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THE SCOUT LAUNCH VEHICLE

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The 1990s have been heralded as the decade of the 'lightsat', or small lightweight satellite, and there has been renewed interest in small economical satellite launchers. The light satellite launcher is not a new idea, however; the first successful such vehicle - NASA's Scout - has been flying since 1960. Its payloads, although small, have included some of the most interesting and historic scientific satellites. This paper reviews the flight history of the Scout, updating the comprehensive studies of a decade ago published in *Spaceflight* [1] and in this Journal [2] by Andrew Wilson. The story of the companion USAF Blue Scout vehicle may be found in Joel Powell's article in ***JBIS*** [3].

1. ORIGIN OF THE SCOUT

The basic Scout is a four stage, all solid propellant rocket, although three and five stage versions have also been used. Prime contractor for the vehicle is the ITV Corp, which was known as Chance Vought at the time of the initial development of Scout in 1958. Unlike the other main US satellite launch vehicles, which are based on the Atlas, Thor and Titan missiles, Scout was developed from the outset as a space rocket under contract for NASA. It grew out of a study at NACA's Langley Field in 1957, and after discussions between the newly formed NASA and the USAF in 1958, 'Scout' was announced in March 1959 as a joint NASA/Air Force launcher project [10]. The name was chosen by W. Stoney Jr. as a parallel to the 'Explorer' satellite series, many of which would ride Scouts to orbit [9]. Langley Field , now NASA Langley Research Center (LaRC), would manage the Scout program until 1990, when Goddard Space Flight Center was given the job. The first stage, the Aerojet Algol, was originally known as Aerojet Senior and was developed as part of the early Polaris submarine-launched missile development program. Its small relative, Aerojet Junior, was used as the first stage of the Astrobee 1500 sounding rocket. The Castor second stage is a descendant of the Sergeant missile, an early short range rocket developed originally by JPL. The Thiokol Corp. which later produced Sergeant developed the Castor and Pollux motors as improved versions. Pollux only saw very limited use, but Castor has been used in a huge variety of orbital and suborbital space programs. Today it is used as the strap-on motor for the Delta and Atlas IIAS launch vehicles, the second stage of Scout, and the first stage of the Strypi and Prospector sounding rockets. The Altair fourth stage has also seen wide use as an upper stage in the Thor Delta, Thor Burner 1, and Atlas/OV1 satellite launch vehicles and in the Javelin, Journeyman, and Shotput sounding rockets. Its original use was as an upper stage for the Vanguard launch vehicle in 1959. The third stage, Antares, is a scaled up version of Altair and has not been widely used outside the Scout program. Suborbital reentry missions have used a Cetus fifth stage to fire the reentry package back down in the atmosphere at high speed; this stage, also known as NOTS-17, was developed by the Naval Ordnance Test Station. One orbital flight also used a fifth stage, the Alcyone BE-3. This Hercules Inc. solid motor was originally developed as a soft landing motor for the Ranger Moon probes, and flew as apogee motors aboard the Vela surveillance satellites. Finally, a few military missions in the 1960's replaced the Altair with an M-2 upper stage, about which nothing has appeared in the open literature.

2. LAUNCHING A SCOUT

Scout vehicles have flown from all three US satellite launch sites, Launch Complex 18 at Cape Canaveral (CC) in Florida, Launch Area 3 at Wallops Island (WI) in Virginia, and Launch Complex D at Point Arguello (PA) in California, as well as Italy's converted oil rig platform off the coast of Kenya in the Indian Ocean, known as the San Marco (SMLC) Platform. In 1964 Point Arguello Naval Missile Facility became part of Vandenberg Air Force Base (VAFB) and PALC-D was later renamed Space Launch Complex 5. On an orbital mission, the first three stages fly suborbital trajectories and land in the ocean. Just before the third stage separates, the fourth stage and payload are spun up (spinning a spacecraft is the easiest way to stabilise its flight path). At about ten minutes after launch, as the third stage falls away, the Altair fires for about half a minute and the spacecraft/Altair combination enters Earth orbit. Shortly after fourth stage burnout, the spacecraft separates from the Altair and activation of its payload can begin.

3. DEVELOPMENT OF SCOUT

Over the thirty years of Scout operations, its useful payload has increased by almost a factor of four. The biggest leaps came with the introduction of the Algol IIIA first stage in 1972 and the Altair III FW-4S fourth stage in 1966. The original NASA Scout versions were given an X series version number, such as X-1, X-2, etc. A basic four stage version such as Scout X-3 could also fly with only the first two stages as the Scout X-3C, or as a five stage reentry test with the Cetus as the Scout X-3A. Each of the new X designations represented the replacement of one of the Scout X-1 stages with an improved version. The X-2 introduced the improved Antares II stage, the X-3 the Algol II first stage, the X-4 the Altair II fourth stage, and the X-5 the Castor II second stage.

Contemporary with the Scout X versions were the USAF Blue Scout vehicles. The Blue Scout II was the USAF version of the Scout X-1, while the Blue Scout 1 was effectively a Scout X-1C. There was also a Blue Scout Junior rocket, which used the second, third, fourth and fifth stages only. This and the related RAM-B rocket are not considered in this paper, which is confined to the Algol based vehicles. The Scout X-2M and X-3M launch vehicles, while apparently not officially Blue Scout configurations [3], may effectively be considered as Blue Scout successors. They were used exclusively for military payloads.

In August 1965 the launch of the Scout Evaluation Vehicle (SEV) ushered in the standard Scout vehicle. The Scout X-5

TABLE I: *Main Scout Versions*

Scout Type	First Stage	Second Stage	Third Stage	Fourth Stage	Fifth Stage
			Basic X Series [1]		
X-1	Algol IB/C	Castor I TX-33	Antares I -254	Altair IA X-248	Cetus NOTS-17
X-2	Algol IC/D	Castor I TX-33	Antares IIA X-259	Altair IA X-248	-
X-3	Algol IIA/B	Castor I TX-33	Antares IIA X-259	Altair IA X-248	Cetus NOTS-17
X-4	Algol IIA/B	Castor I TX-33	Antares IIA X-259	Altair IIA X-258	Cetus NOTS-17
X-5	Algol IIB	Castor IIA TX-354-3	Antares IIA X-259	Altair IIA X-258	-
			USAF Series		
BS I/BS II[2]	Algol I	Castor TX-33	Antares I X-254	Altair IA X-248	-
X-2M	Algol IC/D	Castor I TX-33	Antares IIA X-259	M-2	-
X-3M	Algol IIA/B	Castor I TX-33	Antares IIA x-259	M-2	-
X-2B	Algol ID	Castor I TX-33	Antares IIA X-259	Altair IIA X-258	-
			Standard Series		
A-1[3]	Algol IIC	Castor IIA TX-354-3	Antares IIA X-259	Altair IIA X-258	-
B-1[3]	Algol IIC	Castor IIA TX-354-3	Antares IIA X-259	FW-4S	-
D-1	Algol IIIA	Castor IIA TX-354-3	Antares IIA X-259	FW-4S	-
E-1/F-1[4]	Algol IIIA	Castor IIA TX-354-3	Antares IIB	Altair IIIA Star 20	Alcyone 1A BE-3
G-1	Algol IIIA	Castor IIA TX-354-3	Antares IIIA Star 31	Altair IIIA Star 20	-

[1] 5 stage versions called X-1A, etc; 3 stage versions called X-3C, etc.
[2] Blue Scout I is three stage version, Blue Scout II is four stage version
[3] Also A and B versions using Algol IIB
[4] E-1 is 5-stage version of F-1

became the Scout A (the only Scout X-5 to fly as such was an X-5C which flew much later on), but the SEV used the Scout B, which carried a UTC-built FW-4S fourth stage. This stage, also known as Altair III, had first flown aboard a Thor Burner I vehicle in May 1965, and its FW-4D version would replace the Altair II as the Thor Delta's final stage in 1966. Scout A and Scout B were used in parallel until 1971 when the Algol IIC first stage was introduced, converting them into the Scout A-1 and B-1. A new cycle of improvements followed in the mid 1970s, with the D-1 (Algol III first stage), the F-1 (Antares IIB third stage and Thiokol-built Altair III fourth stage, also known as Star 20 or TE-M-640), and finally the G-1, with a Thiokol Star 31 Antares IIIA third stage. After a decade in which the G-1 has been the standard variant, LTV is now planning a Scout II launch vehicle in collaboration with SNIA BDP of Italy. This would use Ariane strap on boosters to greatly increase the orbital capability.

4. FAILURES IN THE SCOUT PROGRAM

Every launch vehicle suffers occasional failures, and while Scout is now quite reliable, it suffered a large number of setbacks in its early years. Table 2 summarise the failures which are mostly described in more detail in [1]. The first launch, ST-1, was successful except that ground command problems meant that fourth stage ignition never happened [10,15]. The failure of ST-6 was due to problems in the separation of the dead Antares third stage after ignition of the Altair fourth stage; the S-55A satellite reached orbit and was named Explorer 13, but reentered after only three days. In the launch of the Dutch ANS satellite in 1974, the first stage flight was erratic but the satellite still reached orbit; however, it was an elliptical 266 x 1175 km orbit instead of the planned circular 510 x 560 km one, which caused some problems for the spacecraft. A similar problem befell Solrad 9 in 1968. In 1969, the launch of ESRO 1B was officially considered successful, but the Scout under performed significantly and the satellite ended up in a very low orbit which cut short its mission. The last twenty-three launches of Scout have been successful.

5. SCOUT FLIGHT HISTORY: SUBORBITAL LAUNCHES

Besides its use as a small satellite launch vehicle, Scout has been used for launching suborbital probe missions and reentry test missions. The first launch of a Scout class vehicle, Scout X on 18 April 1960, was a test of the Algol and Antares stag Dummy stages were carried in place of the Castor and Alt. The vehicle reached only 48 km; the Algol burned successfully but then the vehicle broke up [10,15]. The first couple of true Scout launches carried radiation measuring instruments to a height of several thousand km in the Earth's magnetosphere, but were mainly suborbital tests of the vehicle prior to the first orbital attempt. USAF Blue Scouts carried similar radiation

TABLE II: *Scout Failures*

Vehicle	Type	Date	Payload	Failure
ST-1	X-1	1960 Jul 2	ST-1	No Altair separation and ignition
ST-3	X-1	1960 Dec 4	S-56	Castor failed to ignite, no orbit
D-6	BS I	1961 May 9	Rad Probe	Castor off course, destoryed
ST-5	X-1	1961 Jun 30	S-55	Antares failed to ignite, no orbit
ST-6	X-1	1961 Aug 25	S-55A	Altair off course, low orbit
D-8	BS II	1961 Nov 1	MS-1	Algol off course, destroyed
D-7	BS I	1962 Apr 12	USAF RV	Castor failed to ignite
S111	X-2	1962 Apr 26	SR 4B	Antares failed, no orbit
S112	X-2M	1962 May 24	P35-1	Castor exploded, no orbit
S114	X-3A	1962 Aug 31	Reentry 2	Unknown failure
S119	X-3	1963 Apr 6	Transit VA-2	Altair failed, no orbit
S121	X-2M	1963 Apr 26	P35-4	Unknown failure, no orbit
S110	X-3A	1963 Jul 20	Reentry 3	Algol exploded
S132	X-2B	1963 Sep 27	P35-5	Antares orientation failed, no orbit
S128R	X-4	1964 Jun 25	ESRS	Castor exploded, no orbit
S151C	B	1967 Jan 31	OV3-5	FW4S exploded, no orbit
S152C	B	1967 May 29	ESRO 2A	Antares burnthrough, no orbit
S160C	B	1968 Mar 5	Solrad 9	Algol malfunction, wrong orbit
S172C	B	1969 Oct 1	ESRO 1B	Orbit too low
S189C	D-1	1974 Aug 30	ANS	Algol malfunction, wrong orbit
S196C	F-1	1975 Dec 5	DAD	Antares failure, no orbit

probes from Cape Canaveral. Some, perhaps all, of these USAF missions were in support of the Vela project to detect nuclear explosions from space. The D-3 launch carried thermal neutron detectors as well as thin films to study micrometeorites [4]. D-5 carried thermal neutron detectors, electrostatic analyzers and impedance probes to measure the ion and electron density, and emulsions to record high energy radiation. The experiments worked well except for the emulsions which were lost when the capsule recovery failed [4].

The SERT 1 Space Electric Rocket Test was an early suborbital test of an ion engine, which operated successfully during the 47 minute flight. The project was followed up with a Thor-launched orbital test, SERT 2, which was still operating in 1990 two decades after its 1970 launch.

NASA collaborated with the West German space agency DFVLR to launch the S166C probe mission which released barium ions high into the magnetosphere. The ions neutralise themselves by recombining with free electrons, releasing a characteristic glow as hey do so; they also travel along the direction of the local magnetic field. Hence, the barium cloud makes the shape of the magnetic field visible to the eye. This kind of experiment had long been carried out on sounding

TABLE III: *Scout Probe Missions*

Vehicle	Type	Data	Site	Payload	Mass (kg)	Apogee (Km)
X	X	1960 Apr 18	WI LA3	Cub Scout	0	48
ST-1	X-1	1960 Jul 2	WI LA3	NASA Radiation Probe		1380
ST-2	X-1	1960 Oct 4	WI LA3	USAF Radiation Probe	57	5600
D-3	BS I	1961 Jan 7	CC LC18B	USAF Radiation Probe/Capsule	178	1600
D-4	BS II	1961 Mar 3	CC LC18B	USAF Radiation Probe	78	2542
D-5	BS II	1961 Apr 12	CC LC18B	USAF Radiation Probe/Capsule	163	1900
D-6	BS I	1961 May 9	CC LC18B	USAF Radiation Probe	202	~30?
ST-7	X-1	1961 Oct 19	WI LA3	NASA/GSFC P-21 Ionosphere Probe		6855
ST-9	X-2	1962 Mar 29	WI LA3	NASA/GSFC P-21A Ionosphere Probe		6291
S124R	X-4	1964 Jul 20	WI LA3	NASA Space Electric Rocket Test	162	4002
S166C	B	1971 Sep 20	WI LA3	DFVLR Barium Ion Cloud		31600
S193C	D-1	1976 Jun 18	WI LA3	NASA Gravity Probe A		10230

TABLE IV: *Scout Reentry Test Missions*

Vehicle	Type	Date	Site	Payload	Mass (kg)	Apogee (km)
ST-8	X-1A	1962 Mar 1	WI LA3	NASA Reentry 1		214
D-7	BS I	1962 Apr 12	CC LC18B	USAF Reentry Test		
S114	X-3A	1962 Aug 31	WI LA3	NASA Reentry 2		217
S116	X-3	1963 May 22	WI LA3	AEC RFD-1		145
S110	X-3A	1963 Jul 20	WI LA3	NASA Reentry 3		0
S129R	X-4A	1964 Aug 18	WI LA3	NASA Reentry 4		183
S130R	X-3C	1964 Oct 9	WI LA3	AEC RFD-2	213	1300
S141C	X-4A	1966 Feb 9	WI LA3	NASA Reentry 4B	91	175
S159C	B	1967 Oct 19	WI LA3	NASA RAM C-1		217
S164C	X-5C	1968 Apr 27	WI LA3	NASA Reentry 5	260	175
S168C	B	1968 Aug 22	WI LA3	NASA RAM C-2	114	221
S171C	B	1970 Sep 30	WI LA3	NASA RAM C-3	135	269
S144CR	B	1971 Jun 20	WI LA3	Planetary Atmosphere Entry Test		

rocket missions, but never at such a high altitude.

The Gravity Probe A mission in 1976 was a pure physics experiment to test the Equivalence Principle which lies at the foundation of the general theory of relativity. The theory implies that clocks run at different rates in different strength gravitational fields; a hydrogen maser atomic clock flown aboard the Scout was compared with a clock kept on the ground, and the tiny difference was consistent with the predictions. A satellite mission called Gravity Probe B is now being planned to test a further prediction of general relativity involving a form of gravity analogous to magnetism. meanwhile, the Navstar navigation satellites incorporate the general relativity clock correction into their navigational signals as a matter of course.

The reentry missions were run by NASA LaRC, to study the aerodynamics of high speed reentry, an important component of preparations for the Apollo lunar missions. The third, fourth and fifth stages fired downward to accelerate the payload to velocities of 28000 km/h. Reentry 4 tested a phenolic nylon heat shield [11]. Reentry 5 carried a special 4m long sharply pointed General Electric nose cone made of beryllium; on that mission the fourth and fifth stages were omitted. The Atomic Energy Commission sponsored two Reentry Flight Demonstrations with dummy nuclear radioisotope generators to study the safety of such RTGs in a launch accident. The first mission used the normal 4-stage Scout and the second one used a three-stage Scout. Another series of reentry tests were carried out under the RAM (Radio Attenuation Measurements) programme, which addressed the problem of communications blackouts during reentry. These are due to the dense, highly ionised plasma that surrounds a reentering spacecraft, which is almost opaque to radio waves. C-1 injected water into the surrounding plasma to try and make it more transparent to radio; C-3 added freon to the mixture. C-2 measured the electron density variations around the nose cone [12]. The RAM A and B series of flights had been carried out with smaller rockets before the three RAM C flights using Scout occurred; the earlier military D-7 flight was also intended to measure radio transmissions through the reentry plasma sheath [4] but the vehicle failed.

NASA Ames Research Center's Planetary Atmosphere Entry Test (PAET), launched in 1971, was a simulated planetary probe, launched down into the Earth's atmosphere carrying instruments to determine its composition and structure, with a special experiment to measure the water vapour profile in the atmosphere. Later that decade, Ames' Pioneer Venus project would make the first entries by American probes into the atmosphere of Venus; PAET was a test of this type of mission.

6. SCOUT FLIGHT HISTORY: ORBITAL LAUNCHES

6.1 NASA Payloads

The first Scout orbital payloads were experiments by NASA's Langley Research center - the S-55 micrometeoroid satellites and the S-56 balloon satellites which were used to measure air density. The third S-55 mission, renamed Explorer 16 on reaching orbit, was the first to be successful, transmitting for seven months. It carried five different kinds of micrometeor sensors; at this early stage of space research, the flux of small particles of dust in near-Earth space was very uncertain and the early experiments often gave spurious and conflicting results. A fourth mission, Explorer 23, operated for twenty months in 1964-1966.

The story of the balloon satellites is given in detail in [5]. Briefly, they consisted of metal cylindrical canisters containing a 12-foot plastic balloon which was ejected and inflated once in orbit. The balloon was essentially passive, visual tracking of the decay of its orbit from the ground providing information about variations in air density in outer space. Some of the balloons carried radio transmitters to aid in orbit determination. The first two balloons were launched in the Beacon program using Juno launch vehicles; both failed to orbit, as did the first S-56 launch on a Scout [10]. However S-56A reached orbit to become Scout's first satellite, Explorer 9, and S-56B became Explorer 19. S-56B was also called Air Density Explorer 9, as NASA phased out the S series nomenclature for scientific satellites. The remaining satellites in the series, Air Density Explorers B and C (Explorer 24 and 39), were launched in tandem with the University of Iowa's Injun 4 and 5 (Explorer 25 and 40) radiation study subsatellites operated by James Van Allen's group. A final pair of more sophisticated balloon satellites, Dual Air Density Explorers A and B, also carried mass spectrometers to study atmospheric composition. They would have become Explorers 56 and 57 had their dual launch on Scout

S196C reached its intended 400 x 1500 km 90-degree polar orbit, but the flight was a failure [14].

The first orbital Mercury spaceship, John Glenn's Friendship Seven, was being prepared for launch at the end of 1961, and the Mercury Scout 1 rocket was to place a small radio transmitter in orbit to act as a practice tracking target for the worldwide net of spacecraft trackers that had been deployed to support the Mercury missions. Unfortunately this launch, the only orbital attempt by the Blue Scout, ended in failure shortly after liftoff.

NASA's Goddard Space Flight Center in Maryland has been responsible for many of NASA's space science satellites. Their first Scout payload was the Topside Ionospheric Sounder (Topsi), named Explorer 20 on achieving orbit. This satellite carried a radio beacon whose signals passed through the ionosphere to stations on the ground; studies of the change in frequency of the signal allow the electron density in the ionosphere to be measured. The satellite operated from August 1965 to July 1966. It was succeeded by the S-66 series of Beacon Explorers which carried a Transit type radio beacon and instruments to measure the ionospheric properties in situ, as well as corner reflectors for laser ranging. The laser ranging experiments could be used to determine precise distances between two points on the Earth which could see the satellite at the same time. The first S-66 was a Delta launch failure, but two others, Beacon Explorers B and C, also known as Explorers 22 and 27, were launched successfully by Scouts, one operating for five years and the other for almost twenty.

NASA's next project for the Scout was the Orbital Frog Otolith satellite [9]. This was the first NASA Scout scientific satellite not to be part of the Explorer program, probably because it was a life sciences payload. The satellite carried a centrifuge containing two bullfrogs (*Rana castebianca*); this Frog Otolith Experiment studied the adaptation of the balance sensors in the frogs' inner ears to free fall. The frogs were killed at the end of the experiment. The final stage Altair rocket carried the Radiation-Meteoroid package, which consisted of two experiments, one to measure on-orbit radiation dose and the other to measure meteoroid fluxes. The final Scout satellite to study the meteoroid environment was the Meteoroid Technology Satellite, Explorer 46, which carried 'bumpers' to dissipate the impact energy of the particles. This multiple-layer defense concept turns out to be an effective way to protect a spacecraft from small impacts.

1970 saw the beginning of a series of important astronomical satellites launched by Scout. The first Small Astronomical Satellite, Explorer 42, was orbited from San Marco. To honour the launch host country of Kenya, the satellite was renamed Uhuru - Swahili for 'freedom'. The Uhuru satellite performed the first survey of the sky in x-rays, discovering many x-ray binary stars, supernova remnants, and a number of quasars. It was turned off in March 1973. Its successor, SAS 2, was the first successful gamma ray astronomy satellite, operating from November 1972 to June 1973. SAS 3 went back to x-rays, defining the location of galactic x-ray sources more accurately. SAS 4 was planned as an ultraviolet satellite, but the project became ambitious enough that the first 'S' was no longer appropriate, and it was renamed the International Ultraviolet Explorer and launched on a Delta.

The Small Scientific Satellite, Explorer 45, was intended to be the first of a series of standard cheap satellites for space science research, but was the only one in the series. Among its experiments were electron, proton and alpha particle detectors and electric and magnetic field sensors; it operated from November 1971 to September 1974. In 1974 another small space science satellite was orbited; Hawkeye 1 (Explorer 42) was also the sixth Iowa Injun satellite, launched to study a polar neutral point in the Earth's magnetic field. The Alcyone fifth stage ignited to change the orbit from an 800 km apogee to a 127000 km one, letting it probe the region of space where the Earth's magnetosphere ends and the solar wind begins. It reentered in April 1978, transmitting data until the last few days in orbit.

With the increased emphasis on short-term applications of space technology in the 1970's, a new series of Applications Explorer Missions was flown. AEM-A was the Heat Capacity Mapping Mission, carrying a radiometer which mapped the Earth in the middle infrared (10 microns). The maps showed the heat emission from the Earth, which could be used to study variations in plant coverage and soil composition, as well as look for pollution sources and potential sources of geothermal heat [17]. AEM-B was the SAGE satellite, carrying the first Stratospheric Aerosol and Gas Experiment. This radiometer was pointed toward the planet's horizon as it orbited, observing the stratosphere at optical and near infrared wavelengths to measure the concentrations of pollutants and ozone. AEM-C was the Magsat Global Magnetic Survey Mission, performing the most detailed mapping of our planet's near-surface magnetic field. The launch of Magsat saw the introduction of the Scout G-1 with the Antares 3 third stage, the Scout version still in service today. These Applications Explorer Missions, like all other Explorer missions from 1976 onwards, were not given Explorer numbers.

NASA Explorer missions in the 1980s suffered from elephantiasis, becoming more complex and more expensive, requiring launches by Delta and Shuttle. These missions also took a long time to come to fruition, and it was realised that there was a need for a continuing series of small, simple, dedicated missions that would provide training opportunities for young scientists and a supply of data for existing groups. Many space scientists find it depressing to spend their whole careers preparing for a single mission or experiment, even if an important one. The Small Explorer (SMEX) program has now been started to address this problem. Although the SMEX projects are still more expensive and longer duration than many scientists would like, they are clearly a step in the right direction.The first, SAMPEX, was launched by Scout in 1992. Initially it seemed that later SMEX missions would also use Scout, but in 1991 it was decided to fly them on the Pegasus launch vehicle instead.

6.2 Military Payloads

The Naval Research Laboratory has conducted an extensive program of solar studies from space since the V-2 launches from White Sands in the late 1940s. Monitoring solar activity is important for predicting aurora and ionospheric activity and corresponding disruptions to radio communications, beyond the interest of solar physics in its own right. The Solar Radiation series of satellites carried detectors to monitor the ultraviolet and x-ray output from the Sun. The first few in the series were carried piggyback with Transit navigation satellites on larger launch vehicles, except for the ill-fated Solrad 4B which flew on Scout. Solrads 8 through 10 were also Scout payloads launched in collaboration with NASA as part of the Explorer series (given Explorer numbers 30, 37 and 44). Solrad 8, part of the 1965 International Quiet Sun Year, studied the Sun at the low point of its 11-year sunspot cycle, operating for two years. Solrad 9, despite a perigee 300 km lower than planned, operated for almost six years before its attitude control failed. Solrad 10, which operated from 1971 to 1978, also carried more sophisticated instruments which studied variability and hard x-rays as well as looking at stellar x-ray sources.

Very little has appeared in the public domain about a series of five small classified military satellites launched by Scout in 1962-63. According to Charles Sheldon [6] they were known as the P35 series. The most probable explanation for them is that they were cloud cover monitoring satellites used to help in targeting spy satellites, early forerunners of the Defense Meteorological Satellite Program. Another possibility is that they were tests of the target vehicle for the SAINT antisatellite weapon; this target vehicle had been planned as a Scout payload. The SAINT program was cancelled shortly before the launches began, and it had been assumed that the target launches were scrapped; but Army suborbital antisatellite tests, Program 505, were underway on Kwajalein Island using Nike-Zeus rockets, and it is possible that the target satellites were transferred to this program.

The main series of military payloads launched by Scout are the US Navy's Transit navigation satellites. The world's first navigation satellite system is still in use; the system uses the doppler shift in the satellites' radio beacons to determine the velocity of the satellites relative to the user, which together with a knowledge of the satellites' orbits leads to the user's position. The program began with test satellites launched on Thor-based launch vehicles to do basic research and development. By 1962 an operational design had been worked out, and three Transit 5A operational prototypes were prepared for launch. The satellites carried the Transit beacon, solar panels for power, and a long extendable boom to orient the satellite by the gravity gradient method (a long thin satellite will remain oriented with its long axis pointing to the center of the Earth). The first payload suffered a communications failure only hours after launch, and the second failed to reach orbit, but VA-3 was the first successful gravity gradient stabilised satellite and was still healthy seven years later. The next few Transits, the heavier Transit 5BN series with radioisotope generators instead of solar panels, were launched on Thor Ablestar. Transit VC, the final operational prototype, was launched by Scout and transmitted for 14 months, but the first five operational satellites were moved back to the Thor Ablestar because of all the Scout failures. The sixth and all subsequent Transit satellites were launched on Scouts.

The nomenclature for Transit becomes rather confusing at this point; the sixth satellite is Navy Navigation Satellite O-6; O stands for Operational, but in the aviation phonetic alphabet ('Alpha, Bravo, Charlie,...') the letter O is read as 'Oscar', and so O-6 is often referred to simply as Oscar 6. There is however another OSCAR 6 satellite, an amateur radio satellite, where OSCAR stands for Orbiting Satellite Carrying Amateur Radio, and this has often led to confusion, so it is worth emphasising that the Transit Oscar satellites have no relation at all to the amateur radio OSCARs. Finally, O-6 is also known as NNS 30060; the nature of the 30000 series numbers is obscure to me. The first few Oscars were built by the Johns Hopkins University Applied Physics Lab (APL) in Maryland, which also built the Beacon Explorers using the same bus, but later ones were built by RCA Corp. The Oscars launched in the late 1960s were so successful, O-12, O-13 and O-14 all operating in to the 1980s, that a large number had to be placed in storage on the ground. In the early 1980s it was decided that it would be cheaper to launch them and store them on orbit until needed. This was known as the SOOS (Stacked Oscars on Scout) program in which eight satellites were launched in pairs between 1985 and 1988.

A number of the surplus Oscars were also converted for other missions. Oscar 11 had a Trident SATRACK targeting experiment added to its navigation payload; after launch in 1977 SATRACK operated for seven years; O-11 then entered operational service as a Transit satellite in 1984. It was known as TRANSAT (Transit + SATRACK). Three Oscars were modified for ionospheric studies. Oscar 15's transmitter was altered to provide a continuous beacon without navigation information, and launched as part of the Defense Nuclear Agency's WIDEBAND progam to study the effects on radio transmissions of plasma phenomena in the polar ionosphere. As part of the USAF Space Test Program, the satellite was renamed P76-5. Oscar 16 also carried an ionospheric beacon, as well as a magnetometer, ultraviolet auroral imager, and particle detectors. It was renamed P83-1 and launched as project HILAT (High Latitude auroral studies) in 1983. Oscar 17, renamed P87-1 and known as Polar Bear (Polar Beacon Experiment and Auroral Research) flew in 1986 to continue the studies. All the Oscars have now been launched (up to O-32) except O-21 and O-28 which remain in storage. Oscar 22 was destroyed in a ground experiment in 1992; the fate of Oscar 26 is unknown.

In 1972 work began to upgrade the Transit system; the first Transit Improvement Program satellite was Triad, also designated OI-1 (Oscar Improved). This had a special damping device to improve gravity gradient control and a nuclear RTG for power. The other two TIP satellites, TIP 2 and 3, were solar powered and had small engines to raise their initial orbits. Both failed due to problems with the solar panels, but nevertheless a similar design was adopted for the operational improved Transits, which were renamed Nova. 3 RCA-built Nova satellites were launched in the 1980s.

The US Air Force Cambridge Research Laboratories (AFCRL, later the USAF Geophysics Lab at Hanscom AFB, Massachusetts), like the Naval Research Lab in Washington, Has been heavily involved in space science research since the dawn of the space age, sponsoring many USAF sounding rocket missions and satellite experiments. It built two dedicated satellites to study the upper atmosphere and ionosphere, known as the Geophysics Research Satellite and the Environmental Sciences Research Satellite. The payloads carried atmospheric composition experiments and electron, ion and micrometeorite detectors. The first reached orbit but transmitted for only a day; the second was lost due to a Scout failure. Two follow on satellites, Atcos 1 and Atcos 2, were launched in 1967; the first was a failure, but the second was a success at last, operating for over a year. It investigated the composition of the atmosphere and the number densities of various ions in the ionosphere.

When NASA launched its operational Scout test flight, the Scout Evaluation Vehicle, in 1965, the US Army Corps of Engineers took advantage of extra payload capacity to hitch a ride for its EGRS 5 geodetic satellite. The EGRS (Electronic Geodetic Ranging Satellite) series were tiny box shaped satellites carrying SECOR (Sequential Collation of Range) transponders which could be used by scientists on the ground to determine exact locations. EGRS 5 was the only one of the series of 14 to piggyback on a Scout.

The first four payloads in the OV3 series of satellites were built by Space General Corp for the USAF Office of Aerospace Research and launched between 1966 and 1967 to study the Earth's radiation belts. The first three studied energetic protons and electrons and the strength of the magnetic field; OV3-4 carried the PHASR (Personnel Hazards Associated with Space Radiation) experiment, measuring the radiation dose that humans would receive in the radiation belts [11]. The AFCRL Atcos satellites discussed above were also part of the OV3 series.

A new military Scout payload was built in the 1980's: the Avco Integrated Target Vehicle, a USAF inflatable balloon to be used for target practice by the F-15/ASAT antisatellite weapon. This weapon was launched from an F-15 fighter plane and flew a suborbital trajectory to impact the target satellite; no explosives were carried, the kinetic energy of the impact being

TABLE V: *Scout Orbital Missions*

Vehicle	Type	Date	Site	Payload	Mass (kg)	Orbit (km x km x deg)
ST-3	X-1	1960 Dec 4	WI LA3	S-56 Beacon	38	-
ST-4	X-1	1961 Feb 16	WI LA3	S-56A Explorer 9	35	634x2583x38.9
ST-5	X-1	1961 Jun 30	WI LA3	S-55		-
ST-6	X-1	1961 Aug 25	WI LA3	S-55A Explorer 13	62	125x1164x37.7
D-8	BS II	1961 Nov 1	CC LC18B	Mercury-Scout 1		-
S111	X-2	1962 Apr 26	PA LC-D	Solrad 4B		-
S112	X-2M	1962 May 24	PA LC-D	USAF Satellite		-
S117	X-2M	1962 Aug 23	PA LC-D	USAF Satellite		620x858x98.7
S115	X-3	1962 Dec 16	WI LA3	S-55B Explorer 16	72	750x1181x52.0
S118	X-3	1962 Dec 19	PA LC-D	Transit VA-1	58	698x725x90.6
S126	X-3M	1963 Feb 19	PA LC-D	USAF Satellite		510x789x100.5
S119	X-3	1963 Apr 5	PA LC-D	Transit VA-2	55	-
S121	X-2M	1963 Apr 26	PA LC-D	USAF Satellite		-
S120	X-3	1963 Jun 16	PA LC-D	Transit VA-3	55	724x757x90.0
S113	X-4	1963 Jun 28	WI LA3	AFCRL GRS	75	411x1311x49.7
S132	X-2B	1963 Sep 27	PA LC-D	USAF Satellite		-
S122R	X-4	1963 Dec 19	PA LC-D	S-56A Explorer 19	41	590x2934x78.6
S127R	X-3	1964 Mar 27	WI LA3	UK Ariel 2	68	389x1214x53.9
S125R	X-4	1964 Jun 4	PA LC-D	Transit VC	55	854x956x90.4
S128R	X-4	1964 Jun 25	PA LC-D	AFCRL ESRS		-
S134R	X-4	1964 Aug 25	V PALC-D	TOPSI Explorer 20	44	871x1018x79.9
S123R	X-4	1964 Oct 10	V PALC-D	S-66A Explorer 22	52	889x1081x79.7
S133R	X-4	1964 Nov 6	WI LA3	S-55C Explorer 23	110	466x977x52.0
S135R	X-4	1964 Nov 21	V PALC-D	ADE-B/Injun 4	65	525x2498x81.4
S137R	X-4	1964 Dec 15	WI LA3	San Marco 1	110	198x846x37.8
S136R	X-4	1965 Apr 29	WI LA3	S-66B Explorer 27	60	941x1317x41.2
S131R	B	1965 Aug 10	WI LA3	SEV/EGRS 5	20	1137x2426x69.3
S138R	X-4	1965 Nov 18	WI LA3	Solrad 8	86	704x891x59.7
S139R	X-4	1965 Dec 6	V PALC-D	FR-1	60	746x762x75.9
S140C	A	1965 Dec 21	V PALC-D	O-6 (NNS 30060)	59	909x1086x89.1
S142C	A	1966 Jan 28	V PALC-D	O-7 (NNS 30070)	59	861x1217x89.8
S143C	A	1966 Mar 25	V PALC-D	O-8 (NNS 30080)	59	891x1128x89.7
S145C	B	1966 Apr 22	V PALC-D	OV3-1	69	351x5741x87.5
S146C	A	1966 May 18	V PALC-D	O-9 (NNS 30090)	59	863x980x90.0
S147C	B	1966 Jun 9	WI LA3	OV3-4 PHASR	75	641x4718x40.8
S148C	B	1966 Aug 4	V SLC5	OV3-3	75	360x4492x81.4
S149C	A	1966 Aug 17	V SLC5	O-10 (NNS 30100)	59	1056x1101x88.9
S150C	B	1966 Oct 28	V SLC5	OV3-2	82	350x1597x82.0
S151C	B	1967 Jan 31	V SLC5	OV3-5 Atcos 1	95	-
S154C	A	1967 Apr 13	V SLC5	O-12 (NNS 30120)	59	1053x1083x90.2
S153C	B	1967 Apr 26	SMLC	San Marco 2	124	217x738x2.9
S155C	A	1967 May 5	V SLC5	UK Ariel 3	90	497x608x80.2
S156C	A	1967 May 18	V SLC5	O-13 (NNS 30130)	59	1074x1105x89.6
S152C	B	1967 May 29	V SLC5	ESRO 2A	66	-
S157C	A	1967 Sep 25	V SLC5	O-14 (NNS 30140)	59	1041x1116x89.3
S158C	B	1967 Dec 5	V SLC5	OV3-6 Atcos 2	95	412x439x90.7
S162C	A	1968 Mar 2	V SLC5	O-18 (NNS 30180)	59	1035x1139x90.0
S160C	B	1968 Mar 5	WI LA3	Solrad 9	90	513x881x59.4
S161C	B	1968 May 16	V SLC5	ESRO 2B Iris	66	334x1085x98
S165C	B	1968 Aug 8	V SLC5	ADE-C/Injun 5	79	670x2538x80.7
S167C	B	1968 Oct 3	V SLC5	ESRO 1A Aurorae	80	258x1538x93.8

TABLE V: *Scout Orbital Missions (contd.)*

Vehicle	Type	Date	Site	Payload	Mass (kg)	Orbit (km x km x deg)
S172C	B	1969 Oct 1	V SLC5	ESRO 1B Boreas	71	291x389x85.1
S169C	B	1969 Nov 7	V SLC5	Azur	71	387x3150x103.0
S176C	A	1970 Aug 27	V SLC5	O-19 (NNS 30190)	59	925x1221x90.0
S178C	B	1970 Nov 9	WI LA3	Orbital Frog Otilith/RM	153	304x518x37.4
S175C	B	1970 Dec 12	SMLC	SAS-1 Uhuru	143	522x563x3.0
S173C	B	1971 Apr 24	SMLC	San Marco 3	171	222x718x3.2
S177C	B	1971 Jul 8	WI LA3	Solrad 10	115	433x632x51.1
S180C	B-1	1971 Aug 16	WI LA3	Eole	84	677x904x50.2
S163CR	B	1971 Nov 15	SMLC	Small Scientific Sat. 1	52	233x26895x3.6
S183C	B-1	1971 Dec 11	V SLC5	UK Ariel 4	100	477x593x83.0
S184C	D-1	1972 Aug 13	WI LA3	Meteoroid Technology Sat.	151	492x811x37.3
S182C	B-1	1972 Sep 2	V SLC5	OI-1X Triad	94	716x863x90.1
S170CR	D-1	1972 Nov 15	SMLC	SAS-2	186	444x632x1.9
S185C	D-1	1972 Nov 22	V SLC5	ESRO IV	114	254x1173x99.1
S181C	D-1	1972 Dec 16	V SLC5	Aeros	127	223x867x96.9
S178C	A-1	1973 Oct 30	V SLC5	O-20 (NNS 30200)	59	895x1149x90.2
S190C	D-1	1974 Feb 18	SMLC	San Marco 4	170	231x910x2.9
S188C	D-1	1974 Mar 8	V SLC5	UK-X4 Miranda	92	714x916x97.8
S191C	E-1	1974 Jun 3	V SLC5	Hawkeye 1	27	513x26896x89.9
S186C	D-1	1974 Jul 16	V SLC5	Aeros 2	127	224x869x97.5
S189C	D-1	1974 Aug 30	V SLC5	Astronomische Nederlandse Satelliet	131	266x1175x98.0
S187C	B-1	1974 Oct 15	SMLC	Ariel 5	135	504x549x2.9
S194C	F-1	1975 May 7	SMLC	SAS-3	195	499x508x3.0
S195C	D-1	1975 Oct 12	V SLC5	TIP 2	94	582x820x90.4
S196C	F-1	1975 Dec 5	V SLC5	Dual Air Density A,B	176	-
S179CR	B-1	1976 May 22	V SLC5	P76-5 (O-15, WIDEBAND)	72	996x1060x99.7
S197C	D-1	1976 Sep 1	V SLC5	TIP 3	94	348x789x90.3
S200C	D-1	1977 Oct 28	V SLC5	O-11 (TRANSAT)	94	1069x1107x89.9
S201C	D-1	1978 Apr 26	V SLC5	Heat Capacity Mapping Mission	134	610x629x97.6
S202C	D-1	1979 Feb 18	WI LA3	SAGE	147	549x661x54.9
S198C	D-1	1979 Jun 3	WI LA3	Ariel 6	154	600x654x55.0
S203C	G-1	1979 Oct 30	V SLC5	Magsat	181	355x562x96.8
S192C	G-1	1981 May 15	V SLC5	NOVA 1 (NNS 30480)	120	1170x1189x90.0
S205C	D-1	1983 Jun 27	V SLC5	P83-1 (O-16, HILAT)	113	770x837x82.0
S208C	G-1	1984 Oct 12	V SLC5	NOVA 3 (NNS 30500)	120	1160x1200x90.0
S209C	G-1	1985 Aug 3	V SLC5	O-24 (NNS 30240)/ O-30 (NNS 30300)	118	1005x1262x89.8
S207C	G-1	1985 Dec 13	WI LA3	USA-13/USA-14	163	313x770x37.1
S199C	G-1	1986 Nov 14	V SLC5	P87-1 (O-17, POLAR BEAR)	125	976x1020x89.7
S204C	G-1	1987 Sep 16	V SLC5	O-27 (NNS 30270)/ O-29 (NNS 30290)	118	1017x1185x90.3
S206C	G-1	1988 Mar 25	SMLC	San Marco 5	237	262x619x3.0
S211C	G-1	1988 Apr 26	V SLC5	O-23 (NNS 30230)/ O-32 (NNS 30320)	118	1020x1310x90.3
S213C	G-1	1988 Jun 16	V SLC5	NOVA 2 (NNS 30490)	120	1154x1201x90.0
S214C	G-1	1988 Aug 25	V SLC5	O-25 (NNS 30250)/ O-31 (NNS 30310)	118	1035x1180x90.0
S212C	G-1	1990 May 9	V SLC5	MACSAT 1/MACSAT 2	140	612x768x86.9
S216C	G-1	1991 Jun 29	V SLC5	REX	85	773x874x89.6
S215C	G-1	1992 Jul 3	V SLC5	SAMPEX	158	515x690x81.7
S210C	G-1	1992 Nov 21	V SLC5	MSTI-1	157	331x443x96.8

enough to destroy the target. Two of the targets were launched on a single Scout, but Congress prohibited tests of the system and the program was later abandoned (One space test had already been carried out, destroying the P78-1 scientific satellite). The balloons were assigned the in-orbit names USA-13 and USA-14. In 1986 one of the balloons was ejected from its canister and inflated as a test of the system; both balloons have now reentered.

The new enthusiasm for 'lightsats' at the Pentagon resulted in the most recent two Scout launches. 1990 saw the launch of the dual MACSAT payload. These two small communications satellites, MACSAT 1 and 2, were built by Defense Systems Inc (DSI) of McLean, Virginia for the US Department of Defense. They were intended for experimental use as message relays but saw operational use in the 1991 Gulf War when they relayed logistics requests between the forces in Saudi Arabia and their headquarters in the USA. Finally, 1991 saw the launch of the REX (Radiation EXperiment) satellite, also built by DSI to a similar design. This USAF satellite is testing new communications equipment's resistance to a high radiation environment.

6.3 International Payloads

The first international satellite was the US/British UK-1, renamed Ariel 1 on reaching orbit. Ariel 1 was launched on a Delta, but all later Ariel satellites used Scout. Ariel 2, launched in 1964, had three experiments: a Meteorological Office experiment to study the distribution of ozone, a Manchester University experiment to measure the flux of micrometeorites, and a very low frequency radio astronomy experiment from Cambridge. It transmitted until it reentered in 1967. It was replaced by Ariel 3 which repeated the radio and ozone experiments and also studied radio propagation and the electron population in the ionosphere from its polar orbit until reentry in 1970. A year later Ariel 4 continued ionospheric investigations from polar orbit for another two years. Another British satellite launch was the Royal Aircraft Establishment's Miranda technology satellite, which between March and November 1974 tested an attitude control system, various horizon and star sensors, and solar cell performance. The remaining two Ariel satellites were used for astronomy; Ariel 5 made a detailed survey of the x-ray sources in the sky, and during its five year mission found that the small quasars known as Seyfert nuclei were strong sources of x-ray emission. This was the only Ariel to be launched from the Indian Ocean San Marco platform into equatorial orbit [18]. The last Ariel, launched in 1979, carried a large cosmic ray detector and a set of x-ray telescopes. Unfortunately the x-ray telescopes suffered a number of technical problems and the satellite did not return data of the quality that had been hoped for. It was shut down in 1982 and reentered in September 1990, ending the independent British scientific satellite programme.

The second international Scout programme was the San Marco project of Italy's Centro Richerche Aerospaziali (CRA). The San Marco satellites consisted of a spherical satellite connected to an outer shell with very sensitive accelerometers to measure the small pressures exerted by winds in the outer atmosphere and drag caused by moving through this atmosphere. The first two satellites also carried ionospheric beacons like Explorer 20; the next two carried instruments to measure the composition of the outer atmosphere and the fifth and last studied properties of the ionosphere. The Italian government also arranged to build a new launch site using two converted oil rigs in the Indian Ocean just off the coast of Kenya. One rig served as the control center while the second carried the pad itself. Originally intended as a mobile launch site, it has in fact remained in its initial location, which has the advantage of being very close to the equator, allowing maximum use of the Earth's rotational velocity during launch. The site was not ready for Scout launches in time for San Marco 1, launched from Wallops in 1964, but San Marco 2 to 5 used the site, as did several NASA satellites.

The FR-1A satellite was launched for France's Centre National d'Etudes Spatiales in December 1965; it studied very low frequency waves in the magnetosphere. At one point it looked as if FR-1A would be the first French satellite, but national pride was satisfied with the successful launch of the A-1 satellite by a French rocket from Algeria a few weeks earlier. Despite having its own launch vehicle, France continued to cooperate with both the USSR and the USA; it launched another satellite with the Scout in 1971, the experimental Eole satellite which collected weather information from balloons and relayed it to a central facility (Eole was originally called FR-2; there was also an FR-1B ground spare for the first satellite).

The first launches of the European Space Research Organisation (ESRO, one of the predecessor organisations of ESA) were also carried out using the Scout. These satellites were dedicated to space science research; the ESRO 2 satellites were ready before ESRO 1. The ESRO 2A launch failed, but ESRO 2B succeeded. The satellite, renamed Iris, studied solar x-rays, cosmic rays, and energetic particles in the magnetosphere, from 1968 to 1971. ESRO 1A and ESRO 1B (Aurorae and Boreas) studied polar ionospheric and auroral phenomena. Unfortunately Boreas' low orbit gave it a very short life. ESRO 4 studied the composition of the atoms and ions in low orbit, as well as the fluxes of auroral and solar particles.

The next European national programme to use the Scout was West Germany's. Their Germany Research Satellite Azur operated for seven months, also contributing to studies of the aurora and the inner magnetosphere [7]. This was followed by two Aeros satellites which studied the atmosphere and ionosphere between 1972 and 1975. These satellites marked the first use of the ground control center at Oberpfaffenhofen now used for many ESA satellites.

The Astronomische Nederlandse Satelliet (ANS, or Astronomical Netherlands Satellite) was a joint project between NASA and the Dutch NIVR agency to orbit a collection of ultraviolet and x-ray telescopes. The ultraviolet telescope produced a useful catalog of hot stars, despite the Scout malfunction that put the satellite in an elliptical orbit instead of the planned 510 x 560 km one. The high radiation background in this orbit caused problems for the x-ray telescopes on board [13].

With the formation of ESA and the development of the Ariane launch vehicle, European countries have moved towards larger satellites and away from using US launch vehicles. Other nations have not filled the gap for Scout, since the trend has been for them to concentrate on developing their own Scout-class launchers (Japan in 1970, India in 1970, and Israel in 1988).

8. THE FUTURE OF SCOUT

After a decade in which it looked as if Scout would soon be retired, the new small satellite projects of the 1990s offer an opportunity for rejuvenating the launch vehicle. However, Scout faces new challenges from commercial competitors. The most serious of these is Pegasus, the winged rocket launched from an airplane. Pegasus is cheaper and has attracted a lot of orders, but it is too early yet to know if it will prove to be a reliable rocket. The Ukrainian Kosmos rocket, based on the R-14 IRBM, is known to be reliable and is also cheap, but political instability both within the former Soviet Union and in its relations with the West may discourage potential users. The Ariane Structure For Auxiliary Payloads, used to carry small satellites piggyback on polar Ariane missions, does not have the flexibility offered by a dedicated launch vehicle. Other potential competitors exist but have not yet flown. Scout's familiarity and demonstrated reliability may allow it to retain an important sector of the small launcher market, and with the thrust augmented Scout 2 promising to fill a gap in the intermediate payload range, it may continue its role in space history in to the next millennium.

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