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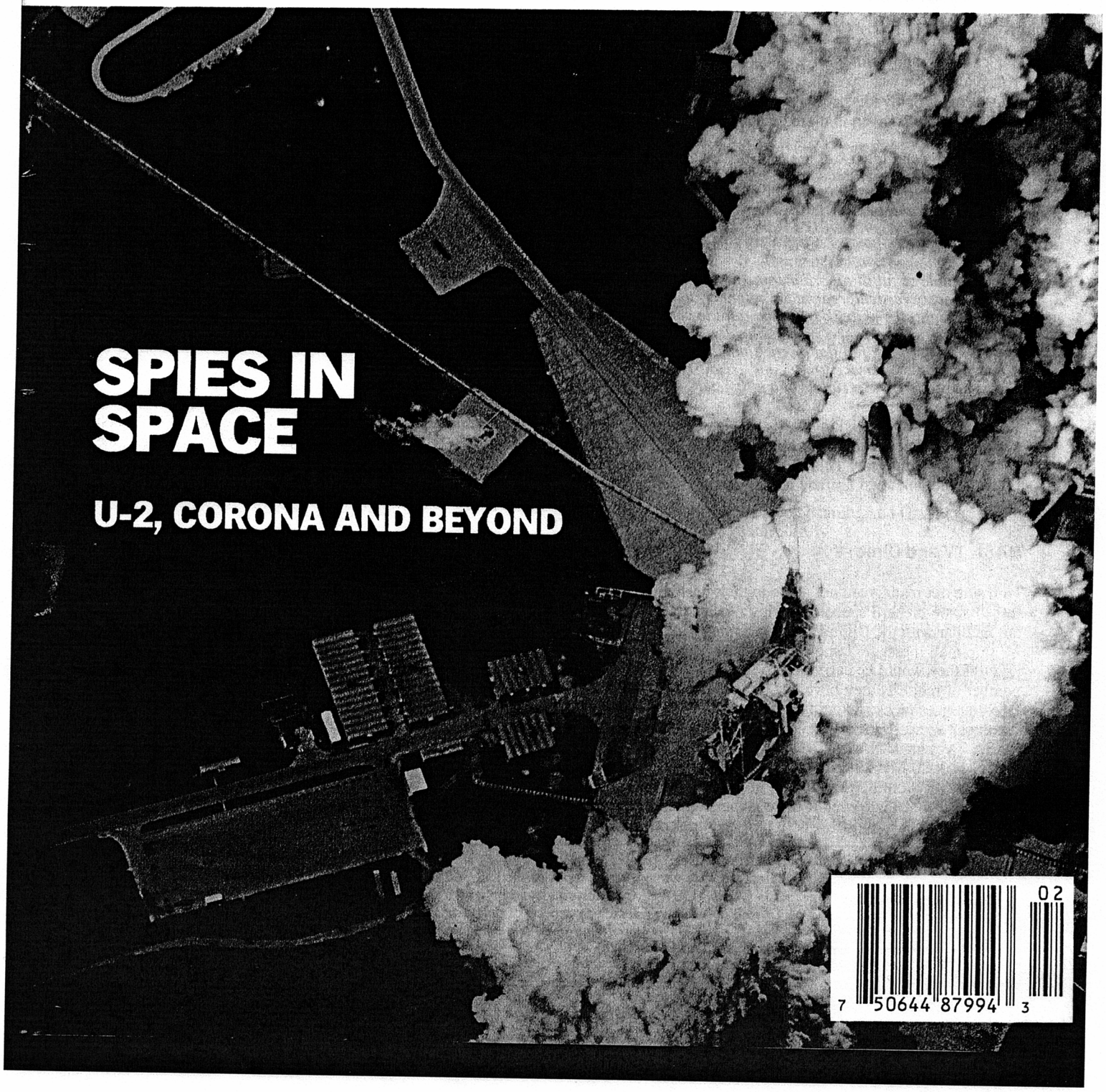
The History of Spaceflight Magazine

Vol. 4 No. 2



SPIES IN SPACE

U-2, CORONA AND BEYOND

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US Reconnaissance Satellite Programs

Part I: Photoreconnaissance

Jonathan McDowell

CORONA was just the first of many American spy satellite programs that continue to this day.

In 1978 the late Anthony Kenden published an article in *Spaceflight* magazine[1] detailing the United States satellite reconnaissance program since its inception in the 1950's, amplifying an earlier book by Klass.[11] A number of important books on aspects of the program have appeared since then[2,3,4,5] which have revised our understanding of the programs described by Kenden, and continued reviews of subsequent activity by Kenden,[22] and others[17,2] but there has been no synthesis of the entire program history in the manner of the Kenden article (with the exception of a book by Peebles[10] which is also seriously out of date). The declassification of the CORONA project, culminating in a conference at George Washington University in May 1995 at which former spies spoke to the academic community about the program's history,[6,7] completes a chapter in this reevaluation of US satellite reconnaissance. This seems an appropriate time to revisit the ground covered in Kenden's influential 1978 article. In Part I, I will discuss imaging satellites, and in Part II, I will discuss signals intelligence, and early warning satellites (Table 1).

When the first reconnaissance satellites flew in 1959-60, they were considered by some[14] to be provocative, invading the airspace over another nation's territory. Today photographic spy satellites are acknowledged as a key component of arms control and international stability, allowing the verification of arms reduction treaties. Signals intelligence satellites, which intercept various kinds of radio signals, remain sufficiently controversial that they are likely to stay shrouded in secrecy. Early warning satellites, whose telescopes detect the launches of space rockets and ballistic missiles, gained fame in the Gulf War despite their relative lack of success in alerting US forces to Scud launches. Spy satellites played a crucial role in both the course of the Cold War and the development of space technology.

In 1956 the US Air Force awarded Lockheed the contract to develop WS-117L, which was intended to be the first spy satellite. There were to be three phases in the WS-117L program: Phase I would be test vehicles launched on Thor Agena rockets starting in November 1958, Phase II would carry more sophisticated test spacecraft aboard Atlas Agena rockets from June 1959, and would transition to the operational Phase III in March 1960. Phase III itself would have three subphases—Pioneer, Advanced, and Surveillance. The Pioneer and Advanced satellites would have a photographic system and signals intelligence equipment, while the Surveillance version would add infrared capability. However, by late 1957 it was apparent that the WS-117L program was far behind schedule, and its secrecy had been compromised, while the need to quantify the strength of Soviet forces was ever more urgent. The Eisenhower Administration decided to go ahead with rapid development of a separate, simpler spy satellite under joint CIA/Air Force management. This system was called CORONA.

The first successes in the CORONA program, in August 1960, coincided with a reorganization of spy satellite management. To contain rivalry between the USAF and CIA, a new umbrella organization was created within the Pentagon: the National Reconnaissance Office (NRO). NRO coordinated a Program A (managed by USAF), Program B (managed by CIA), and Program C (managed by the US Navy). Signals intelligence, the special province of the National Security Agency (NSA), was fronted for them by the United States Air Force, presumably as part of Program A. CORONA came under the CIA umbrella, Program B. NRO would be responsible for all reconnaissance programs from 1960 to the present day, with the probable exception of the early warning satellites.

Table 1
NRO Satellite Programs: Summary

Program	Agency	Contractor	Dates	Mission
CORONA	CIA	Lockheed	1959-1972	Film Return Imaging
ARGON	CIA/Army	Lockheed	1961-1964	Film Return Imaging, Geodesy
LANYARD	CIA	Lockheed	1963	Film Return Imaging, Hi Res
SAMOS	USAF	Lockheed	1960-1961	Radio Readout Imaging
SAMOS E-6	USAF	Lockheed	1962	Film Return Imaging, Hi Res
GAMBIT	USAF	Lockheed	1963-1984	Film Return Imaging, Hi Res
HEXAGON	CIA	Lockheed	1971-1986	Film Return Imaging
KENNAN/CRYSTAL	CIA	TRW	1976-1988	Digital Imaging
IMPROVED CRYSTAL	CIA?	Lockheed	1990-	Digital Imaging
LACROSSE/VEGA	CIA	Martin Marietta	1988-	Radar Imaging
Program 102	USAF/NSA	Lockheed	1962-1971	Electronic intelligence
P-11	USAF/NSA	Lockheed	1963-1964	Electronic intelligence
(SS Type B)	USAF/NSA	Lockheed/Ball?	1965-1974	Electronic intelligence
(SS Type C)	USAF/NSA	Lockheed/Ball?	1968-1983	Electronic intelligence
(SS Type D)	USAF/NSA	Lockheed/Ball?	1976-1986	Electronic intelligence
(USA-41)	?	?	1989	Electronic intelligence?
(Titan II Ferrets)	USAF/NSA	?	1988-	Electronic intelligence
JUMPSEAT	USAF/NSA	Hughes	1971-1981	Signals intelligence/COMINT
CANYON	USAF/NSA	TRW	1968-1977	Signals intelligence/COMINT
RHYOLITE	CIA	TRW	1970-1978	Signals intelligence/TELINT
VORTEX	USAF/NSA	TRW	1978-1987	Signals intelligence/COMINT
MAGNUM	CIA?	TRW	1985-1990	Signals intelligence/TELINT?
Adv. ORION	USAF/NSA?	Hughes	1994-	Signals intelligence/COMINT,TELINT
Adv. JUMPSEAT?	USAF/NSA?	Boeing	1994-	Signals intelligence
PARCAE	USN	Martin Marietta	1976-1987	Ocean surveillance
NOSS II	USN	Martin Marietta?	1990-	Ocean surveillance
MIDAS	USAF	Lockheed	1960-1966	Early warning
DSP	USAF	TRW	1970-	Early warning

The CORONA program: KH-1 to KH-3 systems

CORONA was much more secret than WS-117L, and many fewer people were aware of its existence. In December 1958 it was announced to the general public that WS-117L, now run by the United States Air Force for the Advanced Research Projects Agency (ARPA) at the Pentagon, had been split into three components: DISCOVERER, SENTRY, and MIDAS. SENTRY would be a reconnaissance satellite (later named SAMOS), and MIDAS would be an infrared missile launch warning satellite, but DISCOVERER would be a research series for developing space technology as well as studying the space environment. DISCOVERER would also include other

biomedical and radiation monitoring experiments, according to ARPA. In fact DISCOVERER was simply the cover name for the CIA's secret CORONA spy satellite.

The body of the CORONA satellite was based on Lockheed's Agena upper stage, using a version of the Bell rocket engine developed for use as a takeoff boost unit for the B-58 Hustler jet bomber project. Ahead of the fuel tank was the camera section, and ahead of the camera was a nose cone carrying the Satellite Reentry Vehicle (SRV), developed by General Electric. Film was wound on from the camera into the SRV, and at the end of the mission the film was cut, and the Agena pointed the SRV at the Earth. The SRV then separated from Agena, and fired a solid rocket motor to deorbit itself. The film capsule would reenter the atmosphere over the Pacific, deploy a parachute, and be snatched in mid-air by C-119 (later C-130) cargo aircraft operating out of Hickam AFB, Hawaii.

The 61 cm focal length CORONA cameras were built by Itek in association with Fairchild, and used a scanning panoramic lens. There were six different camera systems used in CORONA, which were eventually given KEYHOLE (KH) designations. The first was the C camera, which was retrospectively designated KH-1.

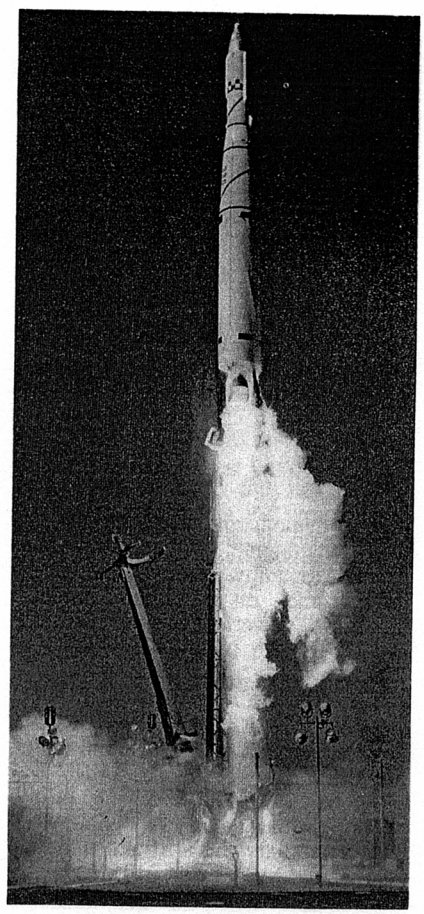
The CORONA Agenas would be launched atop Douglas Thor intermediate range ballistic missiles. Camp Cooke, near Point Arguello in California, was the first operational USAF missile training base and home of the Thor IRBM squadron. It was selected as the nation's military spaceport and renamed Vandenberg Air Force Base. Launches south from Point Arguello could enter polar orbit without passing over land, an important safety consideration. The Navy would also develop a spaceport adjacent to Vandenberg, the Point Arguello Naval Missile Facility (PANMF), which would be used for the USAF's SAMOS launches. PANMF would later become part of Vandenberg in 1965, and is now simply referred to as South Vandenberg.

The first CORONA program launch was Discoverer I, on 28 February 1959. The Thor Agena climbed away from pad 4 on complex 75-3 at Vandenberg, but after six minutes contact was lost. For several days, its fate was uncertain, but from 2 to 5 March intermittent signals and radar contacts were made from a variety of ground stations from the tumbling, out of control satellite.[20] The CORONA history[6] reports that as of the early 1970's the authors remembered the first launch as a probable failure which presumably made a suborbital flight to impact near the South Pole. This is not impossible, since there have been other cases of signals being apparently received from satellites which were later discovered to have never reached orbit. But the quantity and variety of reports over a period of several days reported by the *New York Times* leads me to prefer the standard 1959 version of events over the revisionist 1970's version. Satellite tables still list Discoverer I with the international designation 1959 beta. The RAE Table of Earth Satellites[8] gives an orbit of 163 x 968 km with an inclination of 89.7 degrees, and a reentry date of March 5, while Space Command's Satellite Catalog[9] gives an orbit of 114 x 697 km with an inclination of 90.0 degrees and a reentry date of March 3. It seems that both these sets of information are on shaky ground, and the conflict with the program history's account is a salutary warning to those who accept official sources of information uncritically.

No attempt to recover Discoverer I had been contemplated, and the payload did not carry an SRV. The second vehicle was intended as a recovery test, carrying a small biomedical payload. The SRV ejected too early because of a programming error and landed somewhere near the Spitsbergen Islands in the Arctic. Discoverer II's capsule was probably the first artificial object to return intact to the Earth from orbit. It may even have been the first to be recovered—although the CIA never saw it again, some believed at the time that the Soviets may have located it. Discoverer III, which carried four mice, failed when its Agena misfired, as did Discoverer IV. The later mission was the first to carry a CORONA camera, the C model (later called KH-1), and the first to get a CORONA Mission number, 9001. Mission 9002 (Discoverer V) fired its retro in the wrong direction, sending the capsule to an orbit with an apogee of over 1700 km; it reentered in February 1961. No signals were received after the intended capsule separation on Flight 6 (Mission 9004), and it is assumed the retrorocket failed. Flight 7 lost 3-axis stabilization and recovery was not attempted. The Agena placed Flight 8 in an orbit with a much higher apogee than planned; when recovery was nevertheless attempted, the parachute failed and the capsule was lost. After a stand-down for failure analysis, Flights 9 and 10 both were lost within a couple of minutes of launch due to Thor failures. Mission 9008 (Flight 11) operated successfully until the spin rockets on the recovery capsule exploded during the recovery sequence. As a result of the continuing failures, two diagnostic missions without cameras were flown. The second of these, Discoverer XIII, was successfully recovered from the Pacific Ocean. The next mission, CORONA Mission 9009 (Discoverer XIV), was snatched in mid-air and—on 18 August 1960—completed the first successful spy satellite mission, returning more coverage of the USSR than all U-2 overflights put together (see table 2).

The next phase in the CORONA program was the introduction of the Agena B restartable upper stage and the diversification of the mission objectives. The main CORONA missions continued with the C′ ("C prime" or KH-2) camera and an improved reentry vehicle. Added into the mix was the Argon program, discussed separately. In addition, two ARPA radiometric payloads (Discoverers XIX and XXI) were flown to obtain background data for the MIDAS project.

The Agena B failed on its first launch, but the second flight was a success bar the failure of the camera to take any pictures. Flight 18 was the first fully successful C′ mission. The Flight 21 radiometric mission was the



Launch of Discoverer XXXV on December 12, 1961. This was the last successful KH-3 (C‴) flight. USAF photo courtesey Air Force Magazine)

Table 2
KH-1 and R&D CORONA Missions

CORONA No.	Mission No.	Agena No.	Date	Vehicle	Orbit	Period	SRV Result
CORONA 1	R&D	1022	1959 Feb 28	Thor Agena A	—		Agena failed?
CORONA 2	R&D/Bio	1018	1959 Apr 13-14	Thor Agena A	230 x 346 x 90.4	89.9	Lost in Arctic
CORONA 3	R&D/Bio	1020	1959 Jun 3	Thor Agena A	—		Agena failed
CORONA 4	KH-1 9001	1023	1959 Jun 29	Thor Agena A	—		Agena failed
CORONA 5	KH-1 9002	1029	1959 Aug 13-14	Thor Agena A	217 x 739 x 80.0	94.2	Sep to high orbit
CORONA 6	KH-1 9003	1028	1959 Aug 19-20	Thor Agena A	212 x 848 x 84.0	95.3	Not separated?
CORONA 7	KH-1 9004	1051	1959 Nov 7-8	Thor Agena A	159 x 847 x 81.6	94.7	Not separated
CORONA 8	KH-1 9005	1050	1959 Nov 20-21	Thor Agena A	187 x 1679 x 80.7	103.7	Lost in Pacific
CORONA 9	KH-1 9006	1052	1960 Feb 4	Thor Agena A	—		Thor failed
CORONA 10	KH-1 9007	1054	1960 Feb 19	Thor Agena A	—		Thor failed
CORONA 11	KH-1 9008	1055	1960 Apr 15-16	Thor Agena A	170 x 589 x 80.1	92.2	Lost in reentry
CORONA 12	Diagnostic	1053	1960 Jun 29	Thor Agena A	—		Agena failed
CORONA 13	Diagnostic	1057	1960 Aug 10-11	Thor Agena A	258 x 683 x 82.9	94.0	Recovered from Pacific
CORONA 14	KH-1 9009	1056	1960 Aug 18-19	Thor Agena A	186 x 805 x 79.7	94.6	Recovered over Pacific
CORONA 15	KH-1 9010	1058	1960 Sep 13-14	Thor Agena A	199 x 761 x 80.9	94.2	Sank in Pacific

Table 3
Engineering CORONA Missions

CORONA No.	Mission No.	Agena No.	Date	Vehicle	Orbit	Period	SRV Result
CORONA 19	Radiometric	1101	1960 Dec 20	Thor Agena B	209 x 631 x 83.4	93.0	No SRV
CORONA 21	Radiometric	1102	1961 Feb 18	Thor Agena B	240 x 1069 x 80.7	97.9	No SRV
CORONA 54	STARAD	1401	1962 Oct 26	Thor Agena D	194 x 5537 x 71.4	147.4	No SRV
CORONA 99	R&D	1602	1965 Sep 2	Thor Agena D	—		No SRV; Thor failed

Table 4
KH-2 CORONA Missions

CORONA No.	Mission No.	Agena No.	Date	Vehicle	Orbit	Period	SRV Result
CORONA 16	KH-2 9011	1061	1960 Oct 26	Thor Agena B	—		Agena failed
CORONA 17	KH-2 9012	1062	1960 Nov 12-14	Thor Agena B	190 x 984 x 81.7	96.5	Recovered over Pacific
CORONA 18	KH-2 9013	1103	1960 Dec 7-10	Thor Agena B	243 x 661 x 81.5	93.7	Recovered over Pacific
CORONA 22	KH-2 9015	1105	1961 Mar 30	Thor Agena B	—		Agena failed
CORONA 25	KH-2 9017	1107	1961 Jun 16-19	Thor Agena B	222 x 409 x 82.1	90.9	Recovered from Pacific
CORONA 26	KH-2 9019	1109	1961 Jul 7-10	Thor Agena B	228 x 808 x 82.9	95.0	Recovered over Pacific
CORONA 28	KH-2 9021	1111	1961 Aug 4	Thor Agena B	—		Agena failed
CORONA 30	KH-2 9022	1113	1961 Sep 12-14	Thor Agena B	235 x 546 x 82.7	92.4	Recovered over Pacific
CORONA 31	KH-2 9024	1114	1961 Sep 17-19	Thor Agena B	235 x 396 x 82.7	90.9	Not separated
CORONA 33	KH-2 9026	1116	1961 Oct 23	Thor Agena B	—		Agena failed

Table 5
KH-3 CORONA Missions

CORONA No.	Mission No.	Agena No.	Date	Vehicle	Orbit	Period	SRV Result
CORONA 29	KH-3 9023	1112	1961 Aug 30-Sep 1	Thor Agena B	152 x 542 x 82.1	91.5	Recovered over Pacific
CORONA 32	KH-3 9025	1115	1961 Oct 13-14	Thor Agena B	234 x 395 x 81.7	90.8	Recovered over Pacific
CORONA 34	KH-3 9027	1117	1961 Nov 5-6?	Thor Agena B	227 x 1011 x 82.5	97.1	Not separated
CORONA 35	KH-3 9028	1118	1961 Nov 15-16	Thor Agena B	238 x 278 x 81.6	89.7	Recovered over Pacific
CORONA 36	KH-3 9029	1119	1961 Dec 12-16	Thor Agena B	241 x 484 x 81.2	91.8	Recovered over Pacific
CORONA 37	KH-3 9030	1120	1962 Jan 13	Thor Agena B	—		Agena failed

first to demonstrate in-orbit restart of the Agena engine. This capability was needed to allow retargeting of the ground track on multi-day missions; the more powerful engine was also needed for the higher orbit ARGON missions.

Two more engineering missions were carried out later in the CORONA program: the STARAD mission (satellite 1962 βκ or Agena 1401) was launched in October 1962 into elliptical orbit with a battery of radiation detectors to study the artificial radiation belt created by the STARFISH nuclear explosion in July of that year. CORONA Flight 99 (Agena 1602) was loaded with radio propagation and ionospheric experiments from the Aerospace Corp. and the USAF Cambridge Research Labs, but it was destroyed when its Thor first stage exploded just after lift-off (see tables 3 & 4).

The CORONA system was upgraded in 1961 to use the C‴ camera (KH-3) with twice as fine resolution. There were six launches in the KH-3 program, and four were successful, although the pictures on the first flight were out of focus (see table 5).

Increased Secrecy

With the completion of the KH-3 program in January 1962 and the launch failure of Flight 37, the DISCOVERER cover story had worn too thin to continue. DISCOVERER officially came to an end with the next mission, Flight 38. But in reality, Flight 38 was only the beginning of a new and very successful phase of the CORONA program. From now on, most US military space missions would simply be launched without any name being given to them—a cloak of anonymity descended on Vandenberg. Until CORONA Flight 78 in April 1964, the program had the cover designation Air Force Program 162; it was then redesignated Program 241, and after Flight 112 it was changed again to Program 846.

While this was fairly successful in drawing away massive public attention from the covert launches, articles in the open literature were moderately accurate in their speculations. However, there was one major misunderstanding. In 1961 the trade press reported that

the plan was to have a radio-transmission satellite carry out the "area survey" mission of target location, prototyped as SAMOS, and a film-capsule recovery satellite carry out the "close look" mission of target characterization, prototyped as DISCOVERER. After classification, analysts could see that there were two series of launches, one using Thor Agena and another using Atlas Agena. Klass[11] believed that there was a switch of boosters, with SAMOS succeeded by the classified Thor Agena missions and DISCOVERER succeeded by the lower orbit Atlas Agena missions. Kenden (1978), McDougall (1985), Burrows (1986), and Richelson (1987)[1,2,4,14] followed this orthodoxy. However in 1983[12] I pointed out that comments in the scientific literature about piggyback experiments carried on the Thor Agena proved that these Thor Agena missions returned capsules. We know now that SAMOS was a failure and radio transmission was abandoned; both the area survey and close look missions carried capsules. The Thor Agena missions were the CIA's continuation of the DISCOVERER doing an area survey mission, while the Atlas Agena missions were a USAF program called GAMBIT carrying out close look missions, a successor to the capsule return segment of SAMOS. The main division in the spy satellite program was not between different technologies (radio transmission and physical film recovery) but between rival agencies—the Air Force and the CIA. Richelson's 1990 book was the first one to get the story—and the nomenclature—correct (see table 6).

KH-4 CORONA

The 38th CORONA flight introduced another new camera system, known as M or MURAL (KH-4). MURAL used a pair of C''' cameras to provide stereo imaging. The KH-4 system also included an index camera, which took a lower resolution photograph of a much larger area to help figure out where the main camera was looking. A star tracker was soon added to help determine the spacecraft's attitude more precisely.

The first MURAL flight was successfully recovered, despite the failure of the heat shield to separate after reentry. The second flight saw a shift of the standard CORONA orbit from an 82 degree inclination to a 74 degree one, for reasons which remain unclear—possibly either a change in the highest priority targets, or to allow a greater payload to be carried.

CORONA Flight 45 (the seventh MURAL flight, KH-4 mission 9038) was the first launch of the new Agena D rocket stage. Agena D was more powerful than the Agena B and was built on a standard production line instead of being custom-crafted for each launch. The Agena D would see service as a standard upper stage for a quarter of a century, providing propulsion for many historic space flights. The Agena B and Agena D were both used for Mural flights for the remainder of 1962. In 1963 the Thrust Augmented Thor Agena D was introduced, with three Castor solid rocket boosters attached to the third stage, although its first flight, Mission 60, was a failure.

Of the 26 KH-4 flights, 23 returned capsules to Earth and 20 of the capsules were recovered, 19 in mid-air and one from the sea.[7] Table 7, based on reference 6, notes only two sunken capsules instead of three; the identity of the third is unknown. References in intelligence reports reproduced in reference 7 are used to set lower limits to capsule recovery dates for some of the missions below (see table 7).

KH-4A CORONA

In August 1963 a major change was made to the CORONA system: a second recovery capsule was added. Once the first capsule had separated from the nose, a new nose cone was revealed containing the second RV, and film from the MURAL cameras was diverted to this "bucket." The new double camera/double SRV system was designated J-1, or KH-4A. There were 52 launches in the J-1 program, and 92 SRVs were recovered. The end of the J-1 program saw a shift to the Thorad (Long Tank Thrust Augmented Thor) launch vehicle and the addition of a pack of small solid fuel rockets used to raise perigee and counteract orbital decay. KH-4A missions were designated separately for each phase of the mission; e.g. Flight 79's first four days were designated Mission 1006-1, after which RV-1 was recovered; this was followed by the four-day Mission 1006-2 while film was fed to RV-2. In table 8, the RV-1 and RV-2 missions are listed separately, with the date blank for the second phase when its start date is unknown.

At the time of the 1995 declassification, CIA revealed a dramatic episode. Flight 78 (CORONA KH-4A mission 1005) was launched on April 27, 1964, but when the command to recover SRV-1 was sent from Vandenberg on April 30, nothing happened. Repeated attempts to command the separation failed, and on May 19 the CORONA fell silent. The satellite reentered early on May 26 over southwestern Venezuela. On July 7, farm workers in La Fria found the battered remains of SRV-1, and on August 1 the news reached the US Embassy. According to reference 7:

> A team of CORONA officers, ostensibly representing USAF, flew to Caracas to recover the remains. The capsule was lugged out by peasants to a point where the Venezuelan Defense Ministry could pick it up for flight to Caracas. There the CORONA officers bought the crumpled bucket from the Venezuelan government and quietly dismissed the event as an unimportant NASA space experiment gone awry.

1965 saw regular monthly flights of the KH-4A, with a higher degree of reliability, although the second SRV for flight 94 fired in the wrong direction and ended up in an orbit with a 1000 km apogee instead of reentering. Flight 93 saw the first CORONA in sun-synchronous orbit, but most flights

Table 6
Analyses of 1960s Classified NRO Programs

Author	Date	Thor Agena	Atlas Agena
Klass	1971	Area Survey, radio readout	
Kenden	1978	Area Survey, radio readout	Close Look, capsules
McDowell	1983	?, capsules (and radio readout?)	Close Look, capsules
Richelson	1984	Area Survey, radio readout (KH-5)	?, capsules?
Burrows	1986	USAF Area Survey, radio readout (KH-5 SAMOS)	Close Look, capsules (KH-6)
Peebles	1987	Area Survey, capsules	CIA Close Look, capsules (KH-6 CORONA)
Richelson	1987	USAF Area Survey, radio readout (KH-5 SAMOS)	Close Look, capsules
Richelson	1990	CIA Area Survey, capsules (KH-4 CORONA)	CIA Close Look, capsules (KH-6 CORONA) USAF Close Look, capsules (KH-7 GAMBIT)

Table 7
KH-4 (MURAL) CORONA Missions

CORONA No.	Mission No.	Agena No.	Date	Vehicle	Orbit	Period	SRV Result
CORONA 38	KH-4 9031	1123	1962 Feb 27-Mar 3	Thor Agena B	208 x 341 x 82.2	90.0	Recovered over Pacific
CORONA 39	KH-4 9032	1124	1962 Apr 18-19	Thor Agena B	200 x 441 x 73.5	90.9	Recovered over Pacific
CORONA 40	KH-4 9033	1125	1962 Apr 28-May 4	Thor Agena B	180 x 475 x 73.1	91.1	Sank in Pacific
CORONA 42	KH-4 9035	1128	1962 May 30-Jun 1	Thor Agena B	199 x 319 x 74.1	89.7	Recovered over Pacific:
CORONA 43	KH-4 9036	1127	1962 Jun 2-5	Thor Agena B	211 x 385 x 74.3	90.5	Sank in Pacific
CORONA 44	KH-4 9037	1129	1962 Jun 23-25	Thor Agena B	213 x 293 x 75.1	89.6	Recovered over Pacific
CORONA 45	KH-4 9038	1151	1962 Jun 28-Jul 1	Thor Agena D	211 x 689 x 76.0	93.6	Recovered over Pacific
CORONA 46	KH-4 9039	1130	1962 Jul 21-23	Thor Agena B	208 x 381 x 70.3	90.4	Recovered over Pacific
CORONA 47	KH-4 9040	1131	1962 Jul 28-31	Thor Agena B	225 x 386 x 71.1	90.6	Recovered over Pacific
CORONA 48	KH-4 9041	1152	1962 Aug 2-5	Thor Agena D	204 x 418 x 82.3	90.8	Recovered over Pacific
CORONA 49	KH-4 9044	1153	1962 Aug 29-Sep 1	Thor Agena D	187 x 400 x 65.2	90.4	Recovered over Pacific
CORONA 51	KH-4 9043	1133	1962 Sep 17-18	Thor Agena B	204 x 668 x 81.8	93.3	Recovered from Pacific
CORONA 52	KH-4 9045	1154	1962 Sep 29-Oct 2	Thor Agena D	203 x 376 x 65.4	90.3	Recovered over Pacific
CORONA 55	KH-4 9047	1136	1962 Nov 5-9	Thor Agena B	208 x 409 x 75.0	90.7	Recovered over Pacific
CORONA 56	KH-4 9048	1135	1962 Nov 24-29	Thor Agena B	204 x 337 x 65.1	89.9	Recovered over Pacific
CORONA 57	KH-4 9049	1155	1962 Dec 4-6	Thor Agena D	194 x 273 x 65.1	89.2	Sank in Pacific
CORONA 58	KH-4 9050	1156	1962 Dec 14-17	Thor Agena D	199 x 392 x 71.0	90.5	Recovered over Pacific
CORONA 59	KH-4 9051	1157	1963 Jan 7-11	Thor Agena D	205 x 399 x 82.2	90.5	Recovered from Pacific
CORONA 60	KH-4 9052	1159	1963 Feb 28	TAT Agena D	-		Thor failed
CORONA 62	KH-4 9053	1160	1963 Apr 1-4	Thor Agena D	201 x 408 x 75.4	90.7	Recovered over Pacific
CORONA 65	KH-4 9054	1161	1963 Jun 13-14	TAT Agena D	192 x 419 x 81.9	90.7	Recovered Pacific
CORONA 66	KH-4 9056	1166	1963 Jun 27->30	TAT Agena D	196 x 396 x 81.6	90.5	Recovered Pacific
CORONA 67	KH-4 9057	1412	1963 Jul 18->21	Thor Agena D	194 x 387 x 82.9	90.4	Recovered Pacific
CORONA 73	KH-4 9060	1171	1963 Nov 10	Thor Agena D	-		Thor failed
CORONA 74	KH-4 9061	1172	1963 Nov 27-Dec 1	Thor Agena D	175 x 386 x 70.0	90.2	Not separated
CORONA 75	KH-4 9062	1168	1963 Dec 21-26	TAT Agena D	176 x 355 x 64.9	90.0	Recovered over Pacific

were flown at inclinations of 70, 75, 80 or 85 degrees. From 1967 to 1969 the KH-4A was flown with almost complete success; the official history[7] reports that 28 buckets were flown and recovered in 1967-69 and 92 recovered over the whole program, although reference 6 reports that the March 1969 flight, no. 132 in the program, was terminated early because of problems with the Agena, and a count shows that 30 buckets were actually flown in the 1967-69 period. I have therefore listed the SRVs from Flight 132 as not recovered, despite the record of 'partial success' in reference 6 (see Table 8).

KH-4B CORONA

The final CORONA variant was the KH-4B. The KH-4B retained the twin bucket recovery system, but replaced the C''' cameras with a new panoramic camera called the constant rotator panoramic camera. The Dual Improved Stellar Index Camera (DISIC) with a 3 inch focal length replaced the smaller index camera of the KH-4A, and was supplemented with a pair of horizon cameras. The main camera system included a number of improvements to reduce vibration and image smear, and allow operation at lower altitudes (see table 9).

Tests were carried out with color film, and changeable filters. Life of the system was increased to 20 days. The typical perigee of the KH-4B flights was between 150 and 160 km, about 25 km lower than the KH-4A missions, and the best ground resolution attained with the 24 inch focal length camera was 2 meters. The second part of Flight 136 (KH-4B mission 1108-2) included a test of a new high resolution color film, but it had a factor of two worse resolution. However, the results were used to evaluate the use of such photography for civilian remote sensing applications.

There was one launch failure in

Table 8
KH-4A (J-1) CORONA Missions

CORONA No.	Mission No.	AgenaNo.	Date	Vehicle	Orbit	Period	SRV Result
CORONA 69	KH-4A 1001-1	1162	1963 Aug 25-28	TAT Agena D	161 x 320 x 75.0	89.4	RV-1 recovered over Pacific
	KH-4A 1001-2						RV-2 not separated
CORONA 71	KH-4A 1002-1	1163	1963 Sep 23->25	TAT Agena D	161 x 441 x 74.9	90.6	RV-1 recovered
	KH-4A 1002-2						RV-2 not separated?
CORONA 76	KH-4A 1004-1	1174	1964 Feb 15	TAT Agena D	179 x 444 x 75.0	90.9	RV-1 recovered
	KH-4A 1004-2						RV-2 recovered
CORONA 77	KH-4A 1003	1175	1964 Mar 24	TAT Agena D	-		Agena failed
CORONA 78	KH-4A 1005	1604	1964 Apr 27-May 19	TAT Agena D	178 x 446 x 79.9	90.8	Impact in Venezuela
CORONA 79	KH-4A 1006-1	1176	1964 Jun 4-8	TAT Agena D	149 x 429 x 80.0	90.3	RV-1 recovered
	KH-4A 1006-2		1964 Jun 8-12				RV-2 recovered
CORONA 81	KH-4A 1007-1	1609	1964 Jun 19	TAT Agena D	176 x 462 x 85.0	91.0	RV-1 recovered
	KH-4A 1007-2						RV-2 recovered
CORONA 82	KH-4A 1008-1	1177	1964 Jul 10-13	TAT Agena D	180 x 461 x 85.0	91.0	RV-1 recovered
	KH-4A 1008-2		1964 Jul 13-17				RV-2 recovered
CORONA 83	KH-4A 1009-1	1605	1964 Aug 5-9?	TAT Agena D	182 x 436 x 80.0	90.7	RV-1 recovered
	KH-4A 1009-2						RV-2 recovered
CORONA 85	KH-4A 1010-1	1178	1964 Sep 14-18	TAT Agena D	172 x 466 x 85.0	90.9	RV-1 recovered
	KH-4A 1010-2		1964 Sep 18-23				RV-2 recovered
CORONA 86	KH-4A 1011-1	1170	1964 Oct 5	TAT Agena D	182 x 440 x 80.0	90.8	RV-1 recovered
	KH-4A 1011-2						RV-2 not recovered
CORONA 87	KH-4A 1012-1	1179	1964 Oct 17-20	TAT Agena D	189 x 416 x 75.0	90.6	RV-1 recovered over Pacific
	KH-4A 1012-2		1964 Oct 21-23				RV-2 recovered from Pacific
CORONA 88	KH-4A 1013-1	1173	1964 Nov 2	TAT Agena D	180 x 448 x 80.0	90.7	RV-1 recovered
	KH-4A 1013-2						RV-2 recovered
CORONA 89	KH-4A 1014-1	1180	1964 Nov 18-?	TAT Agena D	180 x 339 x 70.0	89.7	RV-1 recovered
	KH-4A 1014-2		1964 Nov ?->26				RV-2 recovered
CORONA 90	KH-4A 1015-1	1607	1964 Dec 19	TAT Agena D	183 x 410 x 75.0	90.5	RV-1 recovered
	KH-4A 1015-2						RV-2 recovered
CORONA 91	KH-4A 1016-1	1608	1965 Jan 15-20	TAT Agena D	180 x 420 x 75.0	90.5	RV-1 recovered
	KH-4A 1016-2		1965 Jan 20-25				RV-2 recovered

CORONA 92	KH-4A 1017-1	1611	1965 Feb 25	TAT Agena D	177 x 377 x 75.1	90.1	RV-1 recovered
	KH-4A 1017-2						RV-2 recovered
CORONA 93	KH-4A 1018-1	1612	1965 Mar 25-29	TAT Agena D	186 x 265 x 96.1	89.1	RV-1 recovered
	KH-4A 1018-2		1965 Mar 29-31				RV-2 recovered
CORONA 94	KH-4A 1019-1	1614	1965 Apr 29-May 3	TAT Agena D	178 x 473 x 85.0	91.1	RV-1 recovered
	KH-4A 1019-2		1965 May 3-8				RV-2 entered high orbit
CORONA 95	KH-4A 1021-1	1615	1965 May 18	TAT Agena D	198 x 331 x 75.0	89.7	RV-1 recovered
	KH-4A 1021-2						RV-2 recovered
CORONA 96	KH-4A 1020-1	1613	1965 Jun 9	TAT Agena D	176 x 362 x 75.1	89.8	RV-1 recovered over Pacific
	KH-4A 1020-2						RV-2 recovered from Pacific
CORONA 97	KH-4A 1022-1	1617	1965 Jul 19	TAT Agena D	182 x 464 x 85.1	91.0	RV-1 recovered
	KH-4A 1022-2						RV-2 recovered
CORONA 98	KH-4A 1023-1	1618	1965 Aug 17-22	TAT Agena D	180 x 407 x 70.0	90.4	RV-1 recovered
	KH-4A 1023-2		1965 Aug 22-26				RV-2 recovered
CORONA 100	KH-4A 1024-1	1619	1965 Sep 22-27	TAT Agena D	191 x 364 x 80.0	90.0	RV-1 recovered
	KH-4A 1024-2		1965 Sep 27-Oct 2				RV-2 recovered
CORONA 101	KH-4A 1025-1	1616	1965 Oct 5-10	TAT Agena D	203 x 323 x 75.0	89.8	RV-1 recovered
	KH-4A 1025-2		1965 Oct 10-15				RV-2 recovered
CORONA 102	KH-4A 1026-1	1620	1965 Oct 28-Nov 2	TAT Agena D	176 x 430 x 75.0	90.5	RV-1 recovered
	KH-4A 1026-2		1965 Nov 2-7				RV-2 recovered
CORONA 103	KH-4A 1027-1	1621	1965 Dec 9	TAT Agena D	183 x 437 x 80.0	90.7	RV-1 recovered
	KH-4A 1027-2						RV-2 recovered
CORONA 104	KH-4A 1028-1	1610	1965 Dec 24-29	TAT Agena D	178 x 446 x 80.0	90.8	RV-1 recovered
	KH-4A 1028-2		1965 Dec 29-31				RV-2 recovered
CORONA 105	KH-4A 1029-1	1623	1966 Feb 2-7	TAT Agena D	185 x 425 x 75.1	90.6	RV-1 recovered
	KH-4A 1029-2		1966 Feb 7-10				RV-2 recovered
CORONA 106	KH-4A 1030-1	1622	1966 Mar 9-14	TAT Agena D	178 x 432 x 75.0	90.6	RV-1 recovered
	KH-4A 1030-2		1966 Mar 14-19				RV-2 recovered
CORONA 107	KH-4A 1031-1	1627	1966 Apr 7-14	TAT Agena D	193 x 312 x 75.1	89.6	RV-1 recovered
	KH-4A 1031-2		1966 Apr 14-18				RV-2 recovered
CORONA 108	KH-4A 1032	1625	1966 May 3	TAT Agena D	-		Agena failed
CORONA 109	KH-4A 1033-1	1630	1966 May 24	TAT Agena D	179 x 271 x 66.0	89.0	RV-1 recovered
	KH-4A 1033-2						RV-2 recovered
CORONA 110	KH-4A 1034-1	1626	1966 Jun 21	TAT Agena D	194 x 367 x 80.1	90.2	RV-1 recovered
	KH-4A 1034-2						RV-2 recovered
CORONA 111	KH-4A 1036-1	1631	1966 Aug 9-16	Thorad Agena D	194 x 287 x 100.1	89.4	RV-1 recovered
	KH-4A 1036-2		1966 Aug 16-22				RV-2 recovered
CORONA 112	KH-4A 1035-1	1628	1966 Sep 20-25	TAT Agena D	188 x 442 x 85.1	90.9	RV-1 recovered
	KH-4A 1035-2		1966 Sep 25-30				RV-2 recovered
CORONA 113	KH-4A 1037-1	1632	1966 Nov 8	Thorad Agena D	172 x 318 x 100.1	89.4	RV-1 recovered
	KH-4A 1037-2						RV-2 recovered
CORONA 114	KH-4A 1038-1	1629	1967 Jan 14-19	TAT Agena D	180 x 380 x 80.1	90.1	RV-1 recovered
	KH-4A 1038-2		1967 Jan 19-26				RV-2 recovered
CORONA 115	KH-4A 1039-1	1635	1967 Feb 22-27	TAT Agena D	180 x 380 x 80.0	90.1	RV-1 recovered
	KH-4A 1039-2		1967 Feb 27-Mar 4				RV-2 recovered
CORONA 116	KH-4A 1040-1	1636	1967 Mar 30-Apr 4	TAT Agena D	167 x 326 x 85.0	89.5	RV-1 recovered
	KH-4A 1040-2		1967 Apr 4-8				RV-2 recovered
CORONA 117	KH-4A 1041-1	1634	1967 May 9-15	Thorad Agena D	200 x 777 x 85.1	94.4	RV-1 recovered
	KH-4A 1041-2		1967 May 15-22				RV-2 recovered
CORONA 118	KH-4A 1042-1	1633	1967 Jun 16-22	Thorad Agena D	181 x 367 x 80.0	90.0	RV-1 recovered over Pacific
	KH-4A 1042-2		1967 Jun 23-Jul 1				RV-2 recovered from Pacific
CORONA 119	KH-4A 1043-1		1967 Aug 7	Thorad Agena D	174 x 346 x 79.9	89.7	RV-1 recovered
	KH-4A 1043-2						RV-2 recovered
CORONA 121	KH-4A 1044-1		1967 Nov 2	Thorad Agena D	183 x 410 x 81.5	90.5	RV-1 recovered
	KH-4A 1044-2						RV-2 recovered
CORONA 123	KH-4A 1045-1		1968 Jan 24	Thorad Agena D	176 x 430 x 81.5	90.6	RV-1 recovered
	KH-4A 1045-2						RV-2 recovered
CORONA 124	KH-4A 1046-1		1968 Mar 14	Thorad Agena D	178 x 391 x 83.0	90.2	RV-1 recovered
	KH-4A 1046-2						RV-2 recovered
CORONA 126	KH-4A 1047-1		1968 Jun 20	Thorad Agena D	193 x 326 x 85.0	89.8	RV-1 recovered
	KH-4A 1047-2						RV-2 recovered
CORONA 128	KH-4A 1048-1		1968 Sep 18	Thorad Agena D	167 x 393 x 83.0	90.1	RV-1 recovered
	KH-4A 1048-2						RV-2 recovered
CORONA 130	KH-4A 1049-1		1968 Dec 12	Thorad Agena D	169 x 248 x 81.0	88.7	RV-1 recovered
	KH-4A 1049-2						RV-2 recovered
CORONA 132	KH-4A 1050		1969 Mar 19-24	Thorad Agena D	179 x 241 x 83.0	88.7	RV-1,2 not recovered?
CORONA 133	KH-4A 1051-1		1969 May 2	Thorad Agena D	179 x 326 x 65.0	89.5	RV-1 recovered
	KH-4A 1051-2						RV-2 recovered
CORONA 135	KH-4A 1052-1		1969 Sep 22	Thorad Agena D	178 x 253 x 85.0	88.8	RV-1 recovered
	KH-4A 1052-2						RV-2 recovered

the KH-4B program, but apart from that, every single mission was at least partially successful, with both SRVs recovered. The aft camera failed on mission 1106, and the forward camera on mission 1107. The final CORONA SRV was recovered on 31 May 1972, by which time a new spacecraft, the KH-9 HEXAGON or "Big Bird," was operational.

KH-5 ARGON

ARGON, using the KH-5 mapping camera, was a US Army program to obtain geodetic information needed for accurate ICBM targeting, and thus can be seen as the first space-based warfighting tool, in contrast to the CORONA which as a threat detection satellite and the precursor of later treaty verification tools is more defensive in nature. A memo to COMOR (the Committee on Overhead Reconnaissance) dated 18 August 1960 reproduced in reference 7 says:

> The national requirements for reconnaissance and geodesy are both critical and it is difficult to assign relative priorities, i.e. reconnaissance is urgently needed to assess the threat of the USSR, and the geodetic locations must be acquired to ensure effectiveness of weapons systems in being, or soon to be deployed, as well as to maintain an effective deterrent posture...at the earliest possible date a CORONA shot with the C′ camera and Agena B engine...to be followed as soon as possible by the ARGON camera with Agena B engine to fulfill geodesy requirements.

ARGON flights can be distinguished by their orbit's higher perigee, and the 3" focal length camera gave a ground resolution of only 140 meters. The 1960 memo mentioned that the geodetic satellite had an operational season of May to October, presumably because of snow and cloud cover considerations. The first ARGON mission, Discoverer XX, failed, and due to an on board malfunction the capsule was ejected half an orbit away from the Pacific Ocean target area, probably re-

Table 9
KH-4B (J-3) CORONA Missions

CORONA No.	Mission No.	Agena No.	Date	Vehicle	Orbit	Period	SRV Result
CORONA 120	KH-4B 1101-1		1967 Sep 15-?	Thorad Agena D	150 x 389 x 80.1	90.0	RV-1 recovered
	KH-4B 1101-2		1967 Sep ?->25				RV-2 recovered
CORONA 122	KH-4B 1102-1		1967 Dec 9	Thorad Agena D	158 x 237 x 81.7	88.5	RV-1 recovered
	KH-4B 1102-2						RV-2 recovered
CORONA 125	KH-4B 1103-1		1968 May 1	Thorad Agena D	164 x 243 x 83.1	88.6	RV-1 recovered
	KH-4B 1103-2						RV-2 recovered
CORONA 127	KH-4B 1104-1		1968 Aug 7-?	Thorad Agena D	152 x 257 x 82.1	88.6	RV-1 recovered
	KH-4B 1104-2		1968 Aug ?->28				RV-2 recovered
CORONA 129	KH-4B 1105-1		1968 Nov 3-?	Thorad Agena D	150 x 288 x 82.2	88.9	RV-1 recovered
	KH-4B 1105-2		1968 Nov ?->20				RV-2 recovered
CORONA 131	KH-4B 1106-1		1969 Feb 5	Thorad Agena D	178 x 239 x 81.5	88.7	RV-1 recovered
	KH-4B 1106-2		1969 Feb (->10)				RV-2 recovered
CORONA 134	KH-4B 1107-1		1969 Jul 24	Thorad Agena D	178 x 220 x 75.0	88.5	RV-1 recovered
	KH-4B 1107-2						RV-2 recovered
CORONA 136	KH-4B 1108-1		1969 Dec 4-?	Thorad Agena D	159 x 251 x 81.5	88.6	RV-1 recovered
	KH-4B 1108-2		1969 Dec ?->21				RV-2 recovered
CORONA 137	KH-4B 1109-1		1970 Mar 4-?	Thorad Agena D	167 x 257 x 88.0	88.8	RV-1 recovered
	KH-4B 1109-2		1970 Mar ?->11				RV-2 recovered
CORONA 138	KH-4B 1110-1		1970 May 20-?	Thorad Agena D	162 x 247 x 83.0	88.6	RV-1 recovered
	KH-4B 1110-2		1970 May ?->28				RV-2 recovered
CORONA 139	KH-4B 1111-1		1970 Jul 23-Aug 2?	Thorad Agena D	158 x 398 x 60.0	90.0	RV-1 recovered
	KH-4B 1111-2		1970 Aug 2?-11				RV-2 recovered
CORONA 140	KH-4B 1112-1		1970 Nov 18	Thorad Agena D	185 x 232 x 83.0	88.7	RV-1 recovered
	KH-4B 1112-2						RV-2 recovered
CORONA 141	KH-4B 1113		1971 Feb 17	Thorad Agena D	-	-	Thor failed
CORONA 142	KH-4B 1114-1		1971 Mar 24	Thorad Agena D	157 x 246 x 81.5	88.6	RV-1 recovered
	KH-4B 1114-2						RV-2 recovered
CORONA 143	KH-4B 1115-1		1971 Sep 10-?	Thorad Agena D	156 x 244 x 75.0	88.5	RV-1 recovered
	KH-4B 1115-2		1971 Sep ?->29				RV-2 recovered
CORONA 144	KH-4B 1116-1		1972 Apr 19	Thorad Agena D	155 x 277 x 81.5	88.9	RV-1 recovered
	KH-4B 1116-2						RV-2 recovered
CORONA 145	KH-4B 1117-1	1663	1972 May 25-28?	Thorad Agena D	158 x 305 x 96.3	89.2	RV-1 recovered
	KH-4B 1117-2		1972 May 28?-31				RV-2 recovered

entering over the Indian Ocean. The second mission, Flight 23, sent its capsule in the wrong direction, leaving it stranded in orbit for a year. This flight was followed by two launch failures, following which ARGON flights were abandoned for a while. The first successful flight was not until May 1962. This satellite, FTV 1126 or 1962σ, was erroneously identified by Kenden as a Ferret mission, as was the following (September 1962) flight. All but one of the remaining flights was successfully recovered. The later flights were launched on the more powerful Thor Agena D and TAT Agena D rockets, and the last two missions went into highly retrograde 115 degree circular orbits. These flights carried the STAR-FLASH optical beacons; their identification with an open geodetic mission and their distinctive orbits meant that Kenden and Peebles omitted them from their list of spy satellites, although a scientific paper reporting recovery of capsules from 115 degree orbits should have given the game away (see table 10).

KH-6 LANYARD

After the success of CORONA the CIA decided to modify the system with a high resolution camera, almost tripling the focal length to 66 inches for a design resolution of under a meter. This KH-6 camera was derived from one of the SAMOS cameras. The new vehicle, code named LANYARD, required the more powerful TAT Agena D launch vehicle. It was launched three times in 1963, but met with little success. The first launch failed to reach orbit, and was lost together with the first P-11 subsatellite. On the second the Agena failed on orbit; the capsule was apparently returned but the camera payload was never activated. On the third mission the only photos returned from LANYARD were out of focus. This third flight came a few weeks after the test flight of the USAF's GAMBIT high resolution satellite, and the CIA program was canceled in favor of the new Air Force system (see table 11).

SAMOS

The US Air Force retained control over the part of WS-117L that became SAMOS (overall control was given to ARPA in 1958 but returned to USAF in summer 1959[13]). The first component of SAMOS to be tested was the radio readout version, designated Project 101A or E-2 (some references suggest the early Samos satellites were called E-5, but this was the name for a Project 101B which apparently never flew). The SAMOS missions were launched by Atlas Agena from the Point Arguello Naval Missile Facility.

Samos 1 was launched on 1960 October 11 but an Agena failure meant

Table 10
KH-5 ARGON Missions

CORONA No.	Mission No.	Agena No.	Date	Vehicle	Orbit	Period	SRV Result
CORONA 20 (AR1)	KH-5 9014A	1104	1961 Feb 17-21	Thor Agena B	288 x 786 x 80.9	95.4	Lost
CORONA 23 (AR2)	KH-5 9016A	1106	1961 Apr 8-10	Thor Agena B	295 x 651 x 82.3	94.1	Sep to high orbit
CORONA 24 (AR3)	KH-5 9018A	1108	1961 Jun 8	Thor Agena B	-		Agena failed
CORONA 27 (AR4)	KH-5 9020A	1110	1961 Jul 21	Thor Agena B	-		Thor failed
CORONA 41 (AR5)	KH-5 9034A	1126	1962 May 15-19	Thor Agena B	305 x 634 x 82.3	94.0	Recovered over Pacific
CORONA 50 (AR6)	KH-5 9042A	1132	1962 Sep 1-5	Thor Agena B	300 x 669 x 82.8	94.4	Sank in Pacific
CORONA 53 (AR7)	KH-5 9046A	1134	1962 Oct 9-13	Thor Agena B	213 x 427 x 82.0	91.0	Recovered over Pacific
CORONA 63 (AR8)	KH-5 9055A	1411	1963 Apr 26	Thor Agena D	-		Agena failed
CORONA 70 (AR9)	KH-5 9058A	1169	1963 Aug 29-Sep 1	Thor Agena D	292 x 324 x 81.9	90.8	Recovered over Pacific
CORONA 72 (AR10)	KH-5 9059A	1601	1963 Oct 29-Nov 2	TAT Agena D	279 x 345 x 89.9	90.8	Recovered over Pacific
CORONA 80 (AR11)	KH-5 9063A	1606	1964 Jun 13-19	TAT Agena D	350 x 364 x 115.0	91.7	Recovered over Pacific
CORONA 84 (AR12)	KH-5 9064A	1603	1964 Aug 21	TAT Agena D	349 x 363 x 115.0	91.6	Recovered Pacific

Table 11
KH-6 LANYARD Missions

CORONA No.	Mission No.	Agena No.	Date	Vehicle	Orbit	Period	SRV Result
CORONA 61 (LY1)	KH-6 8001	1164	1963 Mar 18	TAT Agena D	-	-	Agena failed
CORONA 64 (LY2)	KH-6 8002	1165	1963 May 18-20	TAT Agena D	153 x 497 x 74.5	91.1	Recovered from Pacific?
CORONA 68 (LY3)	KH-6 8003	1167	1963 Jul 31-Aug 1	TAT Agena D	157 x 411 x 75.0	90.4	Recovered over Pacific

it did not reach orbit. Samos 2, in January 1961, was one of the few successful missions, but its photos were disappointing. Samos 3 saw a switch to the Agena B stage. Project 101A was canceled later in 1961, and the final launch appears to have been the March 1962 one (based on orbital characteristics and Agena numbers, as well as Vandenberg launch records). The Samos satellites separated from the Agena final stage, according to data in the NORAD Satellite Catalog. The idea of real-time surveillance by radio transmission readout of exposed film was permanently abandoned. It would be another 15 years until a digital CCD based system would provide effective near-real-time surveillance from space (see table 12).

The next phase of the SAMOS project was Program 201, also known as E-6. The E-6 satellite used film return like CORONA, but the reentry vehicle did not have its own retrorocket, using the Agena B engine for retrofire instead. The orbital data in table 13 are taken from the Satellite Catalog, since the RAE Tables are unreliable for this series. No orbital data is available for the first flight (satellite 1962π) and the values listed are representative only.

The first mission carried a set of piggyback scientific experiments from the Air Force Cambridge Research Labs (AFCRL), including neutron albedo measurements, electron number density and retarding potential analyzer instruments, and an infrared radiometer, as well as a nuclear emulsion experiment to measure cosmic radiation. Emulsion experiments were also carried on CORONA satellites and were placed in the SRVs for later examination after recovery. The success of the experiment on Agena 2401 is evidence that it too carried an SRV which was recovered.[15] The third flight (Agena 2403) stayed in orbit for 7 to 9 days, with a separately tracked payload. Presumably the retrofire burn was unsuccessful. It carried a neutron albedo experiment. The final flight, Agena 2405, was recovered successfully according to the AFCRL data; flights two and four were deorbited after one day but there is no evidence available on the success of the recoveries.

According to a Lockheed statement, Program 201 was canceled in 1962. It seems likely that this cancellation is analogous to the cancellation of the film return WS-117L in 1958, and simply marks a transition to a deeper shade of black—a new USAF high resolution film return program codenamed Gambit (see table 13).

KH-7 GAMBIT

The GAMBIT program, which unlike CORONA is still highly classified at the time of writing in 1995, was a US Air Force system with long focal length cameras providing sufficiently high resolution to identify and measure the properties of targets such as missiles and aircraft. Its success may have prompted the cancellation of the troubled LANYARD program after only three launches. It is assumed that GAMBIT used recoverable film return capsules, but this has not definitely been established.

The GAMBIT camera system was designated KH-7, continuing the NRO series begun with the CORONA cameras. It was also known as Program 206. The Atlas Agena D would place GAMBIT in low sun-synchronous orbit. Richelson claimed that the early flights had stabilization problems and that the Agena was later left attached to provide this capability. However, throughout the KH-7 program the Space Command Satellite Catalog described extra objects tracked in orbit with the majority of flights as Agena D rocket bodies (R/B), which would imply that the GAMBIT spacecraft continued to operate separately in orbit. The RAE Table also lists separated Agena rockets for some of the flights—sometimes (e.g. 1966-32B on flight 27) for objects where the Space Command list just notes debris! Flights 23 and 24 (1965-90 and 1966-02) had "B" objects which were cataloged as extra payloads, the second with the remark "Agena." It seems likely that the "A" objects on these flights are the GAMBIT satellite, and the "B" object is the Agena stage with a small secondary payload attached to the aft rack. Overall, the evidence seems convincing that the GAMBIT satellite payloads orbited separately from their Agena final stages.

The early GAMBIT flights used an Agena D stage atop Atlas D boosters of the same design as the Atlas D ICBM, but the 10th flight introduced the SLV-3 Standard Launch Vehicle variant of the Atlas, the first designed specifically as a space launcher.

The orbital data given in table 14 is from the RAE Tables; note that the Satellite Catalog orbital heights are often significantly different, but mean

Table 12
SAMOS Program 101 Missions

Satellite	Agena No.	Date	Vehicle	Orbit	Period	Notes
SAMOS 1	2101	1960 Oct 11	Atlas Agena A	-	-	Agena failed
SAMOS 2	2102	1961 Jan 31	Atlas Agena A	474 x 557 x 97.4	95.0	
SAMOS 3	2201	1961 Sep 9	Atlas Agena B	-	-	Atlas failed
SAMOS 4	2202	1961 Nov 22	Atlas Agena B	-	-	Atlas failed
SAMOS 5	2203	1961 Dec 22	Atlas Agena B	244 x 702 x 89.6	94.1	
SAMOS 6	2204	1962 Mar 7	Atlas Agena B	251 x 676 x 90.9	93.9	

Table 13
SAMOS Program 201 Missions (E-6)

Satellite	Agena No.	Date	Vehicle	Orbit	Period	Notes
SAMOS 7?	2401	1962 Apr 26-28	Atlas Agena B	209 x 219 x 90.4	88.6	SRV recovered
SAMOS 8?	2402	1962 Jun 17-18	Atlas Agena B	199 x 199 x 96.3	88.5	
SAMOS 9?	2403	1962 Jul 18-27	Atlas Agena B	163 x 215 x 96.1	88.3	SRV not recovered?
SAMOS 10?	2404	1962 Aug 5-6	Atlas Agena B	205 x 205 x 96.3	88.6	
SAMOS 11?	2405	1962 Nov 11-12	Atlas Agena B	128 x 292 x 96.0	88.7	SRV recovered

Table 14
GAMBIT KH-7 Missions

Satellite	Mission No.	Agena No.	Date	Vehicle	Orbit	Period	Life (days)	Notes
GAMBIT 1	KH-7 1	4702	1963 Jul 12	Atlas Agena D	164 x 164 x 95.4	87.8	5	R/B
GAMBIT 2	KH-7 2	4701	1963 Sep 6	Atlas Agena D	168 x 263 x 94.4	89.1	7.1	
GAMBIT 3	KH-7 3	4703	1963 Oct 25	Atlas Agena D	144 x 332 x 99.1	89.0	4.0	R/B
GAMBIT 4	KH-7 4	4802	1963 Dec 18	Atlas Agena D	122 x 266 x 97.9	88.5	1.3	
GAMBIT 5	KH-7 5	4803	1964 Feb 25	Atlas Agena D	173 x 190 x 95.7	88.2	4	
GAMBIT 6	KH-7 6	4804	1964 Mar 11	Atlas Agena D	163 x 203 x 95.7	88.2	4.3	R/B
GAMBIT 7	KH-7 7	4805	1964 Apr 23	Atlas Agena D	150 x 336 x 103.6	89.4	5.2	
GAMBIT 8	KH-7 8	4806	1964 May 19	Atlas Agena D	141 x 380 x 101.1	89.7	2.9	
GAMBIT 9	KH-7 9	4807	1964 Jul 6	Atlas Agena D	121 x 346 x 92.9	89.2	2.0	
GAMBIT 10	KH-7 10	4808	1964 Aug 14	Atlas Agena D	149 x 307 x 95.5	89.0	8.8	R/B
GAMBIT 11	KH-7 11		1964 Sep 23	Atlas Agena D	145 x 303 x 92.9	89.0	4.8	R/B
GAMBIT 12	KH-7 12		1964 Oct 8	Atlas Agena D	-			Agena failed?
GAMBIT 13	KH-7 13		1964 Oct 23	Atlas Agena D	139 x 271 x 95.6	88.6	5.1	
GAMBIT 14	KH-7 14		1964 Dec 4	Atlas Agena D	158 x 357 x 97.0	89.7	1.2	
GAMBIT 15	KH-7 15		1965 Jan 23	Atlas Agena D	145 x 291 x 102.5	88.9	5.2	R/B
GAMBIT 16	KH-7 16		1965 Mar 12	Atlas Agena D	155 x 247 x 107.7	88.5	5.0	R/B
GAMBIT 17	KH-7 17		1965 Apr 28	Atlas Agena D	180 x 259 x 95.6	89.0	5.1	
GAMBIT 18	KH-7 18		1965 May 27	Atlas Agena D	149 x 267 x 95.8	88.7	5.1	
GAMBIT 19	KH-7 19		1965 Jun 25	Atlas Agena D	151 x 283 x 107.6	88.8	4.9	R/B
GAMBIT 20	KH-7 20		1965 Jul 12	Atlas Agena D	-			Atlas failed?
GAMBIT 21	KH-7 21		1965 Aug 3	Atlas Agena D	149 x 307 x 107.5	89.1	4.1	R/B
GAMBIT 22	KH-7 22		1965 Sep 30	Atlas Agena D	158 x 264 x 95.6	88.8	4.7	R/B
GAMBIT 23	KH-7 23		1965 Nov 8	Atlas Agena D	145 x 277 x 93.9	88.7	2.9	R/B
GAMBIT 24	KH-7 24		1966 Jan 19	Atlas Agena D	150 x 269 x 93.9	88.7	6.0	R/B
GAMBIT 25	KH-7 25		1966 Feb 15	Atlas Agena D	148 x 293 x 96.5	89.0	7.4	
GAMBIT 26	KH-7 26		1966 Mar 18	Atlas Agena D	162 x 308 x 101.0	89.3	5	R/B
GAMBIT 27	KH-7 27		1966 Apr 19	Atlas Agena D	145 x 398 x 117.0	89.9	6	
GAMBIT 28	KH-7 28		1966 May 14	Atlas Agena D	133 x 358 x 110.6	89.4	6	R/B
GAMBIT 29	KH-7 29		1966 Jun 3	Atlas Agena D	143 x 288 x 87.0	88.9	6.2	R/B
GAMBIT 30	KH-7 30		1966 Jul 12	Atlas Agena D	137 x 236 x 95.5	88.3	7	R/B
GAMBIT 32	KH-7 31		1966 Aug 16	Atlas Agena D	146 x 358 x 93.2	89.6	7.5	R/B
GAMBIT 33	KH-7 32		1966 Sep 16	Atlas Agena D	148 x 333 x 94.0	89.4	6	R/B
GAMBIT 35	KH-7 33		1966 Oct 12	Atlas Agena D	155 x 287 x 91.0	89.0	8.2	R/B
GAMBIT 36	KH-7 34		1966 Nov 2	Atlas Agena D	159 x 305 x 91.0	89.2	7.2	R/B
GAMBIT 37	KH-7 35		1966 Dec 5	Atlas Agena D	137 x 388 x 104.6	89.8	8.2	R/B
GAMBIT 39	KH-7 36		1967 Feb 2	Atlas Agena D	136 x 357 x 103.0	89.5	9	R/B
GAMBIT 42	KH-7 37		1967 May 22	Atlas Agena D	135 x 293 x 91.5	88.8	8.2	R/B
GAMBIT 43	KH-7 38	4837	1967 Jun 4	Atlas Agena D	149 x 456 x 104.9	90.6	8.2	R/B

properties of the orbits are similar. The "Mission No" tabulated is simply the sequence of KH-7 launches; it seems likely that the true, still classified, mission number is in the 1000 series like the KH-8, but to avoid the sort of confusion that ensued when analysts tried to guess the KH numbers I have not hypothesized specific mission number designations for the KH-7 flights. Cataloging of separated rocket bodies or secondary low orbit payloads by Space Command is indicated in the Notes column with "R/B" (see table 14).

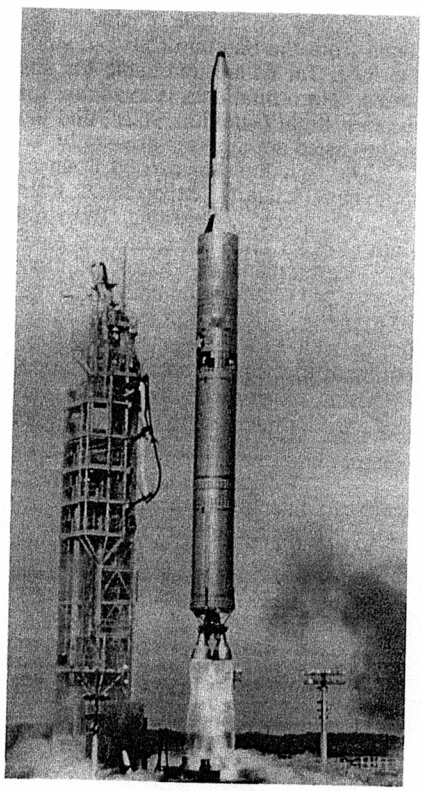
OPS 0974, in March 1966, was a Naval Research Lab experiment to study high frequency wave propagation, also called NRL PL137. The October 1966 secondary payload code named OPS 5345 is also registered as SGLS-1, a test of the Space Ground Link System. This may have been simply a new standardized telemetry command format, or it may have been a new attempt to test out radio transmission of imagery. OPS 5557 carried LOGACS, a Low Gravity Accelerometer Calibration System (see table 15).

KH-8 GAMBIT

Launches with the Titan IIIB first stage began in July 1966. The Titan IIIB is substantially more powerful than Atlas, and only one object was cataloged for each flight (three flights in January, August and October 1971 jettisoned some kind of object into orbit at the end of their missions, possibly associated with the recovery vehicle), confirming that the Agena stage remained attached to the payload. This suggests that the switch of booster and the upgrade to the new KH-8 payload are correlated, in contrast to the phase in of the KH-4B and Thorad booster in the CORONA program. It also seems probable that the KH-8 carried two SRVs instead of one, but this is not certain. The long mission durations from

Table 15
GAMBIT Agena stages with supplementary payloads

Satellite	Date	Vehicle	Orbit	Period	Life (days)
1965-90B (OPS 6232)	1965 Nov 8	Atlas Agena D	155 x 284 x 93.9	88.9	1
1966-02B (OPS 3179)	1966 Jan 19	Atlas Agena D	154 x 246 x 93.9	88.5	3.9
1966-22B (OPS 0974)	1966 Mar 18	Atlas Agena D	152 x 284 x 101.0	88.9	4.9
1966-48B (OPS 1856)	1966 Jun 3	Atlas Agena D	136 x 281 x 87.0	88.7	5.4
1966-90B (OPS 5345)	1966 Oct 12	Atlas Agena D	181 x 258 x 90.9	89.0	8.5
1966-98B (OPS 5424)	1966 Nov 2	Atlas Agena D	208 x 324 x 91.0	89.9	13.7
1967-50B (OPS 5557)	1967 May 22	Atlas Agena D	148 x 240 x 91.5	88.4	4.9



Titan III B, probably launched March 28, 1976. The source of the photo identifies the payload only as "Forward Satellite Vehicle Section", but it can be identified as a KH-8 GAMBIT satellite. (USAF photo courtesy Jack Hagerty)

1970 onwards require that the KH-8 GAMBIT had solar panels; NASA's SERT 2 satellite launched in 1970 had such solar panels attached to the Agena D aft rack.

The first few flights had lifetimes of one to two weeks; starting in 1970 this was gradually increased to three and then four weeks, with 30 day flights becoming standard in 1972. Program flights 56, 57, and 62 in 1968-69 are anomalous, with high apogees ranging from 730 to 1090 km. The 42nd KH-8 mission (GAMBIT program flight 80) in June 1974 saw a jump of mission duration to seven weeks. This jump probably corresponded to a major system upgrade, possibly including an extra recovery vehicle. By the time of the last GAMBIT flight in 1984, on-orbit life had been extended to four months (see table 16).

KH-9 HEXAGON

Flights of NRO's HEXAGON satellite began in 1971. Some analysts believe that HEXAGON was a USAF program, but it was implied at the CORONA Symposium that it was the successor to CORONA, which makes it likely that it was a CIA program. The Hexagon satellite, which was built by Lockheed, was probably still based on Agena hardware, although sufficiently different that the HEXAGON missions are not included in Lockheed's count of Agena flights. HEXAGON was a much larger satellite than CORONA, carrying two large cameras (the KH-9 system) and an enormous fuel tank for long duration with powerful twin solid rocket motors. Its intention was to combine high resolution with the wide area coverage of CORONA. The continued use of GAMBIT suggests that HEXAGON's resolution didn't match that of the Air Force satellite.

HEXAGON continued in use for 15 years, with the 18th flight reaching a record duration of 9 months in orbit. The final HEXAGON satellite was lost when its Titan 34D launch vehicle exploded after liftoff from Vandenberg in April 1986 (see table 17).

KH-11 KENNAN/CRYSTAL

In 1976 the dream of near-real-time surveillance from orbit finally came true as the NRO launched its first KH-11 satellite, Mission 5501. The satellite, a CIA-managed program, was the first imaging spysat to have TRW rather than Lockheed as its prime contractor. However, Lockheed is believed to have built its onboard propulsion system. The KH-11, initially code-named KENNAN, used a CCD (charge coupled device) digital imager and relayed its data via Satellite Data

Table 16
Gambit KH-8 Missions

Satellite	Mission No.	Agena No.	Date	Vehicle	Orbit	Period	Life (days)	Notes
GAMBIT 31	KH-8 1701	4751	1966 Jul 29	Titan IIIB Agena D	158 x 250 x 94.1	88.6	7	
GAMBIT 34	KH-8 1702?		1966 Sep 28	Titan IIIB Agena D	151 x 296 x 94.0	89.0	9.1	
GAMBIT 38	KH-8 1703?		1966 Dec 14	Titan IIIB Agena D	138 x 368 x 109.6	89.6	9	
GAMBIT 40	KH-8 1704?		1967 Feb 24	Titan IIIB Agena D	135 x 414 x 107.0	90.0	10.2	
GAMBIT 41	KH-8 1705?		1967 Apr 26	Titan IIIB Agena D	—	—	—	Titan stage 2 failed
GAMBIT 44	KH-8 1706?		1967 Jun 20	Titan IIIB Agena D	127 x 325 x 111.4	89.0	10.2	
GAMBIT 45	KH-8 1707?		1967 Aug 16	Titan IIIB Agena D	142 x 449 x 111.9	90.4	13	
GAMBIT 46	KH-8 1708?		1967 Sep 19	Titan IIIB Agena D	122 x 401 x 106.1	89.8	10.2	
GAMBIT 47	KH-8 1709?		1967 Oct 25	Titan IIIB Agena D	136 x 429 x 111.6	90.1	9	
GAMBIT 48	KH-8 1710?		1967 Dec 5	Titan IIIB Agena D	137 x 430 x 109.6	90.2	11.2	
GAMBIT 49	KH-8 1711?		1968 Jan 18	Titan IIIB Agena D	138 x 404 x 111.5	89.9	17.1	
GAMBIT 50	KH-8 1712?		1968 Mar 13	Titan IIIB Agena D	128 x 407 x 99.9	89.9	11	
GAMBIT 51	KH-8 1713?		1968 Apr 17	Titan IIIB Agena D	134 x 427 x 111.5	90.1	12	
GAMBIT 52	KH-8 1714?		1968 Jun 5	Titan IIIB Agena D	123 x 456 110.5	90.3	12.2	
GAMBIT 53	KH-8 1715?		1968 Aug 6	Titan IIIB Agena D	142 x 395 x 110.0	89.9	9	
GAMBIT 54	KH-8 1716?		1968 Sep 10	Titan IIIB Agena D	125 x 404 x 106.1	89.8	15	
GAMBIT 55	KH-8 1717?		1968 Nov 6	Titan IIIB Agena D	130 x 390 x 106.0	89.7	14	
GAMBIT 56	KH-8 1718?		1968 Dec 4	Titan IIIB Agena D	136 x 736 x 106.2	93.3	8	
GAMBIT 57	KH-8 1719?		1969 Jan 22	Titan IIIB Agena D	142 x 1090 x 106.2	97.0	12	
GAMBIT 58	KH-8 1720?		1969 Mar 4	Titan IIIB Agena D	134 x 461 x 92.0	90.5	14	
GAMBIT 59	KH-8 1721?		1969 Apr 15	Titan IIIB Agena D	135 x 410 x 108.8	90.0	15	
GAMBIT 60	KH-8 1722?		1969 Jun 3	Titan IIIB Agena D	137 x 414 x 110.0	90.0	11.2	
GAMBIT 61	KH-8 1723?		1969 Aug 22	Titan IIIB Agena D	133 x 366 x 108.0	89.5	16	
GAMBIT 62	KH-8 1724?		1969 Oct 24	Titan IIIB Agena D	136 x 740 x 108.0	93.4	15	
GAMBIT 63	KH-8 1725?		1970 Jan 14	Titan IIIB Agena D	134 x 383 x 110.0	89.7	18	
GAMBIT 64	KH-8 1726?		1970 Apr 15	Titan IIIB Agena D	130 x 388 x 111.0	89.7	21	
GAMBIT 65	KH-8 1727?		1970 Jun 25	Titan IIIB Agena D	129 x 389 x 108.9	89.7	11	
GAMBIT 66	KH-8 1728?		1970 Aug 18	Titan IIIB Agena D	151 x 365 x 111.0	89.7	16	
GAMBIT 67	KH-8 1729?		1970 Oct 23	Titan IIIB Agena D	135 x 396 x 111.1	89.8	19	
GAMBIT 68	KH-8 1730?		1971 Jan 21	Titan 23B Agena D	139 x 418 x 110.9	90.1	19	
GAMBIT 69	KH-8 1731?		1971 Apr 22	Titan 23B Agena D	132 x 401 x 110.9	89.9	21	
GAMBIT 70	KH-8 1732?		1971 Aug 12	Titan 23B Agena D	137 x 424 x 111.0	90.1	22	
GAMBIT 71	KH-8 1733?		1971 Oct 23	Titan 23B Agena D	134 x 416 x 110.9	90.0	25	
GAMBIT 72	KH-8 1734?		1972 Mar 16	Titan 23B Agena D	131 x 409 x 111.0	89.9	25	
GAMBIT 73	KH-8 1735?		1972 May 20	Titan 23B Agena D	—	—	—	Agena failed
GAMBIT 74	KH-8 1736?		1972 Sep 1	Titan 23B Agena D	140 x 380 x 110.5	89.7	29	
GAMBIT 75	KH-8 1737?		1972 Dec 21	Titan 23B Agena D	139 x 378 x 110.5	89.7	33	
GAMBIT 76	KH-8 1738?		1973 May 16	Titan 23B Agena D	136 x 352 x 110.5	89.4	28	
GAMBIT 77	KH-8 1739?		1973 Jun 26	Titan 23B Agena D	—	—	—	Agena failed
GAMBIT 78	KH-8 1740?		1973 Sep 27	Titan 23B Agena D	131 x 385 x 110.5	89.7	32	
GAMBIT 79	KH-8 1741?		1974 Feb 13	Titan 23B Agena D	134 x 393 x 110.4	89.8	32	
GAMBIT 80	KH-8 1742?		1974 Jun 6	Titan 23B Agena D	136 x 394 x 110.5	89.8	47	
GAMBIT 81	KH-8 1743?		1974 Aug 14	Titan 23B Agena D	135 x 402 x 110.5	89.9	46	
GAMBIT 82	KH-8 1744?		1975 Apr 18	Titan 23B Agena D	134 x 401 x 110.5	89.8	48	
GAMBIT 83	KH-8 1745?		1975 Oct 9	Titan 23B Agena D	125 x 356 x 96.4	89.3	52	
GAMBIT 84	KH-8 1746?		1976 Mar 22	Titan 23B Agena D	125 x 347 x 96.4	89.3	57	
GAMBIT 85	KH-8 1747?		1976 Sep 15	Titan 24B Agena D	135 x 330 x 96.4	89.2	51	
GAMBIT 86	KH-8 1748?		1977 Mar 13	Titan 23B Agena D	124 x 348 x 96.4	89.3	74	
GAMBIT 87	KH-8 1749?		1977 Sep 23	Titan 23B Agena D	125 x 352 x 96.5	89.3	76	
GAMBIT 88	KH-8 1750?		1979 May 28	Titan 24B Agena D	131 x 285 x 96.4	88.7	90	
GAMBIT 89	KH-8 1751?		1981 Feb 28	Titan 24B Agena D	138 x 336 x 96.4	89.3	112	
GAMBIT 90	KH-8 1752?		1983 Apr 15	Titan 24B Agena D	136 x 297 x 96.5	88.9	128	
GAMBIT 91	KH-8 1753?		1984 Apr 17	Titan 24B Agena D	127 x 311 x 96.4	88.9	118	

Table 17
HEXAGON (KH-9) Missions

Satellite	Mission No.	Date	Vehicle	Orbit	Period	Life (days)	Notes
HEXAGON 1	KH-9 1901	1971 Jun 15	Titan 23D	184 x 300 x 96.4	89.4	52	
HEXAGON 2	KH-9 1902?	1972 Jan 20	Titan 23D	157 x 331 x 97.0	89.4	40	
HEXAGON 3	KH-9 1903?	1972 Jul 7	Titan 23D	174 x 251 x 96.9	88.8	68	
HEXAGON 4	KH-9 1904?	1972 Oct 10	Titan 23D	160 x 281 x 96.5	88.9	90	
HEXAGON 5	KH-9 1905?	1973 Mar 9	Titan 23D	152 x 270 x 95.7	88.8	71	
HEXAGON 6	KH-9 1906?	1973 Jul 13	Titan 23D	156 x 269 x 96.2	88.8	91	
HEXAGON 7	KH-9 1907?	1973 Nov 10	Titan 23D	159 x 275 x 96.9	88.9	123	
HEXAGON 8	KH-9 1908?	1974 Apr 10	Titan 23D	153 x 285 x 94.5	88.9	109	
HEXAGON 9	KH-9 1909?	1974 Oct 29	Titan 23D	162 x 271 x 96.7	88.9	141	
HEXAGON 10	KH-9 1910?	1975 Jun 8	Titan 23D	154 x 269 x 96.4	88.8	150	
HEXAGON 11	KH-9 1911?	1975 Dec 4	Titan 23D	157 x 234 x 96.3	88.4	119	
HEXAGON 12	KH-9 1912?	1976 Jul 8	Titan 23D	159 x 242 x 97.0	88.5	158	
HEXAGON 13	KH-9 1913?	1977 Jun 27	Titan 23D	155 x 239 x 97.0	88.5	179	
HEXAGON 14	KH-9 1914?	1978 Mar 16	Titan 23D	160 x 240 x 96.4	88.5	179	
HEXAGON 15	KH-9 1915?	1979 Mar 16	Titan 23D	170 x 258 x 96.4	88.8	190	
HEXAGON 16	KH-9 1916?	1980 Jun 18	Titan 23D	169 x 265 x 96.5	88.9	261	
HEXAGON 17	KH-9 1917?	1982 May 11	Titan 23D	177 x 262 x 96.4	88.9	208	
HEXAGON 18	KH-9 1918?	1983 Jun 20	Titan 34D	169 x 229 x 96.5	88.5	275	
HEXAGON 19	KH-9 1919?	1984 Jun 25	Titan 34D	170 x 263 x 96.4	88.9	115	
HEXAGON 20	KH-9 1920?	1986 Apr 18	Titan 34D	-			Titan failed

System communications spacecraft to the ground.

At some point when the KENNAN name became public, no later than 1986, the code-name was changed to CRYSTAL. The KH-11 code-name became public much earlier, when spy William Kampiles was charged with selling the user's manual to the Soviet Union. All the KENNAN/CRYSTAL flights were successful except for a launch failure in 1985. Remarkably, the sixth spacecraft was still in orbit after almost 10 years and appeared to be at least partly operational, having moved to a higher orbit of 544 x 718 km as of October 1994. The last two spacecraft entered more eccentric orbits, with perigees as low as 150 km and apogees over 1000 km (see table 18).

The Hughes Satellite Data System spacecraft were used to relay the real-time data from the KENNAN/CRYSTAL satellites. They also carried transponders for US Air Force communications in polar regions, and were launched into Molniya-type 12 hour elliptical orbits. The identities of SDS satellites 4 and 5 are not certain—see the section on JUMPSEAT in Part II of this article. Two payloads launched from the Shuttle in 1989 and 1992 are believed to be second generation SDS satellites. They were deployed into low orbit and later made maneuvers to a higher orbit, presumably similar to the SDS Satellites (see table 19).

IMPROVED CRYSTAL

The KH-11 was the last series to get a KEYHOLE designation. To date, the secret successor to the KH-11 is known among analysts simply as IMPROVED CRYSTAL or ADVANCED KH-11. IMPROVED CRYSTAL was meant to be launched by the Shuttle from Vandenberg into polar orbit, but the West Coast Shuttle program was abandoned after the Challenger accident. The AFP-731 satellite deployed by the Shuttle into a 65 degree orbit in February 1990 on mission STS-36 is believed to be the first of the new imaging satellites. According to Aviation Week,[16] AFP-731 combines CIA digital imaging sensors and NSA signals intelligence receivers. Its orbit, derived from amateur observations, appears to be optimized for the signals intelligence role. The 65 degree inclination was necessary since the West Coast Titan 4 was not yet available, but the high perigee is a puzzle. A second satellite was launched from Vandenberg aboard a Titan 4 in 1992, into an orbit which is similar to that of the KH-11 satellites. It is believed to have replaced the eighth KH-11, which disappeared from orbit in June 1992 (see table 20).

LACROSSE

One of the main limitations of conventional imaging reconnaissance satellites is their inability to see through clouds. To get around this problem the NRO has developed satellites which use synthetic aperture radars which can make microwave images of the surface in all weather. The first code name rumored for this project was INDIGO; later it became known as LACROSSE, and subsequently it has been given a new name (suggested by J. Richelson to be Vega). I use the Lacrosse name here since the new name is not firmly established. An unusual Titan 3B mission in 1982 is thought to have been a testbed for LACROSSE technology; the first operational Lacrosse satellite was launched from Space Shuttle Atlantis in December 1988 (see table 21). **Q**

In the next issue of Quest: *Part II: Signals Intelligence satellites, Naval Intelligence Satellites, and Early Warning Satellites.*

References

The analysis presented here is the fruit of many useful conversations over the years with other analysts of the mil-

Table 18
KENNAN (KH-11) Missions

Satellite	Mission No.	Date	Vehicle	Orbit	Life (days)	Notes
KENNAN 1	KH-11 5501	1976 Dec 19	Titan 23D	258 x 450 x 96.9	770	
KENNAN 2	KH-11 5502	1978 Jun 14	Titan 23D	272 x 502 x 97.0	1166	
KENNAN 3	KH-11 5503	1980 Feb 7	Titan 23D	309 x 501 x 97.1	996	
KENNAN 4	KH-11 5504	1981 Sep 3	Titan 23D	277 x 524 x 97.0	1177	
KENNAN 5	KH-11 5505	1982 Nov 17	Titan 23D	280 x 520 x 97.0	1000	
KENNAN 6	KH-11 5506	1984 Dec 4	Titan 34D	300 x 650 x 97.1	>10 years?	
KENNAN 7	KH-11 5507	1985 Aug 28	Titan 34D	—	—	Titan failed
CRYSTAL 8	KH-11 5508	1987 Oct 26	Titan 34D	153 x 1029 x 97.8	1700?	
CRYSTAL 9	KH-11 5509	1988 Nov 6	Titan 34D	156 x 1012 x 97.9		

Table 19
SDS Missions

SAtellite	Desig.	Date	Vehicle	Orbit	Period
SDS 1	1976-50A	1976 Jun 2	Titan 34B Agena D	311 x 39192 x 62.5	700.0
SDS 2	1976-80A	1976 Aug 6	Titan 34B Agena D	350 x 39224 x 62.5	702.0
SDS 3	1978-21A	1978 Feb 25	Titan 34B Agena D	311 x 39377 x 63.2	702.8
SDS 4	1980-100A	1980 Dec 13	Titan 34B Agena D	250 x 39130 x 63.8	697.4
SDS 5	1983-78A	1983 Jul 28	Titan 34B Agena D	1028 x 39321 x 63.4	717.1
SDS 6	1985-14A	1985 Feb 8	Titan 34B Agena D	400 x 39700 x 63.0	712.6
SDS 7	1987-15A	1987 Feb 11	Titan 34B Agena D	610 x 39750 x 63.4	718.1
SDS II-1	1989-61B	1989 Aug 8	Shuttle	Orbit unknown	
SDS II-2	1992-86B	1992 Dec 2	Shuttle	Orbit unknown	

Table 20
IMPROVED CRYSTAL Missions

Satellite	Mission No.	Date	Vehicle	Orbit	Designation
IMP CRYSTAL 1? (USA-53)	Unknown	1990 Feb 28	Shuttle	797 x 811 x 65.0	1990-19B
IMP CRYSTAL 2 (USA-86)		1992 Nov 28	Titan 4	258 x 984 x 97.9	1992-83A

Table 21
LACROSSE Missions

Satellite	Mission	Date	Vehicle	Orbit	Life (days)	Designation
INDIGO?	Unknown	1982 Jan 21	Titan 23B AgenaD	553 x 646 x 97.3	122	1982-06A
LACROSSE 1		1988 Dec 2	Shuttle	657 x 686 x 57.0		1988-106B
LACROSSE 2		1991 Mar 8	Titan 4	672 x 676 x 68.0		1991-17A

itary space program. I would like to acknowledge discussions (from London pubs to Washington cocktail receptions!) with, among others, Nick Watkins, Mike Cassutt, Jeffrey Richelson, Peter Hunter, Joel Powell, Phil Clark, Rex Hall, and of course, Anthony Kenden.

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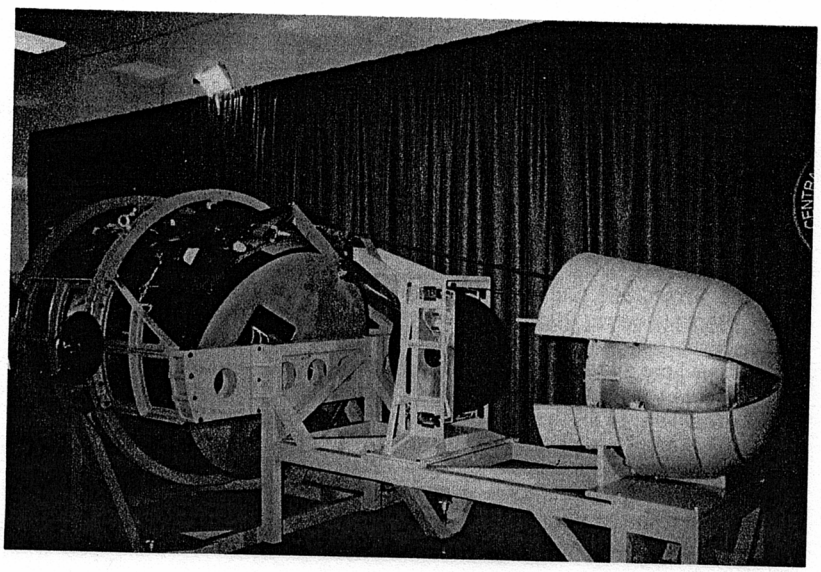

Inside a photoreconnaisance satellite: This KH-4B satellite was unveiled this spring when the CORONA program was declassified. (Photo by Dwayne A. Day)

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Vol. 4 No. 4

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U.S. Reconnaissance Satellite Programs Part 2: Beyond Imaging

Jonathan McDowell

In the first part of this article I discussed United States satellites used for imaging reconnaissance. I will now cover satellites used for other forms of surveillance; here the picture is much murkier, but it is still possible to establish the broad outlines of each program from the open literature.

The Mystery Launches of 1964

On the whole, analysts have been pretty successful at deducing the general mission of most military satellite launches, but there are a few which are harder to figure out. The launch of an Agena D satellite, FTV 2355 (OPS 3762) on December 21, 1964 is particularly mysterious. Its low orbit led previous analysts to lump it with the CORONA missions, but the orbit was not quite consistent with that assumption, and it is not included in the official list of 145 bona fide CORONA flights. It was revealed at the 1995 USAF Space History Symposium by General Bradburn, the launch commander, that the mission was successful and lasted four days. Other documentary evidence suggests that one recoverable capsule was carried. This was a one-off mission - it could possibly have been carrying out signals intelligence on a particular target. Another likely possibility is that it was a radiometric mission gathering data on infrared background radiation for programs like MIDAS, but none of the MIDAS histories refer to it and such missions were usually carried out within the CORONA program.

There were two other strange Thor-Agena D launches in January and June 1964, each of which placed a pair of satellite payloads in medium altitude sun-synchronous orbits. Each payload must have been relatively small—perhaps 100 kg or so. The small size and high altitude make an imaging intelligence mission unlikely, but the sun-synchronous orbit makes some kind of imaging payload probable. The obvious interpretation is that the satellites are early Defense Meteorological Satellite Program payloads.

The early DMSP flights are still classified, but it is known that five Block 1 satellites were launched in 1962-63 on Scout rockets, and that a later generation were launched on Thor Burner 1 rockets starting in 1965, so the 1964 flights would fit in well. However, unofficial sources familiar with the early DMSP program have denied that Thor Agena was ever used, which leaves me without a good candidate mission for the pair of twins. Suggestions to the correspondence pages of *Quest* are welcome.

Signals Intelligence Satellites

Program 102 Ferret Satellites

Signals intelligence (SIGINT) is kept even more secret than overhead photography. The earliest signals intelligence spacecraft, colloquially known as ferrets, were used to catalog the characteristics of air defense radars in the USSR; later spacecraft also carried out COMINT (interception of voice radio communications) and TELINT (interception of telemetry from test launches of missiles).

The first ferret program was Program 102 (also known as 698BK). Program 102 may originally have been managed by USAF under the framework of the SAMOS project on behalf

Unidentified Missions: FTV 2355 and the Twins

Satellite	Mission No.	Agena No.	Date	Vehicle	Orbit	Period	Notes
OPS 3762 (FTV 2355)	(1964-87A)	2355	1964 Dec 21	TAT Agena D	238 x 264 x 70.1	89.5	Mission unknown
OPS 3367A	(1964-02B)	-	1964 Jan 19	Thor Agena D	801 x 830 x 99		
OPS 3367B	(1964-02C)	-	1964 Jan 19	Thor Agena D	811 x 825 x 99		
OPS 4467A	(1964-31A)	-	1964 Jun 18	Thor Agena D	828 x 842 x 99.8		
OPS 4467B	(1964-31B)	-	1964 Jun 18	Thor Agena D	828 x 842 x 99.8		

Program 102 Missions

Satellite	Mission No.	Agena No.	Date	Vehicle	Orbit	Period	Notes
(Ferret 1)	Unknown	2301	1962 Feb 21	Thor Agena B	167 x 374 x 82.0	92.0	
(Ferret 2)		2312	1962 Jun 18	Thor Agena B	370 x 411 x 82.1	92.5	
(Ferret 3)		2313	1963 Jan 16	Thor Agena D	459 x 533 x 81.9	94.7	
(Ferret 4)		2314	1963 Jun 29	TAT Agena B	484 x 536 x 82.3	94.8	
(Ferret 5)		2316	1964 Feb 28	TAT Agena D	479 x 520 x 82.0	94.7	
(Ferret 6)		2315	1964 Jul 3	TAT Agena D	501 x 529 x 82.1	94.9	
(Ferret 7)		2317	1964 Nov 4	TAT Agena D	512 x 526 x 82.0	95.1	
(Ferret 8)		2702	1965 Jul 17	TAT Agena D	471 x 512 x 70.2	94.5	
(Ferret 9)		2703	1966 Feb 9	TAT Agena D	508 x 512 x 82.1	94.8	
(Ferret 10)		2731	1966 Dec 29	TAT Agena D	486 x 496 x 75.0	94.4	
(Ferret 11)		2732	1967 Jul 25	TAT Agena D	458 x 513 x 75.0	94.3	
(Ferret 12)		2733	1968 Jan 17	TAT Agena D	450 x 546 x 75.2	94.5	
(Ferret 13)			1968 Oct 5	Thorad Agena D	483 x 511 x 75.0	94.6	
(Ferret 14)			1969 Jul 31	Thorad Agena D	462 x 541 x 75.0	94.7	
(Ferret 15)			1970 Aug 26	Thorad Agena D	484 x 504 x 75.0	94.5	
(Ferret 16)			1971 Jul 16	Thorad Agena D	488 x 508 x 75.0	94.6	

of NSA. The first launch in February of 1962 was a partial failure[1] since its Agena B engine failed to restart to circularize the orbit; the resulting elliptical orbit was similar to a CORONA flight and led Klass and Kenden to misclassify it. Program 102 may have been redesignated Program 770 in 1965.

Ferret Subsatellites

The Agena based ferret satellites were supplemented by smaller subsatellites, originally based on the P-11 bus developed by Lockheed. These satellites were launched attached to the aft rack of the Agena and fired a solid rocket motor to enter a higher orbit than the host Agena. Three test flights were made with science payloads before flights with SIGINT receivers were begun.

The names in the "Satellite" column in the accompanying table are arbitrary designations, since no true code names for these missions are reliably known. Type A missions with the orig-

Ferret Subsatellite Type A Missions

Satellite	Desig.	Date	Vehicle	Orbit	Period	Host Sat	Notes
P-11 (1)	-	1963 Mar 18	TAT Agena D	-		KH-6 LANYARD	Science [3]
P-11 (2)	1963-25B	1963 Jun 27	TAT Agena D	333 x 4132 x 82.1	132.5	KH-4 CORONA	Science
(SS A3)	1963-42B	1963 Oct 29	TAT Agena D	285 x 585 x 90.0	93.4	KH-5 ARGON	
(SS A4)	1963-55B	1963 Dec 21	TAT Agena D	321 x 388 x 64.5	91.7	KH-4 CORONA	
(SS A5)	1964-36B	1964 Jul 6	Atlas Agena D	297 x 377 x 93.0	91.2	KH-7 GAMBIT	
P-11 (6)	1964-45B	1964 Aug 14	Atlas Agena D	275 x 3748 x 95.7	127.4	KH-7 GAMBIT	Science
(SS A7)	1964-68B	1964 Oct 23	Atlas Agena D	323 x 336 x 95.5	91.1	KH-7 GAMBIT	

Ferret Subsatellite Type B Missions

Satellite	Desig.	Date	Vehicle	Orbit	Period	Host Sat	Notes
(SS B1)	1965-31B	1965 April 28	Atlas Agena D	490 x 509 x 95.3	95.2	KH-7 GAMBIT	
(SS B2)	1965-50A	1965 Jun 25	Atlas Agena D	496 x 510 x 107.7	94.7	KH-7 GAMBIT	
(SS B3)	1965-62B	1965 Aug 3	Atlas Agena D	501 x 515 x 107.4	94.8	KH-7 GAMBIT	
(SS B4)	1966-39B	1966 May 14	Atlas Agena D	517 x 559 x 109.9	95.4	KH-7 GAMBIT	
(SS B5)	1966-74B	1966 Aug 16	Atlas Agena D	510 x 524 x 93.2	95.0	KH-7 GAMBIT	
(SS B6)	1966-83B	1966 Sep 16	Atlas Agena D	460 x 501 x 94.1	94.3	KH-7 GAMBIT	
(SS B7)	1967-43B	1967 May 9	Thorad Agena D	555 x 809 x 85.1	98.4	KH-4A CORONA	
(SS B8)	1967-62B	1967 Jun 16	Thorad Agena D	501 x 517 x 80.2	94.8	KH-4A CORONA	
(SS B9)	1967-109B	1967 Nov 2	Thorad Agena D	455 x 524 x 81.7	94.4	KH-4A CORONA	
(SS B10)	1968-08B	1968 Jan 24	Thorad Agena D	473 x 542 x 81.7	94.8	KH-4A CORONA	
(SS B11)	1968-20B	1968 Mar 14	Thorad Agena D	481 x 522 x 83.1	94.7	KH-4A CORONA	
(SS B12)	1968-52B	1968 Jun 20	Thorad Agena D	437 x 519 x 85.2	94.2	KH-4A CORONA	
(SS B13)	1968-78B	1968 Sep 18	Thorad Agena D	500 x 514 x 83.2	94.8	KH-4A CORONA	
(SS B14)	1969-26B	1969 Mar 19	Thorad Agena D	504 x 513 x 83.1	94.8	KH-4A CORONA	
(SS B15)	1969-41B	1969 May 2	Thorad Agena D	401 x 473 x 65.7	93.4	KH-4A CORONA	
(SS B16)	1969-79B	1969 Sep 22	Thorad Agena D	490 x 496 x 85.2	94.5	KH-4A CORONA	
(SS B17)	1969-82A	1969 Sep 30	Thorad Agena D	446 x 484 x 69.6	93.9	NRL SURCAL	
(SS B18)	1970-16B	1970 Mar 4	Thorad Agena D	442 x 514 x 88.1	94.2	KH-4B CORONA	
(SS B19)	1970-40B	1970 May 20	Thorad Agena D	491 x 503 x 83.1	94.6	KH-4B CORONA	
(SS B20)	1970-98B	1970 Nov 18	Thorad Agena D	487 x 511 x 83.2	94.6	KH-4B CORONA	
(SS B21)	1971-76B	1971 Sep 10	Thorad Agena D	492 x 507 x 75.1	94.6	KH-4B CORONA	
(SS B22)	1972-02D	1972 Jan 20	Titan 23D	472 x 549 x 96.6	94.9	KH-9 HEXAGON	
(SS B23)	1972-52C	1972 Jul 7	Titan 23D	497 x 504 x 96.2	94.7	KH-9 HEXAGON	
(SS B24)	1973-88B	1973 Nov 10	Titan 23D	486 x508 x 96.3	94.6	KH-9 HEXAGON	
(SS B25)	1974-20C	1974 April 10	Titan 23D	503 x 531 x 94.0	95.0	KH-9 HEXAGON	
(SS B26)	1974-85B	1974 Oct 29	Titan 23D	520 x 535 x 96.1	95.2	KH-9 HEXAGON	

Ferret Subsatellite Type C Missions

Satellite	Desig.	Date	Vehicle	Orbit	Period	Host Sat	Notes
(SS C1)	1968-112B	1968 Dec 12	Thorad Agena D	1391 x 1468 x 80.3	114.5	KH-4A CORONA	
(SS C2)	1969-10B	1969 Feb 5	Thorad Agena D	1396 x 1441 x 80.4	114.2	KH-4B CORONA	
(SS C3)	1972-79C	1972 Oct 10	Titan 23D	1423 x 1469 x 95.6	114.8	KH-9 HEXAGON	
(SS C4)	1973-88D	1973 Nov 10	Titan 23D	1419 x 1458 x 96.9	114.6	KH-9 HEXAGON	
(SS C5) SSU-A	1975-51C	1975 Jun 8	Titan 23D	1389 x 1401 x 95.1	113.7	KH-9 HEXAGON	
(SS C6)	1980-52C	1980 Jun 18	Titan 23D	1331 x 1333 x 96.6	112.3	KH-9 HEXAGON	
(SS C7)	1983-60C	1983 Jun 20	Titan 23D	1289 x 1291 x 96.7	111.4	KH-9 HEXAGON	

Ferret Subsatellite Type D Missions

Satellite	Desig.	Date	Vehicle	Orbit	Period	Host Sat	Notes
(SS D1)	1976-65C	1976 Jul 8	Titan 23D	628 x 632 x 96.4	97.3	KH-9 HEXAGON	
(SS D2)	1978-29B	1978 Mar 16	Titan 23D	639 x 645 x 95.8	97.6	KH-9 HEXAGON	
(SS D3)	1979-25B	1979 Mar 16	Titan 23D	621 x 628 x 95.8	97.2	KH-9 HEXAGON	
(SS D4)	1982-41C	1982 May 11	Titan 23D	701 x 707 x 96.0	98.9	KH-9 HEXAGON	
(SS D5)	1984-65C	1984 Jun 25	Titan 34D	689 x 711 x 96.1	98.8	KH-9 HEXAGON	
(SS D6)	-	1986 April 18	Titan 34D	-		KH-9 HEXAGON	Titan failed

Unidentified Subsatellite

Satellite	Desig.	Date	Vehicle	Orbit	Period	Notes
USA-41	1989-61C	1989 Aug 8	Shuttle	296 x 307 x 57.0	90.5	-

inal P-11 satellite entered relatively low orbits with perigees around 300 km. Type B missions followed in 1965, with 500 km orbits similar to the Program 102 Ferret satellites. Type C missions, which began in 1968, were placed in higher 1200-1400 km orbits, and are believed to monitor Soviet anti-ballistic missile radars.[2] In 1976 the low orbit type B missions changed to a slightly higher 600-700 km altitude, which I have designated type D.

It is not known how many ferret subsatellites were lost in launch failures. Based on the pattern of launches, failed Type A subsatellites might have been carried on the TAT Agena D failures of 9 November 1963 and 24 Mar 1964. Type B/C subsatellites might have been on the Atlas launch of 12 July 1965, or the Thorad Agena launch of 17 February 1971. It is assumed that a Type D subsatellite was lost in the failure of a Titan 34D in April 1986.

Finally, a small satellite was deployed from the Shuttle in August of 1989. The USA-41 satellite may have been related to the ferret subsatellites, or it might (as suggested to me by J. Richelson) be related to the Defense Intelligence Agency's COBRA BRASS measurement and signature intelligence (MASINT) experiment.

Titan II Ferrets

These satellites were launched by refurbished Titan II ICBM's into polar orbit from Vandenberg. Their orbit makes it likely that they are for signals intelligence, although some kind of imaging mission is also possible. The satellites enter a low, 200 km orbit together with the Titan II second stage. An attached rocket motor raises the orbit to its operational 800 km altitude. A Russian report claimed that the second satellite, USA-45, reentered from the initial parking orbit because of the failure of its motor.

JUMPSEAT

SIGINT satellites are the most highly classified variety of US spacecraft, and JUMPSEAT is among the most secret or "black" of all. Its existence was mentioned by Jane's All The World's Aircraft (1970-71) (and referenced by Kenden) as AFP-711, a highly elliptical orbit Titan 3 launched heavy ferret built by Hughes. However Kenden noted that no such launches had taken place as of 1978—he and other observers were fooled by the cover story that the series of launches which began in 1971 were part of a comsat program.

Orbital data in the table is based on submissions to the United Nations. The orbit for JUMPSEAT 6 is probably not the final orbit. The identification of JUMPSEAT and SDS satellites is not definite, and in particular the pairs SDS 3/JUMPSEAT 5 and SDS 4/JUMPSEAT 6 may be switched. Klass[4] identified the February 1978 and December 1980 launches as Jumpseat rather than SDS, but omitted discussion of the August 1978 and April 1981 launches.

Titan II Ferrets

Satellite	Desig.	Date	Vehicle	Orbit
USA-32	1988-78A	1988 Sep 5	Titan 23G	786 x 794 x 85.0
USA-45	1989-72A	1989 Sep 5	Titan 23G	
USA-81	1992-23A	1992 April 22	Titan 23G	800 x 800 x 85.0 ?

Jumpseat Missions

Satellite	Desig.	Date	Vehicle	Orbit	Period
JUMPSEAT 1	1971-21A	1971 Mar 21	Titan 23B Agena D	328 x 39264 x 63.2	701.8
JUMPSEAT 2	-	1972 Feb 16	Titan 23B Agena D	-	
JUMPSEAT 3	1973-56A	1973 Aug 21	Titan 23B Agena D	392 x 39132 x 63.3	701.0
JUMPSEAT 4	1975-17A	1975 Mar 10	Titan 34B Agena D	295 x 39338 x 63.5	702.0
JUMPSEAT 5	1978-75A	1978 Aug 5	Titan 34B Agena D	315 x 39053 x 62.5	697.1
JUMPSEAT 6	1981-38A	1981 April 24	Titan 34B Agena D	188 x 708 x 62.7	93.0

CANYON Missions

Satellite	Desig.	Date	Vehicle	Orbit	Period
CANYON 1	1968-63A	1968 Aug 6	Atlas Agena D	31680 x 39862 x 9.9	1436.0
CANYON 2	1969-36A	1969 Apr 12	Atlas Agena D	32672 x 39251 x 10.2	1436.0
CANYON 3	1970-69A	1970 Sep 1	Atlas Agena D	31947 x 39855 x 10.3	1441.9
CANYON 4	-	1971 Dec 4	Atlas Agena D	-	
CANYON 5	1972-101A	1972 Dec 20	Atlas Agena D	31012 x 40728 x 9.7	1440.4
CANYON 6	1975-55A	1975 Jun 18	Atlas Agena D	30200 x 40800 x 9.0	1422.0
CANYON 7	1977-38A	1977 May 23	Atlas Agena D	34325 x 34500 x (0.3?)	1440.0

CANYON

Another NSA/USAF satellite program which was successfully hidden for decades was CANYON (Program 827), the first geosynchronous signals intelligence satellite. The CANYON satellites, which were used to intercept communications,[5] were launched by Atlas Agena D rockets from Cape Canaveral into distinctive near-geostationary elliptical orbits. They were misidentified by Kenden and other analysts as infrared missile early warning satellites in the Defense Support Program. Further confusion arose from the erroneous report that 1975-55A was launched by a Titan 3C. CANYON and RHYOLITE launches can be distinguished using reference 6, except for the 1977 launches. The May 1977 launch is identified as a CANYON on the basis of the size of the nose shroud in launch photos, although fragment 1977-38C is registered with the UN in a synchronous orbit with an inclination of 0.3 degrees instead of the higher inclination expected from a CANYON mission.

RHYOLITE

Better known than CANYON is the CIA's geostationary signals intelligence satellite, RHYOLITE, which was used for telemetry interception.[7] RHYOLITE became notorious after the trial of spies Lee and Boyce in 1977; they had sold the secrets of RHYOLITE to the Soviets. Program 720 RHYOLITE was thus renamed Program 472 AQUACADE.

VORTEX, MAGNUM and ORION

Program 366 CHALET (renamed VORTEX after the CHALET name was leaked in 1979) was the COMINT successor to CANYON. Launched to geostationary orbit by Titan 3C, they were originally confused with the DSP early warning satellites, but the secrecy surrounding their launches and the absence of the scientific radiation monitor payloads which were carried aboard the DSP's alerted analysts to the fact that a new series of satellites was aloft. It appears that their orbits were elliptical and inclined, like CANYON. A rumor that VORTEX 4 had a Transtage failure and was stranded in transfer orbit was incorrect, and arose from the DoD's practice of only announcing the transfer and not the final orbit. However, it appears that VORTEX 5 did indeed fail to reach its final orbit, and six years later a number of debris objects in transfer orbit were cataloged as coming from the 1988-77 launch.

The CIA RHYOLITE telemetry interception satellites were replaced by the larger MAGNUM payloads launched by the Shuttle. The payloads were inserted into geostationary orbit by a two stage solid IUS rocket. After the MAGNUM codename was leaked, the name was reportedly changed to ORION. Now that has been leaked, the name is presumably changed once again.

An advanced geostationary signals intelligence satellite, possibly replacing both MAGNUM/ORION and VORTEX, was developed for launch on the Titan 4 Centaur. Two appear to have been orbited to date. I will call the program ADVANCED ORION for lack of a better name. The second launch has a larger shroud than the first, and may be a different program.

A heavy payload was launched into a JUMPSEAT-type orbit in May 1994 by a Titan 4 Centaur rocket. It is tentatively assumed that this spacecraft is a signals intelligence satellite, which I refer to as ADVANCED JUMPSEAT because of its orbit. However, it is not clear if their is any relation between the mission of the new satellite and the old JUMPSEAT series. A second payload of this type was launched in July of 1995 (since this article was submitted to Quest, the author has informed us that the correct codename has been revealed to be "TRUMPET."—*ed.*)

US Naval Intelligence Satellites

NRL Elint Satellites

A number of classified satellites launched by the Naval Research Laboratory may have carried electronic intelligence (elint) payloads. These small satellites had masses between 20 and 50 kg. In the official list of NRL satellite launches[8] a number of classified satellites are identified as "gravity gradient experiments" in addition to the unclassified GGSE flights. It is probable that these flights are technology precursors to the PARCAE interferometer system (see below) and possible that they also carried elint payloads. The table of NRL elint satellites should be considered as provisional as the identification of the payloads in NRL's multiple launches remains uncertain.

RHYOLITE Missions

Satellite	Desig.	Date	Vehicle	Orbit	Period
RHYOLITE 1	1970-46A	1970 Jun 19	Atlas Agena D	35804 x 35863 x 0.1	1426.5
RHYOLITE 2	1973-13A	1973 Mar 6	Atlas Agena D	35855 x 36679 x 0.2	1435.0
AQUACADE 3	1977-114A	1977 Dec 11	Atlas Agena D		
AQUACADE 4	1978-38A	1978 Apr 8	Atlas Agena D		

PARCAE

The US Navy's only major space reconnaissance system, the Naval Ocean Surveillance System or PARCAE used a cluster of three subsatellites. The satellites were released from a dispenser attached to the upper stage, designated object A in the RAE Table; object B is a plume shield and not a rocket as reported elsewhere. The dispenser may carry a secondary payload which operates for about a month, but is not an active part of the subsatellite interferometry system or a "main" satellite, although it is assigned a USA code name. The subsatellites maintain precisely known distances to each other, to locate surface shipping by interferometric measurements of their radio transmissions. PARCAE is also known by the unclassified nickname WHITE CLOUD. The satellites are built by Martin Marietta, although the first two flight systems were built by the Naval Research Laboratory. The system arose from gravity gradient experiments carried out by NRL in the 1960s.

A second generation NOSS system uses triplets of satellites launched by Titan 4 rockets. There is some evidence that the A object from each launch is a separate payload in a lower orbit, and the second table gives amateur-observed orbits for these objects. USA-59 was first launched into a 250 km altitude orbit, and was then observed in a 450 km one; the triple cluster was then seen in an 1100 km orbit. The dual orbit change strongly suggests the deployment of another payload in the 450 km orbit. Furthermore, the cargo capacity of the Titan 4 to this orbit is around 15000 kg, compared to under 2000 kg expected for NOSS. Against this, only four USA code numbers were assigned, corresponding to the expected three subsatellites and the upper stage dispenser.

The USA code numbers are assigned to each DoD satellite by Space Command in the order that they are tracked and cataloged, which explains why the numbers are not always in sequence. The first launch of the series was from Cape Canaveral, with the subsequent ones from Vandenberg. The third payload was destroyed when its Titan 4 launch vehicle failed.

VORTEX Missions

Satellite	Desig.	Date	Vehicle	Orbit	Period
CHALET 1	1978-58A	1978 Jun 10	Titan IIIC	29929 x 42039 x 12	1446.3
VORTEX 2	1979-86A	1979 Oct 1	Titan IIIC	30443 x 41497 x 7.5	1445.5
VORTEX 3	1981-107A	1981 Oct 31	Titan IIIC		
VORTEX 4	1984-09A	1984 Jan 31	Titan 34D/Transtage		
VORTEX 5	1988-77A	1988 Sep 2	Titan 34D/Transtage	465 x 39449 x 26.7	708.9
VORTEX 6	1989-35A	1989 May 10	Titan 34D/Transtage		

MAGNUM Missions

Satellite	Desig.	Date	Vehicle	Orbit	Notes
MAGNUM 1	1985-10B	1985 Jan 24	Shuttle/IUS	Geostationary	
ORION 2	1989-90B	1989 Nov 23	Shuttle/IUS	Geostationary	

ORION and ADVANCED JUMPSEAT Missions

Satellite	Desig.	Date	Vehicle	Orbit	Period
ADV ORION 1	1994-54A	1994 Aug 27	Titan 401/Centaur	Geostationary	
ADV ORION 2	1995-22A	1995 May 14	Titan 401/Centaur	Geostationary	
ADV. JUMPSEAT 1	1994-26A	1994 May 3	Titan 401/Centaur	1323 x 39034 x 64.4	717.9
ADV. JUMPSEAT 2	1995-34A	1995 Jul 10	Titan 401/Centaur		

Early Warning Satellites

MIDAS

The final component of the original WS-117L system was the ability to detect enemy missile launches. The missile warning program seems to have stayed entirely with USAF rather than being made an NRO responsibility, but I have included it here for complete-

(a) Probable NRL Elint Flights

Satellite	Date	Orbit	Period	Desig.	Notes
NRL PL 120	1962 Dec 13	231 x 2786 x 70.4	116.3	1962 βτ 1	
NRL PL 121	1962 Dec 13	229 x 2785 x 70.3	116.2	1962 βτ 5	
NRL PL 112	1963 Jun 15	181 x 829 x 69.9	94.8	1963-21E	
NRL PL 135	1964 Jan 11	905 x 934 x 69.9	103.5	1964-01E	
NRL PL 142	1965 Mar 9	910 x 939 x 70.1	103.5	1965-16A	Possibly scientific
NRL PL 176	1969 Sep 30	906 x 940 x 70.0	103.5	1969-82G	Classified

(b) NRL Classified Gravity Gradient Experiments

NRL PL 151	1967 May 31	915 x 927 x 69.9	103.4	1967-53G	Grav grad
NRL PL 153	1967 May 31	915 x 926 x 69.9	103.4	1967-53H	Grav grad
NRL PL 161	1969 Sep 30	906 x 941 x 70.0	103.5	1969-82B	Grav grad
NRL PL 162	1969 Sep 30	907 x 940 x 70.0	103.5	1969-82D	Grav grad
NRL PL 163	1969 Sep 30	906 x 941 x 70.0	103.5	1969-82E	Grav grad
NRL PL 164	1969 Sep 30	906 x 940 x 70.0	103.5	1969-82F	Grav grad
NRL PL 171	1971 Dec 14	983 x 999 x 70.0	104.9	1971-110A	Grav grad
NRL PL 172	1971 Dec 14	983 x 999 x 70.0	104.9	1971-110C	Grav grad
NRL PL 173	1971 Dec 14	982 x 997 x 70.0	104.9	1971-110D	Grav grad
NRL PL 174	1971 Dec 14	981 x 997 x 70.0	104.9	1971-110E	Grav grad

ness.

The first USAF satellite to test a missile warning capability was MIDAS, built around the Agena spacecraft. Unfortunately, the system was plagued with false alarms and was temporarily abandoned. A second generation MIDAS also known as the Research Test Series was flown in 1966, and contributed to the design of the later successful DSP program. The first RTS satellite, MIDAS 10 or FTV 1351, was stranded in transfer orbit when its Agena failed to restart, but the other two appear to have been successful.

DSP

The first successful infrared early warning satellites were TRW's Program 647 Defense Support System or DSP satellites,[7,9] which used spinning infrared Schmidt telescopes from geostationary orbit. The first DSP was launched in November of 1970, but a failure of the Transtage upper stage left it in sub-synchronous orbit. Nevertheless, some tests were carried out. The next three launches were stationed over the Indian Ocean, Panama, and the Pacific respectively, completing the Block 1 constellation. A launch in 1975 failed shortly after it reached geosynchronous orbit when a fuel line ruptured. Flights continued into the 1980's, and in 1989 the first of a new generation was orbited, the Block 14 DSP, on the initial flight of the Titan 4 rocket.

Comments

With the Cold War over, the veil on early US military activities in space is beginning to lift. It is already clear that space assets played an important stabilizing role by showing that the worst fears of a missile gap were unfounded, and later by providing the confidence that hostile preparations would be detected and that some level of arms control verification was possible. The huge sums of money expended on military spaceborne intelligence may be offset by the even huger sums that might otherwise have been spent on extra offensive weapons to cover worst-case scenarios. Much as the enormous arms race of the Cold War affected the American economy and American society, it was less extreme than envisaged by some military planners prior to the first CORONA photos arriving to dampen the missile gap paranoia. As we enter a period when the US intelligence community in general and the NRO in particular is facing significant budget cutbacks, we need an understanding of the history of space

PARCAE Flights

Satellite	Subsats	Date	Vehicle	Orbit	Desig.
PARCAE 1	SSU 1-3	1976 Apr 30	Atlas F	1092 x 1128 x 63	1976-38A,C,D,J
PARCAE 2	SS 1-3	1977 Dec 8	Atlas F	1054 x 1169 x 63	1977-112A,D,E,F
PARCAE 3	EP 1-3	1980 Mar 3	Atlas F	1048 x 1166 x 63	1980-19A,C,D,G
PARCAE 4	-	1980 Dec 9	Atlas E	-	
PARCAE 5	SS A-C	1983 Feb 9	Atlas H	1052 x 1168 x 63	1983-08A,E,F,H
PARCAE 6	GB 1-3	1983 Jun 9	Atlas H	1051 x 1170 x 63	1983-56A,C,D,G
PARCAE 7	JD 1-3	1984 Feb 5	Atlas H	1052 x 1172 x 63.4	1984-12A,C,D,F
PARCAE 8	USA 15-18	1986 Feb 9	Atlas H	1049 x 1166 x 63.0	1986-14A,E,F,H
PARCAE 9	USA 22-25	1987 May 15	Atlas H	1045 x 1179 x 63	1987-43A,E,F,H

Advanced NOSS Flights

Cluster	Subsats	Date	Vehicle	Orbit	Desig.
NOSS II-1	USA-60, USA-61, USA-63	1990 Jun 7	Titan 4	1067 x 1150 x 63.4	1990-50B,C,D
NOSS II-2	USA-74, USA-76, USA-77	1991 Nov 7	Titan 4	1052 x 1164 x 63.4	1991-76C,D,E
NOSS II-3		1993 Aug 2	Titan 4	-	

Advanced NOSS main payloads (provisional)

Satellite	USA Desig.	Date	Vehicle	Orbit	Desig.
?	USA-59	1990 Jun 7	Titan 4	447 x 447 x 61.0	1990-50A
?	USA-72	1991 Nov 7	Titan 4	300 x 590 x 63.5	1991-76A

MIDAS Flights

Satellite	Agena No.	Date	Vehicle	Orbit	Period	Notes
MIDAS 1	1008	1960 Feb 26	Atlas Agena A	-		Agena failed
MIDAS 2	1007	1960 May 24	Atlas Agena A	484 x 511 x 33.0	94.4	
MIDAS 3	1201	1961 Jul 12	Atlas Agena B	3358 x 3534 x 91.2	161.5	
MIDAS 4	1202	1961 Oct 21	Atlas Agena B	3496 x 3756 x 95.9	166.0	
MIDAS 5	1203	1962 April 9	Atlas Agena B	2814 x 3382 x 86.7	153.0	
MIDAS 6	1205	1962 Dec 17	Atlas Agena B	-		Atlas failed
MIDAS 7	1206	1963 May 9	Atlas Agena B	3604 x 3680 x 87.4	166.5	
MIDAS 8	1204	1963 Jun 12	Atlas Agena B	-		Atlas failed
MIDAS 9	1207	1963 Jul 18	Atlas Agena B	3670 x 3727 x 88.4	167.8	
MIDAS 10	1351	1966 Jun 9	Atlas Agena D	174 x 3616 x 90.0	124.9	Agena Failed
MIDAS 11	1352	1966 Aug 19	Atlas Agena D	3680 x 3700 x 90.1	167.6	
MIDAS 12	1353	1966 Oct 5	Atlas Agena D	3682 x 3702 x 90.2	167.6	

intelligence, with both its successes and failures. In these articles I have tried to provide a summary of the scope and nature of the US reconnaissance satellite programs, which I hope will serve as a useful backdrop for the policy analyses being carried out by other researchers.

Notes:

In Part 1, the launch date of Discoverer 4 should read 1959 Jun 25.

Part 1 of this article described the Improved CRYSTAL imaging reconnaissance satellites. A third satellite in that series was launched on December 5, 1995, into a 156 x 976 km x 98.7° orbit.

A payload launched by the Space Shuttle in November of 1990, USA-67, is still a mystery. It will be discussed in a later issue of *Quest*.

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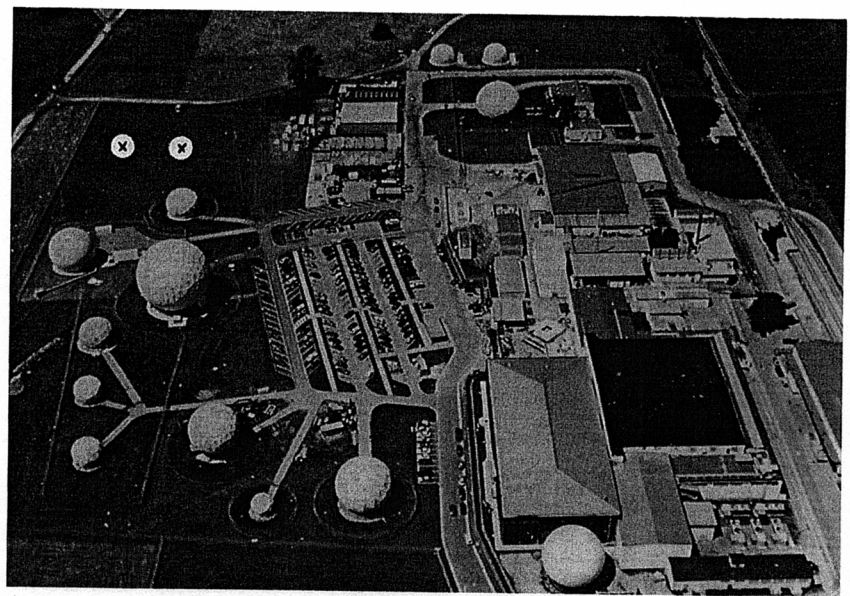

A rare photo of the secret National Security Agency Intelligence station at Bad Aibling, Germany. The large radar domes ("golfballs") are used to receive and relay transmissions from the NRO's constellation of signal intelligence satellites (SIGINTs). These may also be used to intercept signals from civilian communication satellites and Russian spacecraft. This facility is operated by the U.S. Army. Two additional golfballs have been constructed at the Bad Aibling installation (at the two crosses) since this photo was taken, probably to support the NRO's new geosynchronous SIGNITS. Photo originally appeared in the July 1995 issue of "Communications World" and reprinted with permission.

DSP Flights

Flight	Satellite (Production)	Desig.	Date	Vehicle	Orbit	Period
DSP F1	DSP 1	1970-93A	1970 Nov 6	Titan IIIC	26050 x 35886 x 7.8	1197.1
DSP F2	DSP 2	1971-39A	1971 May 5	Titan IIIC	35651 x 35840 x 0.9	1434.0
DSP F3	DSP 3	1972-10A	1972 Mar 1	Titan IIIC	35416 x 35962 x 0.2	1429.9
DSP F4	DSP 4	1973-40A	1973 Jun 12	Titan IIIC	35777 x 35786 x 0.3	1435.9
DSP F5	DSP 7	1975-118A	1975 Dec 14	Titan IIIC	35671 x 35785 x 3.0	1436.0
DSP F6	DSP 8	1976-59A	1976 Jun 26	Titan IIIC	35620 x 35860 x 0.5	1433.3
DSP F7	DSP 9	1977-07A	1977 Feb 6	Titan IIIC	35532 x 35755 x 0.1	1436.0
DSP F8	DSP 11	1979-53A	1979 Jun 10	Titan IIIC	35712 x 35854 x 1.8	1435.9
DSP F9	DSP 10	1981-25A	1981 Mar 16	Titan IIIC	35463 x 35527 x 2.0	1421.2
DSP F10	DSP 13	1982-19A	1982 Mar 6	Titan IIIC	35520 x 35598 x 2.0	1424.4
DSP F11	DSP 12	1984-37A	1984 April 14	Titan 34D/Transtage	35530 x 35530x 1.3	1423.0
DSP F12	DSP 6R	1984-129A	1984 Dec 22	Titan 34D/Transtage	35915 x 36190 x 3.4	1445.8
DSP F13	DSP 5R	1987-97A	1987 Nov 28	Titan 34D/Transtage	35514 x 35558 x 2.9	1423.3
DSP F14	DSP 14	1989-46A	1989 Jun 14	Titan 4/IUS	35614 x 35699 x 3.1	1421.8
DSP F15	DSP 15	1990-95A	1990 Nov 13	Titan 4/IUS	35614 x 35699 x 3.1	1421.8
DSP F16	DSP 16	1991-80B	1991 Nov 25	Shuttle/IUS	35795 x 35787 x 2.5	1421.9
DSP F17	DSP 17	1994-84A	1994 Dec 22	Titan 4/IUS		