only 47 days. Double the mass of the first SR, it carried four X-ray sensors and possibly four UV detectors. Next up was SR 7A, launched in January 1964. SR 7A covered the X-ray range out to 60A, and operated until July 1966. The next multiple NRL launch was in March 1965, carrying SR 7B in its cluster of satellites. SR 7B appears to have been remarkably successful, operating for 52 months until July 1969. From the same launch, the satellite now identified by NRL as PL 142 has been listed in several sources as SR 6B, but no information about it has been released.

Nineteen sixty-five was the International Quiet Sun Year (IQSY), devoted to the study of the Sun at solar minimum. At this point NRL joined forces with NASA and the Solrad satellites became the Solar Explorer programme. SR 8 was also known as Explorer 30; it was launched in November 1965 on a NASA Scout from Wallops Island as part of US participation in the IQSY, monitoring X-rays in the 0.5-60A range and carrying a Lyman-alpha UV photometer. It operated until November 1967. It was followed by two more Solar Explorers of an improved design, with three axis stabilisation and deployable solar panels. The mission of Explorer 37 (SR 9) in March 1968 nearly came to a premature end seconds after launch when the Scout's Algol first stage malfunctioned. In the event, the launch vehicle recovered, but the achieved orbit was 513 x 881 km instead of the intended 840 km circular one. SR 9 worked well in the low orbit until February 1974 when the attitude control system failed, and was turned off in October 1974. Its successor, Explorer 44/SR 10, had been launched in July 1971 and operated until July 1978. In addition to the usual X-ray and UV photometers, it carried an electron temperature sensor, and a cosmic X-ray sky survey experiment. The final two Solrads were flown under the USAF's Space Test Program and were far more ambitious. The 180 kg twin spacecraft, SR 11A and SR 11B, were launched into a deep circular orbit at 120000 km from the Earth. The experiment payload included proportional counter and ion chamber X-ray detectors, a three-band solar extreme ultraviolet monitor, an X-ray polarimeter and UV and X-ray spectrometers. Instruments to study gamma ray bursts and the galactic X-ray background were also aboard. SR11A only worked until June 1977 but SR 11B was operated until June 1979 and then switched off. The Solrad programme had lasted 20 years, almost two solar cycles. NRL solar experiments continued to monitor the Sun aboard the P78-1 satellite into the 1980s (P78-1 seems to be technically considered a USAF satellite although most of the major experiments aboard were from NRL).

3. LOFTI

NRL carried out studies of ionospheric propagation during the 1960s to understand how the quality of radio transmission

TABLE 1:

No	Date	Launch Vehicle	Upper Stage	Payloads	Total
			*USN Transit/**Ablestar** Flights*		
1	1960 Apr 13	Thor Ablestar	AB 002?	Transit 1B	1
2	1960 Jun 22	Thor Ablestar	AB 003?	Transit 2A, SR 1	2
3	1960 Nov 30	Thor Ablestar	AB 006?	Transit 3A, SR 2	2
4	1961 Feb 22	Thor Ablestar	AB 007?	Transit 3B, Lofti I	3
5	1961 Jun 29	Thor Ablestar	AB 008	Tansit 4A, SR 3, Injun I	3
6	1961 Nov 15	Thor Ablestar	AB 009?	Transit 4B, Traac	2
7	1963 Sep 28	Thor Ablestar	AB 013	Transit 5BN-1, 5E-1	2
8	1963 Dec 5	Thor Ablestar	AB 015	Transit 5BN-2, 5E-3	2
9	1964 Apr 21	Thor Ablestar	AB 014	Transit 5BN-3, 5E-2	2
10	1964 Oct 6	Thor Ablestar	AB 016	NNS O-1, DRAGSPHERE I, DRAGSPHERE II	3
11	1964 Dec 13	Thor Ablestar	AB 017	NNS O-2, 5E-5	2
12	1965 Mar 11	Thor Ablestar	AB 018	NNS O-3, Secor 2	2
13	1965 Jun 24	Thor Ablestar	AB 019	NNS O-4	1
14	1965 Aug 13	Thor Ablestar	AB 020	NNS O-5, TEMPSAT I, LONG ROD, SURCAL V, CALSPHEREII, DODECAPOLE II	6
			NRL Composite Flights		
1	1962 Jan 31	Thor Ablestar	AB 010	SR IVA, LOFTI IIA, SURCAL I, Injun 2, Secor1	5
2	1962 Dec 13	Thor Agena D	2351	PL 120, PL 121, SURCAL II, CALSPHERE I, Injun 3	5
3	1963 Jun 15	Thor Agena D	2353	SR VI, LOFTI IIB, PL 112, Dosimeter, SURCAL III	5
4	1964 Jan 11	Thor Agena D	2354	SR VIIA, GGSE I, PL 135, Secor 1	4
5	1965 Mar 9	Thor Agena D	2701	SR VIIB, PL 142, GGSE II, GGSE III, SURCAL IV, DODECAPOLE I, Secor, 3, Oscar 3	8
6	1967 May31	Thor Agena D	2704	PL 151, GGSE IV, PL 153, GGSE V, TIMATION I, CALSPHERE III, CALSPHERE IV, (PL 159??)	8?
7	1969 Sep 30	Thorad Agena D	-	PL 161, PL 162, PL 163, PL 164, TIMATION II, PL 176, TEMPSAT II, CONE, CYLINDER, USAF Hitchhiker	10
8	1971 Dec 10	Thorad Agena D	-	PL 171, PL 172. PL 173, PL 174	4

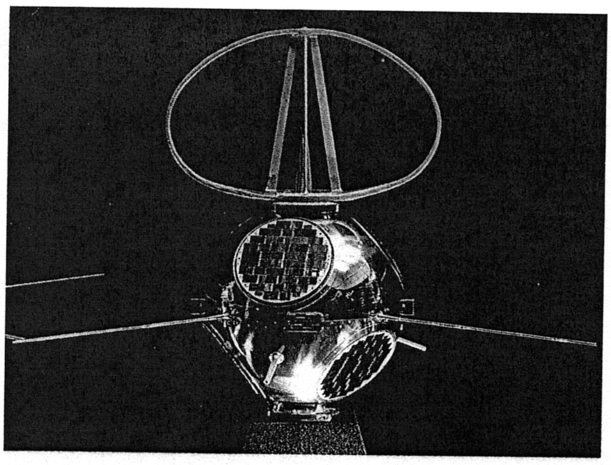

Fig. 1 Lofti 1, launched 22 February 1961.

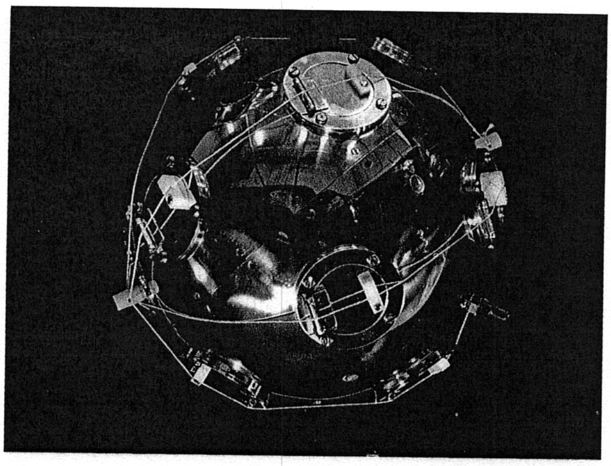

Fig. 2 Dodecapole I, launched 9 March 1965.

through the ionosphere varies. Presumably the research was to be applied to both Navy communications satellites and electronic eavesdropping payloads. The LOFTI (Low Frequency Transmission through the Ionosphere) payload was a sphere similar to SR, topped with a distinctive 20-inch loop-shaped antenna. LOFTI I was launched with a Transit payload in 1961 and subsequent flights went up on the early composite launches (fig. 1). The first LOFTI was left in an elliptical orbit still attached to its Transit main payload and the rocket stage. The 15-foot long whip antennas were unable to deploy. However, the unintended elliptical orbit was actually an advantage to LOFTI since it could sample propagation at a range of altitudes, and the loop antenna worked well. In its brief life, the first LOFTI demonstrated that the ionosphere was transparent to very low frequency radio waves. It picked up radio signals from a Navy transmitter in the Panama Canal Zone and retransmitted them to ground stations in the USA

4. ORBIS

In 1966 PL 137, reported to have studied high frequency radio propagation, was launched as a secondary payload on a classified reconnaissance satellite. It appears to have remained attached to the Agena D rocket in orbit and reentered after 5 days. The ORBISCAL payloads for HF propagation studies were launched as part of the USAF Space Test Program. They were a follow-on to ORBIS Orbiting Radio Beacon for Ionospheric Studies payloads carried on some CORONA satellites.

5. SURCAL AND SOICAL

The US Navy is responsible for the NAVSPASUR Fence, a chain of radars in the southern United States which form part of America's space tracking network. The cross sections and signatures returned by these radars can be used to estimate the size and shape of orbiting satellites, but only if they can be compared with returns from satellites of known size and shape and with radio signals of known strength. To provide this calibration, NRL launched the SURCAL (Surveillance Calibration) satellites, 20-cm rectangular boxes covered with solar cells on five sides which carried active transponders and a 6-meter antenna, as well as a series of passive satellites of various sizes and shapes. A cone and cylinder launched in September 1969 were described as part of the SOICAL (Space Object Identification Calibration) programme and I will assume this name applies to all the passive calibration test objects.

There were five launches in the SURCAL programme, with continuous operation from the successful launch of SURCAL II in December 1962 until the end of operations with SURCAL V in 1972.The first SOICAL passive payload was CALPSHERE, a 1 kg sphere 15 cm in diameter. Two DODECAPOLE satellites, launched in 1965, deployed twelve 7-meter booms to serve as a large radar test target (fig. 2). LONG ROD had a single long boom which should have extended to 60 meters, but may not have worked. It was launched with the second DODECAPOLE (also known as PORCUPINE) and a second CALSPHERE, this time 35 cm in diameter and painted with a special NASA-developed white reflecting paint to make it more visible from the ground. TEMPSAT I and II were 35-cm spheres launched in 1965 and 1969 and reported to be thermal design experiments, using matt black paints to control the spacecraft temperature near the freezing point of water (fig. 3).

Other passive satellites were launched to measure the effects of atmospheric drag on orbits; these have usually been called CALSPHERE, but the NRL list implies this is incorrect. The two launched in 1964 were named DRAGSPHERE, and were each spheres 36 cm in diameter. One sphere had a mass of 1 kg, and the other a mass of 10 kg. Launched into 1000-km high circular orbits, the orbit of the massive sphere was practically unchanged thirty years later, while the light sphere was 50 km lower. The three launched in 1971, called PL 170, consisted of two polished

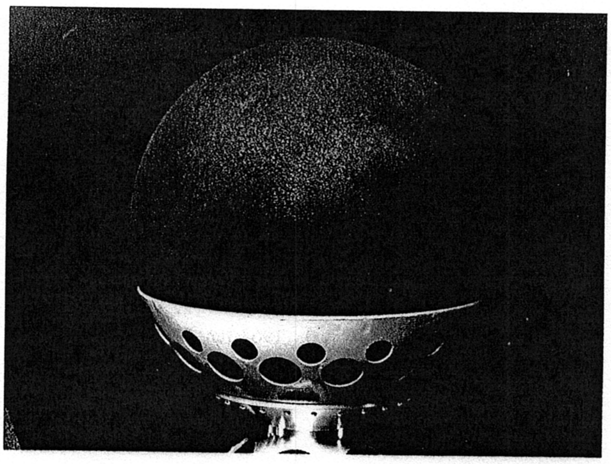

Fig. 3 Tempsat, launched 13 August 1965.

aluminium spheres and a gold plated sphere, each with a mass of 0.7 kg and a diameter of 26 cm. All three satellites reentered during their second solar maximum in the winter of 1989-90. A radiation dosimeter was launched in 1963 and orbited for 45 days. The purpose of the mission is unclear.

6. GGSE

The Naval Research Laboratory was one of the pioneers of gravity gradient stabilisation, first developed by Johns Hopkins' Applied Physics Laboratory for Transit. Gravity gradient technology was used in a later classified naval reconnaissance system. As a satellite orbits the Earth, the effects of atmospheric drag, the changing direction of gravity, and other small perturbations tend to make it tumble. Most early satellites were spun up to a revolution per minute or so about an axis of symmetry, which then remains fixed in the local inertial frame. Another method is to use gyroscopes and flywheels to actively manage angular momentum changes - three-axis stabilisation, first used in the CORONA satellite. Three-axis stabilisation is used by most modern spacecraft. A third solution is to make the spacecraft long and thin, in which case it will align itself with the local vertical. This method, gravity gradient stabilisation, is achieved by deploying an end mass on a long boom.

NRL's GGSE I (Gravity Gradient Stabilisation Experiment I) was launched in January 1964. Four more identified GGSE payloads were launched over the next few years, but ten further classified payloads in the 1967-1971 period are identified as gravity gradient experiments in the NRL list.

7. TIMATION

NRL pioneered the use of atomic clock based navigation which underlies the success of the modern Global Positioning System. Four Timation satellites were launched as precursors to the Navstar GPS, which was developed for military navigation but is now finding hundreds of uses in everyday life. The first two Timations were small boxes. Timation III was renamed NTS 1 (Navigation Technology Satellite 1). A much larger satellite launched on a dedicated Atlas booster, it was made part of a joint US Navy/US Air Force programme and inserted into a high circular orbit. The final satellite, NTS 2, was launched only a year before the first Navstar and was used during initial tests of the GPS system.

8. LIPS

The Living Plume Shield satellites (LIPS) were used as a cheap technology testbed using operational debris from the classified WHITE CLOUD launches. After orbit insertion, a flat metal plate which had been used to shield the subsatellites from the upper stage rocket plume was ejected. In the LIPS experiments, a small payload such as an experimental solar cell package was attached to this shield. The first LIPS was lost in a launch failure but the other two seem to have worked well.

9. CONCLUSION

In recent years NRL has been involved in more ambitious space experiments. The LACE (Laser Atmospheric Compensation Experiment) satellite was used to develop technology for missile defence, and the Clementine Deep Space Probe Sensor Experiment (DSPSE) were still cheap missions by modern standards, but were vastly more ambitious than the tiny Solrads and Surcals of the 1960s. The 1990s have seen the comeback of the microsatellite with missions such as Astrid, Microsat and Orbcomm, and it seems an appropriate time to recall the little-documented tiny pioneers from the Naval Research Lab.

TABLE 2: *NRL Satellites*

Name	Satellite	Date	Orbit	Period	Desig.	Mass (kg)	Op life	Mission
			Solar Radiation Satellites					
SR I		1960 Jun 2	614 x 1061 x 66.7	101.7	1960 η 2	19	10 mo	Solar X
SR II		1960 Nov 30	-			18	f	Solar X
SR III		1961 Jun 29	882 x 999 x 66.8	103.9	1961 o 2	18	5 mo	Solar X
SR IVA		1962 Jan 24	-			25		Solar X
SR IVB		1962 Apr 26	-			25		Solar X
SR VI		1963 Jun 15	155 x 590 x 69.9	92.1	1963-21C	38	47d	Solar X
SR VIIA		1964 Jan 11	905 x 934 x 69.9	103.5	1964-01D	40	23 mo	Solar X
SR VIIB		1965 Mar 9	910 x 939 x 70.1	103.5	1965-16D	47	52 mo	Solar X
SR VIII	NRL PL 145	1965 Nov 19	704 x 891 x 59.7	100.8	1965-93A	57	24 mo	Solar X
SR I X	NRL PL 155	1968 Mar 5	513 x 881 x 59.4	98.7	1968-17A	119	6 yr	Solar X
SR X	NRL PL 165	1971 Jul 8	433 x 632 x 51.1	95.2	1971-58A	119	7 yr	Solar X
SR 11A	NRL PL 175	1976 Mar 14	118383 x 119180 x 25.7		1976-23C	183	15 mo	Solar X
SR 11B	NRL Pl 177	1976 Mar 14	115720 x 116645 x 25.6		1976-23D	183	40 mo	Solar X
			LOFTI Satellites					
LOFTI I		1961 Feb 22	167 x 1002 x 28.4	96.2	1961 η	26	36d	LF radio
LOFTI IIA		1962 Jan 24	-			27		LF radio
LOFTI IIB		1963 Jun 15	171 x 925 x 69.9	95.7	1963-21B	29	33d	LF radio
			SURCAL Satellites					
SURCAL I		1962 Jan 24	-			2.2		Spasur cal
SURCAL II		1962 Dec 13	231 x 2784 x 70.2	116.2	1962 $\beta\tau$ 4	4	36 mo	SPASUR cal

SURCAL III	NRL PL 133?	1963 Jun 15	169 x 887 x 69.9	95.3	1963-21F	4	19 d	Spasur cal
SURCAL IV		1965 Mar 9	901 x 945 x 70.1	103.5	1965-16G	4.5	5 yr	Spasur calib
SURCAL V	NPL PL 150C?	1965 Aug 13	1094 x 1184 x 90.0	108.1	1965-65K	5	7 yr	Spasur cal
			Passive Object Identification and Drag Satellites					
CALSPHERE I		1962 Dec 13	226 x 2763 x 70.3	115.9	1962 $\beta\tau$ 3	1.4	Passive	Object ID
DRAGSPHERE I		1964 Oct 6	1054 x 1084 x 89.9	106.6	1964-63C	0.9	Passive	Drag
DRAGSPHERE II		1964 Oct 6	1056 x 1086 x 90.0	106.7	1964-63D	9.5	Passive	Drag
DODECAPOLE I		1965 Mar 9	910 x 939 x 70.1	103.5	1965-16H	4	Passive	Obj ident
DODECAPOLE II		1965 Aug 13	1094 x 1184 x 90.0	108.1	1965-65C	4	Passive	Obj ident
LONG ROD		1965Aug 13	1074 x 1209 x 90.0	108.2	1965-65G	3	Passive	Obj ident
TEMPSAT		1965 Aug 13	1096 x 1186 x 90.0	108.2	1965-65E	9	3 mo?	Thermal design expt.
CALSHERE II	NRL PL 158?	1965 Aug 13	1082 x 1201 x 90.0	108.2	1965-65H	4	Passive	Obj ident
CALSPHERE III	NRL PL 160	1967 May31	919 x 934 x 70.0	103.6	1967-53A	4.5	Passive	Object ID
?	NRL PL 159	1967 May31	915 x 926 x 70.0	103.5	1967-53F		Not in NRL list	
CALSPHERE IV	NRL PL 150B	1967 May31	917 x 922 x 69.9	103.4	1967-53J	3	Passive	Object ID
SOCIAL CONE		1969 Sep 30	903 x 945 x 70.0	103.5	1969-82K	3	Passive	Object ID
SOCIAL CYLINDER		1969 Sep 30	904 x 940 x 70.0	103.5	1969-82J	2.7	Passive	Object ID
TEMPSAT II		1969 Sep 30	906 x 940 x 70.0	103.5	1969-82H	14	8 mo	Thermal design
	NRL PL 170A	1971 Feb 17	765 x 834 x 98.8	100.9	1971-12E	0.7	Passive	Drag exp, gold plate
			NRL Satellites					
	NRL PL 170B	1971 Feb 17	763 x 833 x 98.8	100.9	1971-12D	0.7	Passive	Drag (polished Al)
	NRL PL 170C	1971 Feb 17	773 x 932 x 98.8	100.9	1971-12C	0.7	Passive	Drag (polished Al)
			Classified Satellites					
	NRL PL 120	1962 Dec 13	231 x 2786 x 70.4	116.3	1962 $\beta\tau$ 1	25	36 mo	Classified
	NRL PL 121	1962 Dec 13	229 x 27785 x 70.3	116.2	1962 $\beta\tau$ 5	25	36 mo	Classified
Dosimeter	NRL PL 130?	1963 Jun 15	175 x 837 x 69.9	94.8	1963-21D	38	45d	Radiation counter
	NRL PL 112	1963 Jun 15	181 x 920 x 69.9	94.8	1963-21E	27	42d	Classified
	NRL PL 135	1964 Jan 11	905 x 934 x 69.9	103.5	1964-01E	38	21 mo	Classified
Greb 6?	NRL PL 142	1965 Mar 9	910 x 939 x 70.1	103.5	1965-16A	48	15 mo	Classified
	NRL PL 176	1969 Sep 30	906 x 940 x 70.0	103.5	1969-82G	23	2 yr	Classified
			Gravity Gradient Experiment Satellites					
GGSE I		1964 Jan 11	898 x 942 x 69.9	103.5	1964-01B	38	48 mo	Grav grad
GGSE II		1965 Mar 9	902 x 946 x 70.1	103.5	1965-16B	59	44 mo	Grav grad
GGSE III		1965 Mar 9	910 x 939 x 70.1	103.5	1965-16C	59	16 mo	Grav grad
GGSE IV		1967 May31	915 x 929 x 70.0	103.5	1967-53C	85	5 yr	Grav grad
GGSE V		1967 May31	915 x 929 x 70.0	103.4	1967-53D	105	6 yr	Grav grad
	NRL PL 151	1967 May 31	915 x 927 x 69.9	103.4	1967-53G	52	4 yr	Grav grad
	NRL PL 153	1967 May 31	915 x 926 x 69.9	103.4	1967-53H	77	6 yr	Grav grad
	NRL PL 161	1969 Sep 30	906 x 941 x 70.0	103.5	1969-82B	100	12 mo	Grav grad
	NRL PL 162	1969 Sep 30	907 x 940 x 70.0	103.5	1969-82D	101	6 mo	Grav grad
	NRL PL 163	1969 Sep 30	906 x 941 x 70.0	103.5	1969-82E	102	3 yr	Grav grad
	NRL PL 164	1969 Sep 30	906 x 940 x 70.0	103.5	1969-82F	103	6 mo	Grav grad
	NRL PL 171	1971 Dec 14	983 x 999 x 70.0	104.9	1971-110A	123	8 yr	Grav grad
	NRL PL 172	1971 Dec 14	983 x 999 x 70.0	104.9	1971-110C	123	-	Grav grad
	NRL PL 173	1971 Dec 14	982 x 997 x 70.0	104.9	1971-110D	128	-	Grav grad
	NRL PL 174	1971 Dec 14	981 x 997 x 70.0	104.9	1971-110E	128	-	Grav grad
			ORBISCAL Satellites					
	NRL PL 137	1966 Mar 18	152 x 284 x 101.0	88.9	1966-22B	41	5 d	HF Wave Prop (partial suc)
ORBISCAL I		1968 Aug 16	-			30		HF wave prop
ORBISCAL II		1969 Mar 18	175 x 309 x 99.1	89.4	1969-25D	39	6d	HF wave prop
			Navigation Satellites					
Timation I		1967 May31	915 x 926 x 69.9	103.4	1967-53E	39	24 mo	Navigation
TIMATION II		1969 Sep 30	906 x 940 x 70.0	103.5	1969-82C	62	6 yr	Navigation
Timation III (NTS-1)		1974 Jul 14	13445 x 13767 x 125.1	468.4	1974-54A	513	5 yr	Navigation
NTS-2		1977 Jun 23	20181 x 20181 x 63.3	717.9	1977-53A	776	Op	Navigation

TABLE 2 (*contd.*): *NRL Satellites*

Name	Satellite	Date	Orbit	Period	Desig.	Mass (kg)	Op life	Mission
			Ocean Surveillance Satellites					
MSD		1976 Apr 30	1092 x 1128 x 63.5	107.5	1976-38A	589	41d	Upper stage/Dispenser
	NRL PL 181	1976 Apr 30	1093 x 1129 x 63.4	107.5	1976-38C	196	Op	Classified
	NRL PL 182	1976 Apr 30	1093 x 1130 x 63.4	107.5	1976-38D	196	Op	Classified
	NRL PL 183	1976 Apr 30	1083 x 1139 x 63.4	107.5	1976-38J	196	Op	Classified
			NRL Satellites					
MSD		1977 Dec 8	1054 x 1169 x 63.4		1977-112A	589	31d	Upper stage/Dispenser
	NRL PL 191	1977 Dec 8	1054 x 1169 x 63.4	107.5	1977-112D	196	Op	Classified
	NRL PL 192	1977 Dec 8	1055 x 1168 x 63.4	107.5	1977-112E	196	Op	Classified
	NRL PL 193	1977 Dec 8	1055 x 1168 x 63.4	107.5	1977-112F	196	Op	Classified
TLD		1990 Jun 8			1990-50A	726	Op	Upper stage/ sat. Dispenser
			Later NRL Satellites					
LIPS I		1980 Dec 8	-		FTO	46		Devel. test experiment
LIPS II		1983 Feb 9	1047 x 1184 x 63.4	107.6	1983-08B		Op	Devl. test experiment
LIPS III		1987 May 15	1045 x 1179 x 62.9	107.8	1987-43B	63	Op	Solar cell experiment
LACE		1990 Feb 14	486 x 515 x 43.1	94.6	1990-15A	1440	Op	Laser experiment
CLEMENTINE		1994 Jan 25	Lunar and solar orbit		1994-04A	230		
ISA		1994 Jan 25	Elliptical orbit		1994-04B	49		

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