US MILITARY ACTIVITES IN SPACE - 1986

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1. INTRODUCTION

1986 was a bad year for the US space effort, and military projects were hit particularly hard. A number of key programmes were set to make the transition to the Shuttle in 1986, following the first two dedicated military flights in 1985. Of a total of 14 Shuttle missions scheduled for 1986, five were to carry military payloads. The destruction of the Shuttle Challenger on 28 January put an end to these plans.

As the investigation into the accident progressed it became obvious that flights would not resume until well into 1988. To make matters worse, when flights did resume there would be only three orbiters, so their frequency would be much reduced. Also, there had been doubts for some time that the quick turnaround anticipated for the Shuttle would ever be achieved in practice.

This left the Department of Defense (DoD) with a major problem. The delay and the reduction in flight rate meant that a backlog of payloads to be launched would soon build up, with little possibility of it being cleared for as much as a decade. It was not feasible to transfer them to expendable launchers because many were designed specifically for the Shuttle, and were too heavy or too big for other types of vehicle. In any case, almost all of the expendable launchers the DoD had in its inventory already had payloads allocated to them, and their production lines were being closed down.

As luck would have it, the DoD had taken steps to provide a limited back-up for the Shuttle in March 1985, when Martin Marietta were contracted to produce ten Titan 34D-7s, known as Complementary Expendable Launch Vehicles. They will have a similar capacity to the Shuttle, but are intended only for launches to synchronous orbit. It was also decided to refurbish 13 Titan 2 missiles for launching smaller payloads to polar orbit.

On 31 July the DoD announced details of its recovery plan. This had three main features - storage of payloads and stages whose launch had been delayed, redesign of critical payloads to make them compatible with expendable launchers, and acquisition of additional launchers. The Titan 34D-7 order was increased to 23, with some to be launched from Vandenberg Air Force Base for polar orbit missions. Another 12 boosters, of a new design to be called the Medium Launch Vehicle (MLV), will be procured for the Navstar programme. By 1990 the DoD expects to be launching each year up to four Titan 34D-7s and four MLVs from Cape Canaveral, plus two Titan 34D-7s and two Titan 2s from Vandenberg [1].

In August President Reagan gave the go-ahead to build a new Shuttle orbiter to replace Challenger, and its first flight is expected in 1992. It will be based at Vandenberg and be used exclusively for polar orbit missions. In October NASA published a new Shuttle schedule, showing the first flight in February 1988, and a further four flights in the year, followed by ten flights in 1989.

While NASA was investigating the Challenger accident, the USAF was trying to solve an equally serious problem. Unlike the pads at Cape Canaveral, the Shuttle facility at Vandenberg has an enclosed exhaust duct. It was feared that large amounts of gaseous hydrogen, vented from the Shuttle, could accumulate there. This would, of course, be highly explosive. By August the USAF believed that it had a solution, but it decided to put the facility into "operational caretaker" status as soon as it was finished, awaiting the arrival of the new orbiter.

By the end of 1986 it was becoming doubtful whether the use of lightweight filament wound cases for the solid rockets would be approved in the light of the Challenger failure. There was also the possibility that the Shuttle's main engines might be restricted to 104% of their rated power [2]. Polar missions are planned to use the lightweight cases and 109% power, so any restrictions would put the Shuttle's capacity below the requirements of some Vandenberg flights. The site's future as a Shuttle base is therefore uncertain.

Launches of expendable boosters resumed on 5 September, with a highly complex mission for the SDI Organisation. One civil and two more military flights were successfully completed by the end of the year. A total of nine defence payloads were launched in 1986, certainly less than had been originally planned, but not quite as low as the levels of 1981 and 1982.

This paper reviews the DoD's activities in space in 1986, and follows earlier reviews covering 1983, 1984 and 1985 [3,4,5]. Activities are divided into ten principal categories, with the status at the start of the year and events during the year discussed for each. Future plans are also considered. Orbital data is included for those vehicles for which it has been released. A table at the end of the review gives details of DoD payloads launched in 1986.

2. PHOTO RECONNAISSANCE

Since 1984 all photo reconnaissance has been carried out by KH-11 satellites. The normal mode of operation is to have two satellites in sun-synchronous orbits, one making its observational passes at about 10am local time, and the other at about 1pm. When a satellite reaches the end of its life it is de-orbited, and a replacement launched within a week or two. The most recent KH-11 launch, to fill the "afternoon" slot, came on 28 August 1985, but failed a few minutes after liftoff. Consequently, at the start of 1986 photo reconnaissance coverage was being provided by a solitary "morning" satellite.

Photo Reconnaissance Satellites at 1 January 1986

Satellite	Months in Orbit
1984-122A	13

A new satellite was obviously required, and a Titan 34D was launched on 18 April, but 8½ seconds after liftoff the vehicle exploded, showering debris over a wide area. Extensive damage was caused to its pad (SLC-4E), and lesser damage to its neighbour (SLC-4W). The time of launch, 10:45 PST, would have resulted in observational passes at about 10:30 local time. The satellite was not therefore simply a replacement for the August 1985 failure, which was launched at 13:20 PST and would have made its passes at about 13:05 local time.

It was later reported that the launch had carried a Big Bird satellite rather than a KH-11 [6]. This was the last one of its class, and it appears to have been some sort of qualification or ground test vehicle which was pressed into service. Subsequent investigation attributed the loss to de-bonding of thermal insulation in one of the Titan's solid rocket motors, although the exact cause could not be found.

The failure placed the DoD in a very awkward position. It was dependent on one reconnaissance satellite in orbit, and this could provide only part of the coverage usually available. It will be some time before the Titan 34D is cleared for flight again, and with a production rate of only seven vehicles in nine years it is uncertain when a replacement KH-11 will be ready. U-2 and SR-71 aircraft operations are being expanded to help conserve consumables on the KH-11 in orbit and prolong its life as much as possible.

The principal improvement the KH-11 has over its predecessors is the use of digital imaging and transmission. This, in conjunction with relaying the data through communication satellites, enables images to be available for analysis within an hour or two of them been taken. Unfortunately the technique produces much poorer resolution than was achievable with earlier types of reconnaissance satellite. The KH-12 is an upgraded version of the KH-11, intended to provide the same resolution as earlier types while still using the digital imaging technique. Intended for launch on the Shuttle, KH-12 is designed to be refuelled in orbit, and retrieved and brought back to Earth for refurbishment.

Work started on KH-12 in the mid 1970s, as the first KH-11 was entering service. During development the spacecraft weight grew from 12 tonnes to 14½ tonnes, taking it beyond the Shuttle's capabilities [7]. A number of ways of augmenting the Shuttle's performance were examined, such as extra solid rockets and adding a liquid propellant rocket package, but the ultimate choice was filament wound cases for the Shuttle's solid booster rockets. Work began on this in 1982, and the first Shuttle launch from Vandenberg AFB, scheduled for March 1986, was to be the first to use the filament wound cases. The second launch, mission 62-B in September, would carry the first KH-12.

The loss of Challenger delayed Vandenberg Shuttle launches until 1992 at the earliest. The KH-12 is too heavy for the Titan 34D, whose capacity is only 12½ tonnes, so it will have to wait for the Titan 34D-7, but the first Titan 34D-7 launch from Vandenberg is not scheduled until 1989.

As an interim measure the DoD decided to launch KH-12s from Cape Canaveral as soon as Shuttle flights resume [8]. The maximum inclination available from there is 57°, against the 96° normally used from Vandenberg. This would restrict the coverage to latitudes up to 57°N, cutting out parts of the northern Soviet Union. Potentially more important is the fact that the orbit will no longer be sun-synchronous, so lighting conditions will vary during a flight. However, the KH-12 will reportedly employ thermal infra-red sensors, allowing it to gather data regardless of sun angle [9]. IR sensors do have much lower resolution than optical ones, however.

When NASA finally published its launch schedule following the Challenger loss the third flight (STS-28), to be launched in July 1988, was reserved for a KH-12.

3. EARLY WARNING

Missile early warning is carried out by Defense Support Program (DSP) satellites in synchronous orbit. The system requires three operational satellites, stationed at 70°W, 134°W and 69°E, plus a number of in-orbit back-ups.

In supporting documentation for its FY82 budget request the DoD stated that it planned one more DSP launch on a Titan 3C, one on a Titan 34D/Transtage, and one on a Titan 34D/IUS. All subsequent launches would use the Shuttle. The Titan 3C launch came on 6 March 1982, and the Titan 34D/Transtage on 14 April 1984 (or possibly 22 December 1984). The Titan 34D/IUS launch was planned for the late summer of 1985, but it was postponed following the KH-11 failure on 28 August, which also used a Titan 34D. At the start of 1986 it was scheduled to go in February [10].

The first Shuttle DSP launch was set for mission 71-B in December 1986. It was to carry the first of the new generation Sensor Evolutionary Development (SED) spacecraft. DSP satellites detect missile launches by sensing the IR radiation produced by missile exhausts, and SED satellites have greatly improved IR sensors. Their focal planes are modified to operate at two wavelengths to prevent jamming by ground-based lasers, and their sensitivity is enhanced to provide better discrimination between different types of missile. The satellites also have better on-board computers and more powerful sensors to detect nuclear explosions in space. Externally, SED satellites are characterised by longer cylindrical equipment sections than earlier versions [11].

The status of the satellites in orbit at the start of 1986 was not clear. The imminence of the Titan 34D/IUS launch indicated that the DoD wanted to replace one of them, but the pace of its preparations suggested that they were operating satisfactorily for the moment. A reasonable assumption is that the three operational and two back-ups which had been in use the previous year were still functioning.

Early Warning Satellites at 1 January 1986

Satellite	**Months in Orbit**
1977-07A	107
1979-53A	79
1981-25A	57
1982-19A	46
1984-37A	20

The delay in launching the Titan 34D/IUS satellite resulted in problems early in 1986 with the payload itself, but these were solved and the launch reset for April or May [12]. When the Big Bird launch failed on 18 April the DSP flight was again put off until the cause of this was found. The failure was traced to the Titan's solid rocket boosters, but uncertainties over the state of the boosters on the DSP launcher led the USAF to roll the whole vehicle back from the pad at Cape Canaveral in July and de-stack it. The motor segements were checked out, and the launch is now expected in early 1987.

The Challenger loss set back plans for the Shuttle DSP mission, but when NASA's new launch schedule was published in October 1986, the DSP was set for the second flight, STS-27, in May 1988.

4. ELECTRONIC INTELLIGENCE (ELINT)

4.1 The Subsatellite Programme

Routine monitoring of communications and radar has traditionally been performed by small ELINT subsatellites ejected from photo reconnaissance satellites. They have used two types of circular orbit, one at 600km to 700km altitude, and the other at 1300km to 1400km.

The subsatellites do not manoeuvre, and have relatively long lives before decaying from orbit. Because of this there is no simple way of telling which subsatellites are operational. Previous reviews considered only those which had been in orbit less than five years to be operational. Their status at the start of 1986 would then be:

ELINT Subsatellites at 1 January 1986

Satellite	Orbit	Months in Orbit
1982-41C	low	44
1983-60C	high	30
1984-65C	low	18

KH-11 photo reconnaissance satellites have never carried ELINT subsatellites, and their missions seem to have ceased with the end of the Big Bird programme. The most likely explanation is that electronic monitoring is now performed by the KH-11s themselves. Indeed, the orbits currently used by the KH-11s are more like the low ELINT subsatellite orbits than those of earlier classes of photo reconnaissance vehicle.

4.2 Synchronous Orbit Programmes

The 1985 review noted that the Rhyolite synchronous orbit ELINT satellites had all ceased operating by the start of that year, and the only operational ELINT satellites at that time were the most recent three Chalet vehicles. During 1985 the first of a large new type of ELINT satellite, code named Magnum, was launched on Shuttle mission 51-C. It is assumed here that these four were still operational at the start of 1986.

ELINT Satellites at 1 January 1986

Satellite	Months in orbit
1979-86A	75
1981-107A	50
1984-129A	12
1985-10B	11

The DoD has always been very secretive about its ELINT activities, and its plans were not at all clear at the start of 1986. Magnum has an in-orbit mass three times as large as a Chalet, giving it a substantially greater payload for monitoring equipment. It is also a much more recent design, so a reasonable assumption was that the Chalet class would be phased out. Two military Shuttle missions were planned from Cape Canaveral for 1986, and while one (71-B) was known to be for a DSP, no mission had been reported for the other (61-N). A second Magnum was therefore a possibility, although a pair of DSCS communication satellites did seem more likely.

However, Chalet spacecraft are launched by Titan 34D boosters, and there were seven of these still in the inventory at the start of 1986, all with payloads allocated. One would be used for the Big Bird, another for a DSP, and possibly two or three for KH-11s. The remaining two or three can only be for Chalet satellites. The most recent Chalet launch was in 1984, and the last Titan 34D is to go in late 1988. This suggests that Chalet launches might have been planned for 1986 and 1987, and perhaps 1988.

There is only one Titan 34D pad at Cape Canaveral, Pad 40, and the DSP vehicle occupied this for almost a year, until July 1986 (see section 3). No Chalet launch was possible while the DSP was on the pad, and the delays the DSP suffered now make its launch all the more pressing. A Chalet launch cannot therefore be expected before the summer of 1987.

5. OCEAN SURVEILLANCE

Ocean surveillance is carried out by clusters of subsatellites in 1100km orbits. The programme, code named White Cloud, had achieved six successful launches and one failure by the start of 1986. Each cluster consists of three small subsatellites which are dispensed from the "parent" spacecraft over a period of weeks following orbital insertion. At the begining of the year there were four operational clusters.

Ocean Surveillance Satellites at 1 January 1986

Satellite	Subsatellites	Months in orbit
1980-19A	C, D, G	70
1983-08A	E, F, H	35
1983-56A	C, D, G	31
1984-12A	C, D, F	23

A new launch had been expected in 1985, but did not occur until 9 February 1986. No orbital elements were released for it, but calculations based on the time of launch (2:06 PST) show it was a straight replacement for the 1983-56 cluster. In line with the DoD's current policy, the "parent" satellite was named simply USA-15. Two and a half weeks later two subsatellites, USA-16 and USA-17, were dispensed, followed a week later by the third, USA-18.

In the past, reports of White Cloud flights have always claimed that the launchers used were refurbished Atlas F missiles. It is now known that, while this was the case for the first launch, subsequent ones have used Atlas H vehicles. In fact, the Atlas H seems to have been used solely for White Cloud flights. The main difference between the F and H versions is the size of payload that can be carried. Quoted capabilities to low Earth orbit are 1360kg for the Atlas F and 2000kg for the Atlas H [13].

Following the 9 February launch there is only one Atlas H left, and the production line has been shut down. Subsequent launches will apparently use refurbished Titan 2 missiles, but under current planning these will not start until 1990. This suggests the next White Cloud launch, using the last Atlas H, will be in 1988, followed by the first on a Titan 2 in 1990.

6. WEATHER MONITORING

Weather monitoring is performed by the Defense Meteorological Satellite Program (DMSP), which employs two satellites in sun-synchronous orbit. The programme has been operating since 1965, and has gone through a number satellite upgrades. The two DMSP satellites in use at the start of 1986 were the first and second Block 5D-2 vehicles:

Weather Monitoring Satellites at 1 January 1986

Satellite	Perigee (km)	Apogee (km)	Incl (°)	Period (min)	Months in Orbit
1982-118A	813	825	98.7	101.3	36
1983-113A	813	832	98.7	101.4	25

The satellites were providing complementary coverage, with 1982-118A making its observational passes at about 6:23 local time and 1983-113A at about 10:05.

The design life for the 5D-2 version is three years, so a launch had been expected in 1985. It is possible that one was planned for early 1986 but was delayed following the Delta failure in May - Block 5D-2 satellites use Atlas E launchers, which have similar engines to Delta first stages. When Atlas launches resumed later in the year, NOAA 10 (launched 17 September) took precedence.

No new DMSP mission materialised in 1986, but one must be expected soon. There are seven Block 5D-2 vehicles left, and all are planned to be launched by 1990, when the first Block 5D-3 flight will begin.

7. COMMUNICATIONS

7.1 Defense Satellite Communications System

The Defense Satellite Communications System (DSCS) provides high volume, high data-rate links between large, fixed ground stations. At the start of 1986 there eight operational DSCS satellites (four prime and four back-up), and two more being deployed.

DSCS Satellites at 1 January 1986

Name	Satellite	Perigee (km)	Apogee (km)	Incl (°)	Period (min)	Station	Months in Orbit
Prime							
II-12	1978-113B	35,781	35,790	3.8	1435.9	60°E	84
II-13	1979-98A	35,780	35,788	2.9	1435.9	175°E	73
II-14	1979-98B	35,779	35,793	3.0	1436.0	12°W	73
III-1	1982-106B	35,770	35,801	0.1	1435.9	135°W	38
Back-Up							
II-4	1973-100B	35,783	35,794	7.3	1436.1	66°E	144
II-8	1977-34B	35,776	35,791	4.9	1435.8	180°E	103
II-11	1978-113A	35,774	35,793	3.7	1435.8	130°W	84
II-15	1982-106A	35,782	35,792	0.6	1436.0	15°W	38
Being Deployed							
III-2	1985-92B		orbit not disclosed				3
III-3	1985-92C		orbit not disclosed				3

The two satellites being deployed were launched on Shuttle mission 51-J in October 1985, and were to have been the start of a major effort to improve the DSCS network. This involves progressively replacing DSCS II satellites by DSCS IIIs. DSCS III-2 and III-3 were the first to be launched on the Shuttle, and no Two Line Orbital Elements were released for them, in contrast to earlier vehicles. Because of this there was no direct way of telling where they were stationed.

Early in 1986 the first orbital data appeared for DSCS III-2 and III-3 in the form of a submission to the UN, which gave the following details:

1985-92B (payload):	0.3°,	35634-35963km,	1436.6min
1985-92C (payload):	0.3°,	35634-35963km,	1436.6min
1985-92D (rocket body):	28°,	509-35200km,	625.2min
1985-92E (rocket body):	2.1°,	35185-35953km,	1424.9min

This confirms that the standard IUS launch profile was used, with object D being the IUS lower stage and object E the IUS upper stage (see sections 4.2 and 7.1 of the 1985 review). The UN submission gave no indication of the satellites' orbital stations, but clues to these were to come during the year.

DSCS II-14 started 1986 on the Atlantic prime station at 12°W, but it manoeuvred on 17 March, resulting in drift of 1°W per day. Past practise has always been that when an operational satellite is to be moved off station, a replacement is brought in so that it can take over the slot within two or three days. All other prime and back-up DSCSs were stationary, so the replacement must have been one of the satellites from the Shuttle launch.

On May 14 II-14 manoeuvred a second time, increasing its drift rate to 3°W per day. Its destination was to be the back-up slot at 180°E, but three days before it got there the current occupant, II-8, manoeuvred to produce an eastwards drift of 4° per day. II-14 was stabilised at 180°E on 21 June.

The next manoeuvre came on 3 August, when II-8 was stabilised at 0°W. This station has not been used by DSCS before, but the DoD had said in 1985 that it was considering adding a new station over the Atlantic, where additional capacity was needed. For the rest of the year no further manoeuvres were made by the eight satellites for which data is released. The second DSCS III from the Shuttle mission had therefore not taken over any of the standard stations, so it and II-8 must have become the prime and back-up at the new Atlantic slot. Given its greater capabilities, the DSCS III will be the prime, with II-8 its back-up. This would place the DSCS III at about 5°E.

In terms of launch plans, the Titan 34D/IUS combination's payload capability to synchronous orbit (1900kg) is insufficient to carry two DSCS IIIs (total weight 2086kg). The first DSCS III had been launched on a Titan 34D/IUS with a DSCS II (total weight 1633kg), and there had been plans to make another such launch. However, this seems to have been overtaken by Shuttle launches of pairs of DSCS IIIs. At the start of 1986 there was a Shuttle mission, 61-N, scheduled for September, and this appears to have been for DSCS.

The loss of Challenger has delayed this indefinately. The next opportunity to launch a DSCS III pair will be when the Titan 34D-7 enters service in late 1988. In the meantime the DSCS II/DSCS III launch on a Titan 34D/IUS may be resurected, although with ten functioning satellites in orbit the programme cannot be in desperate need of such a flight.

7.2 Fleet Satellite Communications Program

The Fleet Satellite Communications Program (FLTSATCOM) is for communications between mobile users, mainly ships of the US Navy. Five spacecraft were launched, but the fifth, intended as an in-orbit spare, was damaged during booster separation. The other four spacecraft continue to function as planned.

FLTSATCOM Satellites at 1 January 1986

Name	Satellite	Perigee (km)	Apogee (km)	Incl (°)	Period (min)	Station	Months in Orbit
F-1	1978-16A	35,786	35,791	4.2	1436.1	100°W	95
F-2	1979-38A	35,734	35,838	2.9	1436.0	72°E	80
F-3	1980-04A	35,777	35,794	2.7	1435.9	23°W	71
F-4	1980-87A	35,777	35,790	2.1	1435.8	172°E	62

In 1981 the US Navy received Congressional approval to order three more FLTSATCOMs, and the first of these was set for launch in April as 1986 began. With the general caution resulting from the failures in the early months of 1986 FLTSATCOM 6's launch was delayed a number of times. In the summer spacecraft number 7 was substituted for number 6, and this finally lifted off at 21:30 EST on 4 December. FLTSATCOM satellites are launched for the Navy by NASA, and FLTSATCOM 7 was to undergo two months of in-orbit testing before being handed over to the Navy [14].

As the Centaur rocket, with its payload still attached, crossed the Equator a quarter of a rev after launch its motor was re-ignited, placing them in their desired transfer orbit. The satellite then separated from the Centaur, entering a 172km by 35,745km, 28.5° orbit. For the checkout period it was to be stationed at 180°E, so flight controllers waited until an apogee occurred near this longitude before circularising the orbit. This came on 7 December, and after two small burns, on 9 and 11 December, FLTSATCOM 7 was stabilised at 179°W. Its orbit was from 35,551km to 36,024km, inclined at 5.2°, with a period of 1436.0 minutes.

Before its hand-over to the Navy, FLTSATCOM 7 is to be drifted to its operational station at 105°W, a slot which has been occupied by Leasat 2 since its launch in August 1984. FLTSATCOM 6 is now scheduled for launch in February 1987, followed by FLTSATCOM 8 in May.

7.3 Leasat Programme

The Leasat programme resulted from a directive from Congress in 1977 that if the US Navy wished to augment its first batch of FLTSATCOM satellites, it must do this by leasing channels rather than procuring actual spacecraft. This decision was reversed in 1981, when the second batch of FLTSATCOMs was approved, but by this time the Leasat programme had been started.

Two Leasats were launched in 1984 and two in 1985. Of the two launched in 1985, one had to be rescued in orbit, while the other failed within days of launch. Their status at the start of 1986 was:

Leasat Satellites at 1 January 1986

Name	Satellite	Perigee (km)	Apogee (km)	Incl (°)	Period (min)	Station	Months in Orbit
L-2	1984-93C	35,782	35,792	2.3	1436.0	105°W	16
L-1	1984-113C	35,757	35,808	2.5	1435.8	15°W	14
L-3	1985-28C	35,772	35,801	3.1	1436.0	178°W	9

As noted earlier, FLTSATCOM 7 is to take over Leasat 2's slot when it reaches operational status. However, its checkout position was very close to the station occupied by Leasat 3. A day after FLTSATCOM 7 was stabilised Leasat 3 was manoeuvred, giving it a drift of 2.4°E per day. It was still in this orbit at the end of 1986.

The Leasat contract called for the construction of five spacecraft, four operational and one spare. When Leasat 3 developed problems after release from the Shuttle it was decided to launch the fifth vehicle. Leasat 4's failure caused the fifth launch to be delayed, but at the start of 1986 it was set to fly on Shuttle mission 61-L in November.

The loss of Challenger and the ensuing changes to Shuttle priorities resulted in Leasat 5 not being scheduled until STS-51 in November 1990.

7.4 Satellite Data System

The Satellite Data System (SDS) provides critical communications links to strategic forces operating in polar regions, and data relays for the Satellite Control Facility. The satellites are placed in eccentric 12-hour orbits which, by using an inclination of 63.4°, have groundtracks which are fixed on the Earth's surface. They use the Titan 3B launch vehicle, its only application besides KH-8 photo reconnaissance satellites.

The DoD is very reluctant to talk about this programme, and the barest orbital data is released. Nevertheless, it is possible to identify launches in this class, and there had been twelve by the start of 1986:

Satellite Number	International Designation	Launch Date
1	1971-21A	21 Mar 71
2	1973-56A	21 Aug 73
3	1975-17A	10 Mar 75
4	1976-50A	2 Jun 76
5	1976-80A	6 Aug 76
6	1978-21A	25 Feb 78
7	1978-75A	5 Aug 78
8	1980-100A	13 Dec 80
9	1981-38A	24 Apr 81
10	1983-78A	31 Jul 83
11	1984-91A	28 Aug 84
12	1985-14A	8 Feb 85

Most writers consider that the first two satellites were test vehicles, with operational missions starting at the third launch. However, there are indications that this set of flights includes another class of spacecraft besides SDS. A DoD briefing chart dated 10 December 1980 lists the first SDS launch as occuring in June 1976, which would make it satellite number 4 in the table above. The second is listed as occurring in August 1976, making it satellite number 5, and the third in August 1978, making it satellite number 7. The chart also lists the delivery date for the fourth vehicle as May 1980, suggesting it was satellite number 8, and for the fifth vehicle as October 1980, suggesting it was satellite number 9.

The most likely role of the other SDS-type spacecraft is electronic intelligence gathering, complementing the coverage provided by synchrounous orbit vehicles like Rhyolite and Chalet in much the same way as the true SDS satellites augment synchronous orbit communications satellites.

A report appeared in 1986 which seems to confirm this. Describing the incident in April 1978 when a Korean airliner strayed over prohibited Soviet airspace, it states "There was a newly deployed intelligence satellite, code named Jumpseat, that was capable of loitering eight or more hours a day over the northern reaches of the Soviet Union, intercepting all kinds of communications, including voice messages from the Soviet ground personnel up to the pilots tracking the errant airliner" [15].

Assuming the first two SDS-type spacecraft were test vehicles, the second Jumpseat satellite would have been in orbit for eight weeks at the time of the airliner incident. The analysis in the 1984 review showed that two spacecraft were needed for a full SDS system, and the same would be true of Jumpseat. This would tie in with the statement that the system was "newly deployed". The reference to loitering over the northern reaches of the Soviet Union also agrees well with Jumpseat's orbital characteristics.

It is not possible to deduce which of the subsequent launches were for SDS and which were for Jumpseat, so they are considered here together. Taking the active satellites as those less than five years old gives the status of the systems as:

<u>SDS/Jumpseat Satellites at 1 January 1986</u>

Satellite	Months in Orbit
1981-38A	56
1983-78A	29
1984-91A	16
1985-14A	11

There was only one Titan 3B launch vehicle left at the start of 1986, so a launch in the year did not appear likely. The Big Bird failure in April 1986 damaged the Titan 3B pad, but it had been repaired by the end of the year. A launch in 1987 therefore seems a distinct possibility.

Just what launch vehicle will be used after this is not at all clear. It has been reported that the DoD was considering launching SDS satellites on the Shuttle from Cape Canaveral, but the loss of Challenger will have delayed any Shuttle SDS or Jumpseat launch significantly [16]. To fill the gap the DoD may be forced to use some of the Titan 34D-7 vehicles it now has on order.

8. NAVIGATION

8.1 Navy Navigation Satellite System

The Navy Navigation Satellite System was in its twenty second year of operation at the start of 1986. A number of satellites were in storage, but the cost of this has become so high that it is now cheaper to launch them and store them in orbit. The Scout boosters used by this programme, known as Stacked Oscars on Scout (SOOS), are able to carry two Transit satellites, each weighing only 59kg. The first SOOS launch was made in August 1985. One satellite went into operational use while the other was put in orbital storage.

At the start of 1986 the complete system consisted of seven satellites, as follows:

Transit and Nova Satellites at 1 January 1986

Name	Satellite	Perigee (km)	Apogee (km)	Incl (°)	Period (min)	Months in Orbit
Operational						
Transit O-13	1967-48A	1064	1097	89.7	106.9	223
Transit O-20	1973-81A	890	1137	90.0	105.5	146
Transat	1977-106A	1063	1104	89.8	107.0	110
Nova 1	1981-44A	1167	1188	90.0	109.0	55
Nova 2	1984-110A	1154	1202	90.1	109.0	15
Transit O-30	1985-66B	1003	1263	89.8	108.0	5
In Storage						
Transit O-24	1985-66A	1004	1263	89.8	108.0	5

The second SOOS launch is scheduled for mid 1987.

8.2 Navstar Global Positioning System

At the start of 1986 the Global Positioning System, more commonly known as Navstar, was about to make the transition from technology proving to operational deployment. Eleven Block 1 R&D satellites had been launched, and the desired performance had been successfully demonstrated.

Operational Block 2 satellites are larger than Block 1 vehicles, with a launch weight of 1667kg compared with 871kg for Block 1. They have increased survivability and nuclear hardening, longer design lives (7½ years against 5 years), and incorporate cross-links to enable data from their nuclear explosion detectors to be transmitted via other Navstar satellites if necessary. The availability of cross-links ensures that data can always be sent to the United States in real-time, regardless of where in orbit a satellite is [17].

Block 1 Navstars were launched on Atlas F/SVS vehicles, but Block 2s require the greater capacity of the Shuttle/PAM-D2 combination. Ten Block 2 Navstars were scheduled for launch in 1987, starting with Shuttle mission 71-A in January. These were to be followed by nine in 1988, and two more by mid 1989 to produce the full constellation of 18 operational satellites and three in-orbit spares.

Meanwhile, at the start of 1986 there were seven Block 1 Navstars still functioning in orbit. They were arranged in two orbital planes 120° apart, with approximately 45° between satellites within planes. Their orbital data was as follows:

Navstar Satellites at 1 January 1986

Name	Satellite	Perigee (km)	Apogee (km)	Incl (°)	Period (min)	Months in Orbit
First Plane						
Navstar 4	1978-112A	20,055	20,308	63.3	718.0	85
Navstar 8	1983-72A	19,890	20,474	62.9	718.0	30
Navstar 9	1984-59A	20,065	20,300	62.6	718.0	19
Navstar 11	1985-93A	19,832	20,531	63.4	717.9	3
Second Plane						
Navstar 3	1978-93A	20,086	20,278	64.1	718.0	87
Navstar 6	1980-32A	19,890	20,473	63.9	718.0	68
Navstar 10	1984-97A	19,953	20,410	63.4	717.9	16

Navstar 11 was the lead vehicle in the first plane, with Navstar 4 trailing it by 48°. Navstar 11 manoeuvred on 28 October and 1 November, with the result that its orbital period was increased by slightly under one minute. This caused its lead over Navstar 4 to decrease at the rate of almost a degree per day. On 20 December Navstar 11 passed Navstar 4, and at the end of 1986 it lagged by 11° and was still dropping back. None of the other satellites in the plane have manoeuvred recently, but it must be assumed that one of them will be replaced by Navstar 11 early in 1987.

The loss of Challenger not only put back the first Block 2 launch, but when flights resume they will be at a much reduced rate. There would therefore be an even greater delay before a full constellation could be established. To overcome this the DoD decided to procure a number of expendable launchers specifically to orbit Block 2 Navstars. Four companies were chosen in August 1986 to carry out six month design studies for this, to be known as the Medium Launch Vehicle (MLV).

The four companies were:

- General Dynamics, proposing a slightly modified Atlas Centaur,

- Hughes Aircraft Company, proposing a booster based on elements of the Shuttle external tank and engine designs from the Saturn programme,

- Martin Marietta, proposing a version of the Titan 34D/IUS,

- McDonnell Douglas, proposing an uprated Delta booster.

At the end of the studies there will be a design review, and a contractor for the project will be selected. The first launch is to be in January 1989, with four flights a year for five years [18]. Navstars will also be launched on the Shuttle, starting with STS-35 in June 1989. By using the Shuttle and the MLV in parallel it is hoped to have the 21-satellite constellation in orbit by autumn 1991, a delay of two years over pre-Challenger plans.

9. ANTI-SATELLITE (ASAT)

Flight testing of the US anti-satellite (ASAT) system began in 1984. The first test, on 21 January, demonstrated the operation of the F-15/missile combination. The second test, on 13 November, carried the first Miniature Homing Vehicle. Aimed at a star, its objective was to prove the operation of the vehicle's tracking and guidance systems. It emerged later that this test was only partially successfuly. The third test was to be the first targetted at an actual object in orbit. A special target satellite, known as the Instrumented Test Vehicle (ITV), had been developed for the ASAT programme, but it was not ready on time, and an old DoD research satellite was used instead. The test took place on 13 September 1985, and was completely successful.

ITVs are launched in pairs, and the first two finally reached orbit on 13 December. However, within a couple of days Congress placed a ban on any testing against objects in orbit. The ban was effective for FY86 (i.e. until 30 September 1986). The USAF claimed that the batteries onboard the ITVs would not last that long (their orbital lives are estimated at ten years), so the $20 million they had cost would be wasted [19]. At the start of 1986 their orbital data was as follows:

ASAT Target Satellites at 1 January 1986

Name	Satellite	Perigee (km)	Apogee (km)	Incl (°)	Period (min)	Months in Orbit
ITV 1	1985-114A	312	773	37.1	95.4	½
ITV 2	1985-114B	312	770	37.1	95.4	½

The USAF's original plans for FY86 were for two tests against ITVs, in the first and second quarters of 1986, and one Infra-Red Probe (IRP) test. The IRP test would be aimed at a star instead of an object in orbit, similar to the second flight test. The new test would differ from the earlier one in that the "target" would be nearer the horizon, thus testing the ASAT's ability to engage satellites at low altitude. This is a much more demanding problem for the vehicle's tracking and guidance systems than a target at higher elevation [20].

As a result of the Congressional ban the two ITV tests were cancelled, and a second IRP test, which had been planned for later in the programme, brought forward to 1986. The USAF also took steps to prolong the life of the two ITVs in orbit, in the hope that they could be used after the ban expired.

The first IRP test was carried out on 22 August, and seems to have been successful, as was the second. The latter was made on 30 September, the last day possible to meet the USAF's schedule of two flights in FY86.

While these were going on the USAF was re-evaluating the whole ASAT effort. In the spring the decision was made to limit the programme to meeting the "near-term threat" only. The original procurement of 112 ASAT vehicles was cut to just 35, and plans for a base on the US West Coast were scrapped [21]. In October Congress extended its ban on testing against objects in orbit to FY87, and in the wake of this a major re-assessment of the project was made. One option considered was dropping it altogether; another was going to full deployment before the test programme had been completed. In the end both of these were rejected, and the project was continued as before [22].

The three ITV tests that had been scheduled for FY87 were cancelled, and further measures were taken to prolong the life of the ITVs in orbit. Communications sessions with them were reduced to conserve battery power, and the USAF was hopefull that they would last until autumn 1987, when the ban would have expired.

Examination of the Two Line Orbital Elements, however, reveals that this was not the whole story. In mid December ITV 2 produced two objects, 1985-114D and E. Each ITV consists of a balloon housed in a canister. Shortly before a test is to take place the balloon is released from the canister and inflated. The most obvious explanation of the two new objects is that the USAF, having never tested the deployment in space, decided to use one of the ITVs in orbit to test this rather than save it until the Congressional ban was over. Both objects D and E were decaying much more quickly than their parent, as would be expected from a balloon and the canister cover.

10. STRATEGIC DEFENSE INITIATIVE (SDI)

A number of experiments have been conducted in space for SDI, but the first dedicated satellite launch was to take place in 1986. This was an extremely complex mission, but needed only 14 months from conception to execution.

The object of the experiment was to gather vital data for the design of kinetic energy weapons that could be used to destroy ICBMs in the early stages of flight. To do this two payloads would be launched. One would simulate the behaviour of a missile while the other made observations of it. At the end of the flight one of the payloads would be steered to make a high-velocity impact on the other, testing the guidance and control technologies that would be required in a kinetic energy weapon.

At the start of 1986 the mission was set for 19 August, but it actually lifted off at 11:08 EDT on 5 September. It was the first US satellite launch since the string of failures earlier in the year, and its success would be an immense boost to the morale of the US space effort. The launch vehicle used was a Delta 3920, one of three bought by the SDI Organisation in July 1985.

One payload was essentially a third stage of the launcher, built around an Aerojet 201 liquid propellant rocket engine. Its main piece of equipment was a radar tracker from a Phoenix air-to-air missile. The other payload was the Delta second stage, to which a number of instruments had been added. Four sensors pointed forward, to observe the rocket plume of the third stage vehicle, and four more pointed aft to observe the plume of the stage's own motor. Two cameras, operating at different wavelengths, also pointed forward. In addition, the second stage carried an IR imager from a Maverick air-to-ground missile and the first laser radar to be sent into space. To enable the Phoenix radar on the third stage to be able to detect the second stage at the separations planned for the mission, a corner radar reflector was attached to the second stage [23].

The second and third stages were placed in a 206km by 228km, 28.5° orbit, and separated 45 minutes into the flight, over the southern Indian Ocean. As the third stage moved away from the second stage it manoeuvred to simulate an ICBM bus dispensing its re-entry vehicles, observed all the time by the second stage's sensors. The second stage then fired its motor, producing a 204km by 227km, 28.9° orbit. The paths of the two vehicles now crossed twice each orbit, drifting up to 220km apart between crossings. During approaches the third stage again simulated an ICBM, to be observed by the second stage against various Earth and space backgrounds.

Ninety two minutes into the flight the vehicles made a close approach over the Mexican state of Chihuahua. Due north of their track lay White Sands Missile Range, and as they passed an Aries/Minuteman rocket was launched. Television views from the Maverick camera on the second stage were transmitted to the ground, and showed that it easily picked up the solid propellant rocket firing.

Sixty four minutes later, as the vehicles neared maximum separation, they crossed the Equator moving northwards, having just flown over New Guinea. They were then oriented to observe each other, enabling the Phoenix radar on the third stage to lock on to the second stage. The engines in both stages were then ignited. The second stage followed a predetermined course, while the third stage tracked it and manoeuvred to achieve a head-on collision. This came at 13:53 EDT, over a spot in the central Pacific at 15°N, 168°E. The whole mission had lasted two hours and forty five minutes.

The groundtracks of the two stages during the flight are shown in Figure 1. The continuous line shows the track of the third stage, and the dashed line shows the track of the second stage following its separation.

The next SDI mission is planned for November 1987. Launched on a Delta booster, it will carry seven different experiments to support development of a ballistic missile defence system [24]. This is to be followed by two more Delta launches, carrying the Laser Communications Experiment in the third quarter of 1988 and the High Brightness Laser Experiment in the fourth quarter of 1989 [25]. Subsequent flights will all use the Shuttle.

11. RESEARCH AND DEVELOPMENT (R&D)

11.1 Shuttle Mission 62-A

The most important R&D flight for several years was to be Shuttle mission 62-A. At the start of 1986 this was scheduled for launch from Vandenberg Air Force Base on 15 July. The payload consisted of the AFP-888 satellite and the AFP-675 experiment-carrying pallet. The satellite was to be released from the Shuttle and boosted to a 740km orbit by its own propulsion unit, while the pallet would remain in the Shuttle's cargo bay throughout the flight [26].

The satellite was designed around the Teal Ruby sensor, whose aim was to test the detection and tracking of aircraft from space. This used an advanced IR sensor and specially developed image processing algorithms [27]. The satellite also carried three add-on experiments:

- Extreme Ultra-Violet Photometer, to map the UV sources in the sky,
- Ion Auxiliary Propulsion System, to test satellite manoeuvring using very low thrust levels,
- Stellar Horizon Atmospheric Dispersion experiment, to measure the positions of stars near the horizon.

The pallet carried six experiments:

- Cryogenic Infra-Red Radiance Instrument for the Shuttle, to collect data on the aurora and the Earth's atmosphere,
- Far Ultra-Violet Camera, to photograph the UV spectrum from low orbit,
- Uniformly Redundant Array, to photograph deep space X-ray sources,
- Gamma Ray Advanced Detector, to collect data on gamma rays from the galaxy's centre,
- Horizon Ultra-Violet Photometer, to scan the Earth's horizon and airglow,
- Quadruple Ion Neutral Mass Spectrometer, to measure contaminants in the Shuttle's cargo bay.

To underline the importance of the mission, the USAF selected as one of its two payload specialists for the mission the Undersecretary of the Air Force, Edward C. Aldridge.

The Challenger accident and ensuing delays in Shuttle launches from Vandenberg immediately halted plans for the mission, and the satellite was put in storage. Consideration is being given to launching it on an expendable booster, but its size -

its basic structure is a box 4½m square - means that the only vehicle able to carry it will be a Titan 34D-7. Another alternative being considered is launch to a lower inclination orbit by a Shuttle from Cape Canaveral [28]. When work started on Teal Ruby in 1976 the planned flight date was March 1980; whichever option is chosen, the earliest opportunity will not now come before 1990.

11.2 Polar Bear

The only R&D satellite to be launched in 1986 was an old Transit satellite which had been on display in the Smithsonian Museum since the mid 1960s, and its Scout booster was made up from flight-qualified spare parts. This was the Polar Bear (for Beacon Experiment and Auroral Research) experiment, continuing the investigations of the Hilat satellite launched in 1983. Polar Bear carried three experiments; a sensor to provide visual and IR images of the aurora borealis, a beacon experiment to measure ionospheric distortion, and a magnetometer data processor experiment. The overall aim of these was to find ways of improving radio communications over the poles.

The 125kg spacecraft was launched from Vandenberg Air Force Base at 04:23 PST on 13 November, and entered a 963km by 1019km, 89.6° orbit as planned. It has a design life of three years.

DEFENSE PAYLOADS LAUNCHED IN 1986

NAME	DATE	LAUNCH VEHICLE	SITE	COMMENTS
1986-14A	9 Feb	Atlas H	VAFB	White Cloud
" E	"	"	"	"
" F	"	"	"	"
" H	"	"	"	"
none	18 Apr	Titan 34D	VAFB	Big Bird failure
1986-69A	5 Sep	Delta 3920	CC	SDI Experiment
" B	"	"	"	Delta 2nd stage
1986-88A	14 Nov	Scout	VAFB	Polar Bear
1986-96A	5 Dec	Atlas Centaur	CC	FLTSATCOM 7

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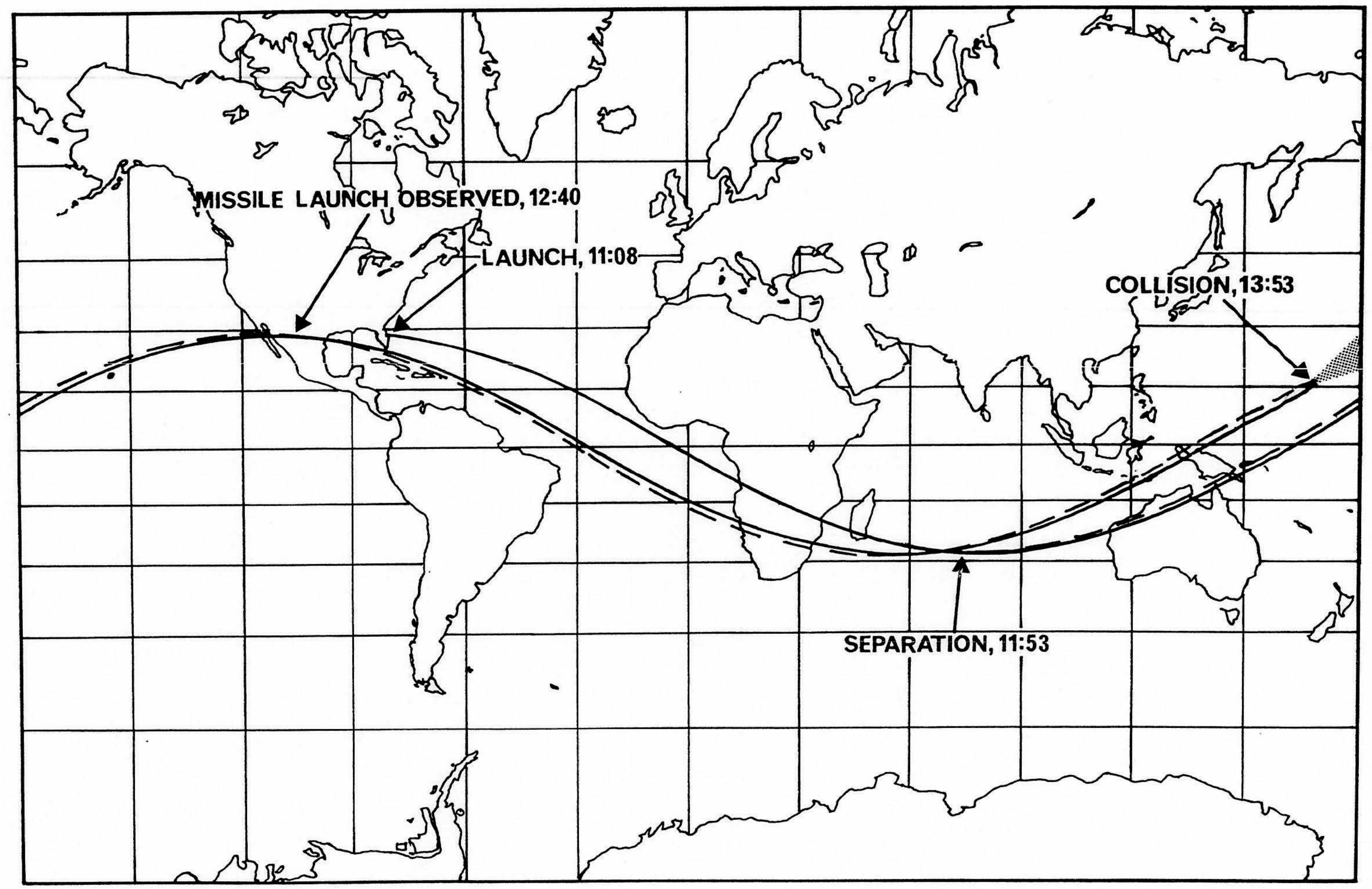

Figure 1: The SDI Space Experiment, 5 September 1986