HEXAGON

Keeping watch over the cold war threat.

HEXAGON

The HEXAGON program was initiated to satisfy the US intelligence need for a broad area medium resolution system to collect across the 8-million square miles of denied area during the critical Cold War build up. The program conceived in 1964 achieved first operational launch in June 1971. The final design was a 52-ft long and 10-ft diameter satellite, twice the diameter of the previous Agena based CORONA & GAMBIT satellites.

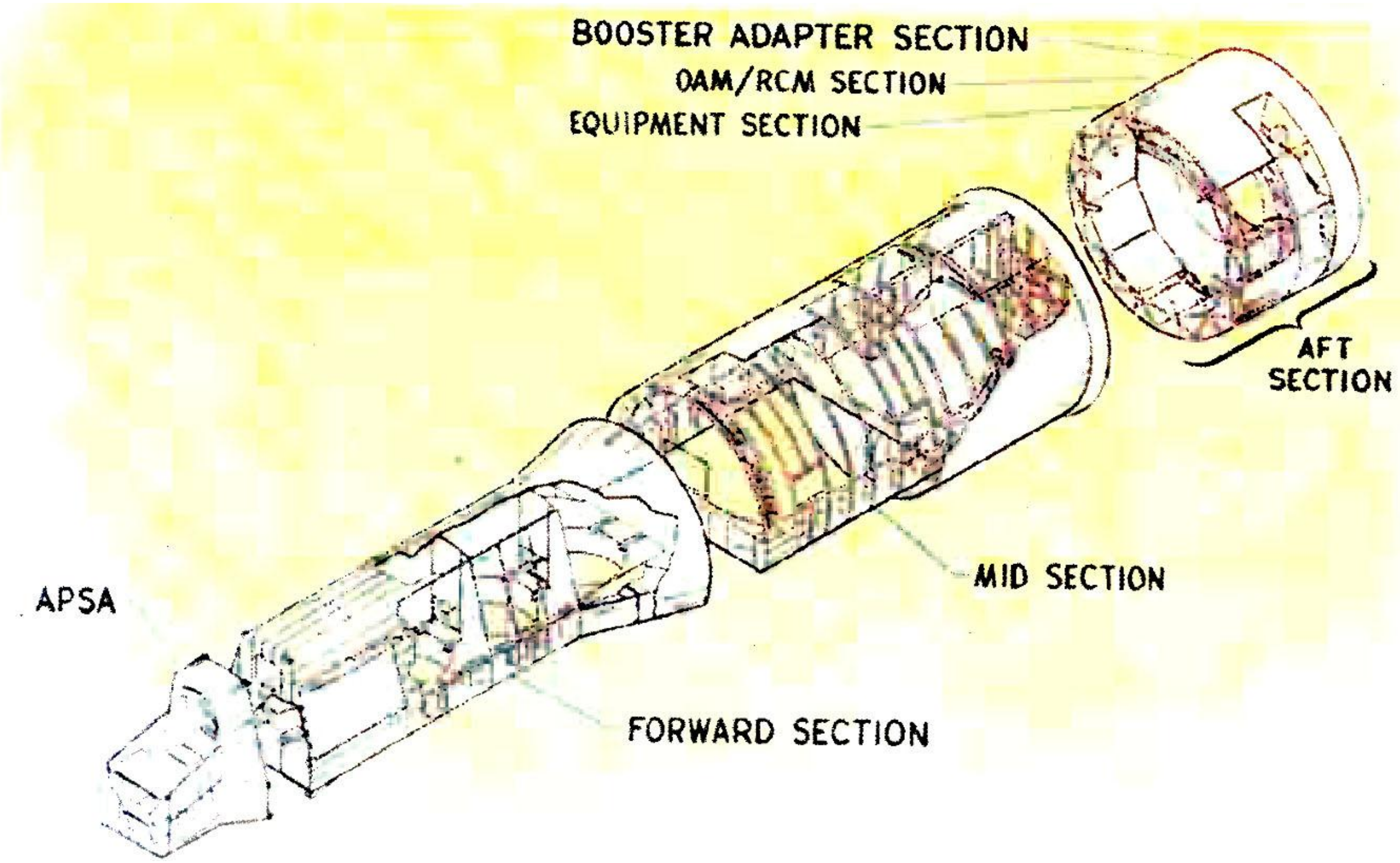
Participating Contractors = Aerospace, Eastman Kodak, General Electric, Itek, Lockheed, McDonnell Douglas, Perkin-Elmer, Raytheon, RCA & TRW.

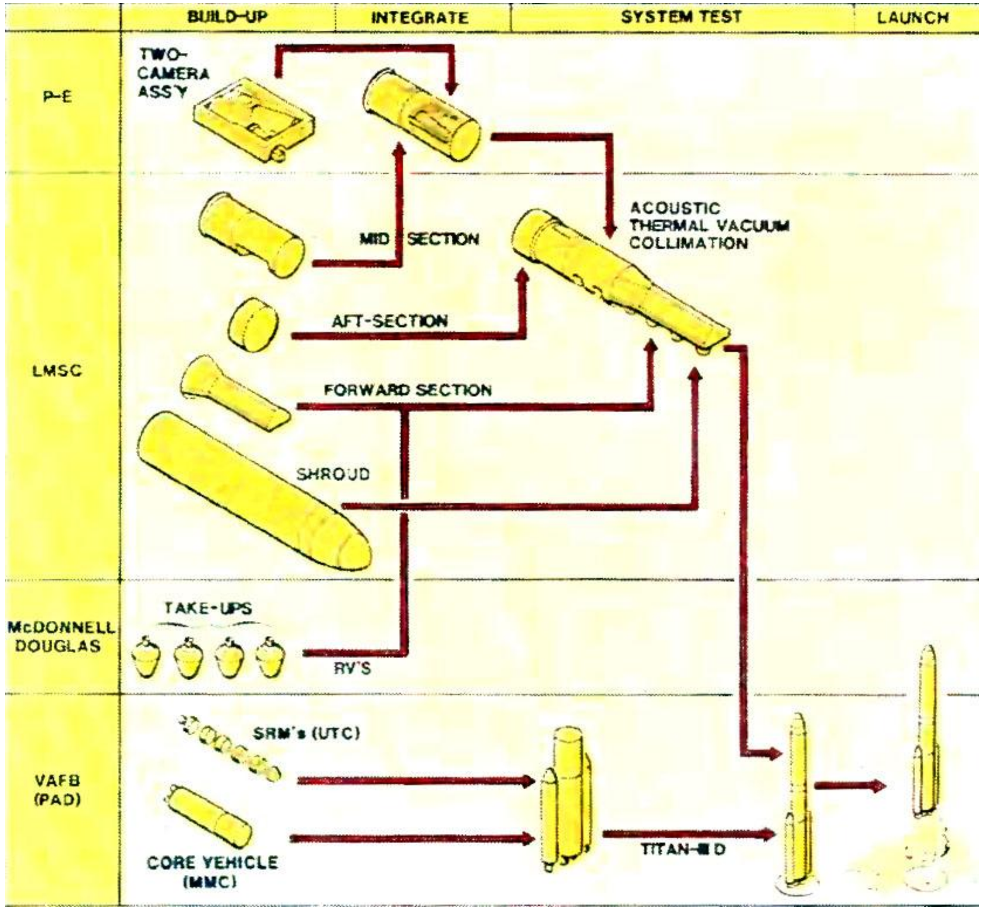
This program played a critical role in US strategic defense as well as the Strategic Arms Limitation Talks (SALT) and the Strategic Arms Limitation Treaty (START) negotiations & verification by providing wide area medium resolution coverage of the threat regions.

HEXAGON Program

- System Operational Requirements
  - Initiated 1964
  - Systematically search 12-million square miles semiannually
  - Periodically image (revisit) known target areas to assess change
  - Ground resolution of 2.7-ft or better
- Historic Summary of Operational Service
  - 20 Satellites were built
    - Successfully flew 19 between June 1971 to October 1984
      - Satellite #20 was destroyed 9-seconds nto launch in April 1986
    - Achieved better than 2-ft resolution
    - Instrumental in SALT & ABMT treaty negotiations
    - 12 vehicles included a mapping camera module (SV # 1205-1216)
      - Provided "the best Mapping Charting & Geodesy (MC&G) support with large scale highly accurate contiguous imagery"
- The HEXAGON program was declassified & put on public viewing
  - On 17 September 2011 it was displayed at the at the National Air & Space Museum (Udvar-Hazy Center) On 26 January 2012 it was moved to the National Museum of the Air Force (NMUSAF) where it is now displayed

HEXAGON FACTORY ASSEMBLY & TEST





The structure was built in segments that were assembled as modules then integrated for assembly and testing. The mid-section was shipped to have the camera assembly installed; the aft section contained the electronic and orbit modules; and the forward section contained recovery vehicles. On 12 satellites the Auxiliary Payload Structure Assembly (APSA), stellar terrain camera was mounted on the forward section increasing the total length to 60-ft. The assembly flow is indicated on the right. Then complete & tested satellite (minus the RV retro rockets & fuel) was transported to Vandenberg AFB for launch. SAFSP had factory to pad oversight.

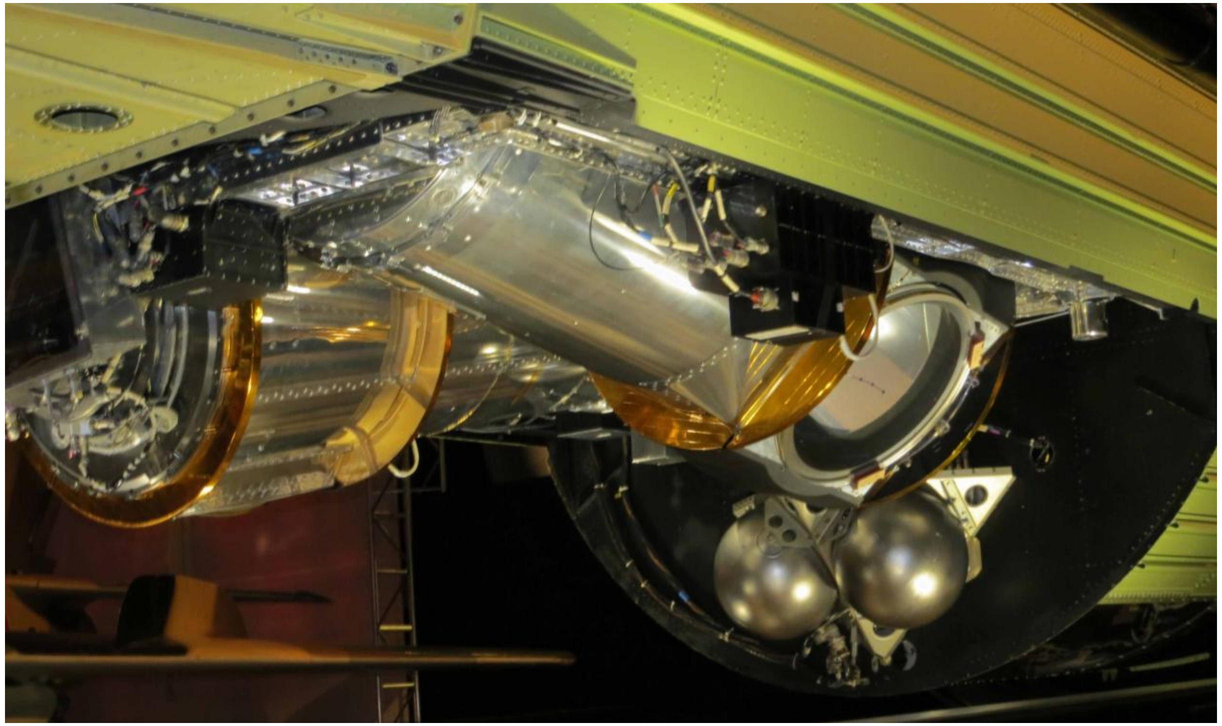
Midsection Camera Integration

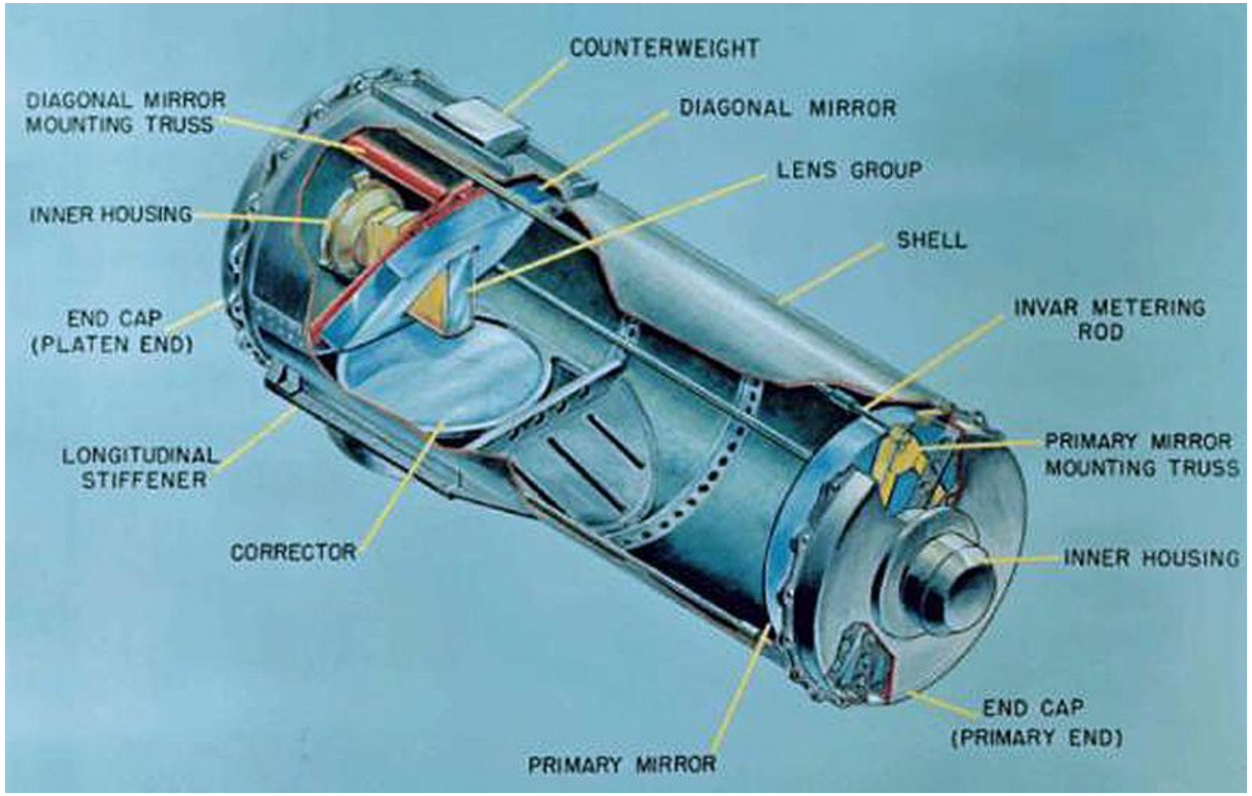
The midsection structure was flown on a C-5A to Perkin Elmer for camera installation then returned to Lockheed for satellite assembly, integration, and verification testing.

Camera System Overview

The pan camera system consisted of two panoramic scanning cameras, one pointing Forward 10°, the other Aft 10°, for a 20° stereo angle. They could scan up to 120° cross track for swaths ~300 nm wide. Specific scan angle widths of 30°, 60°, 90°, or 120° were programmable with scan centers every 15° between ±60° degrees. All paired camera and film transport elements rotated in opposing directions to maintain vehicle stability and minimize camera movement.

CAMERA DETAILS



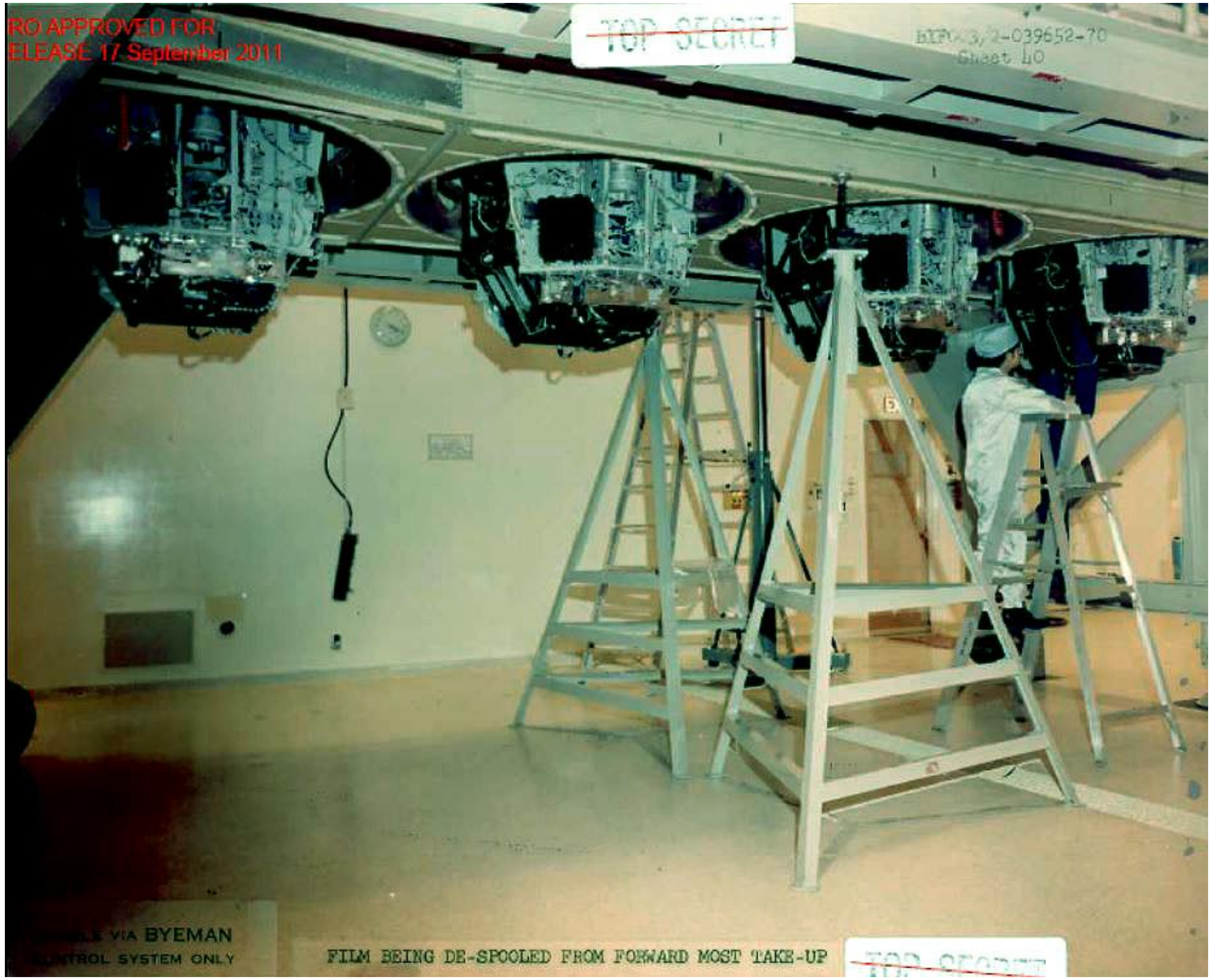


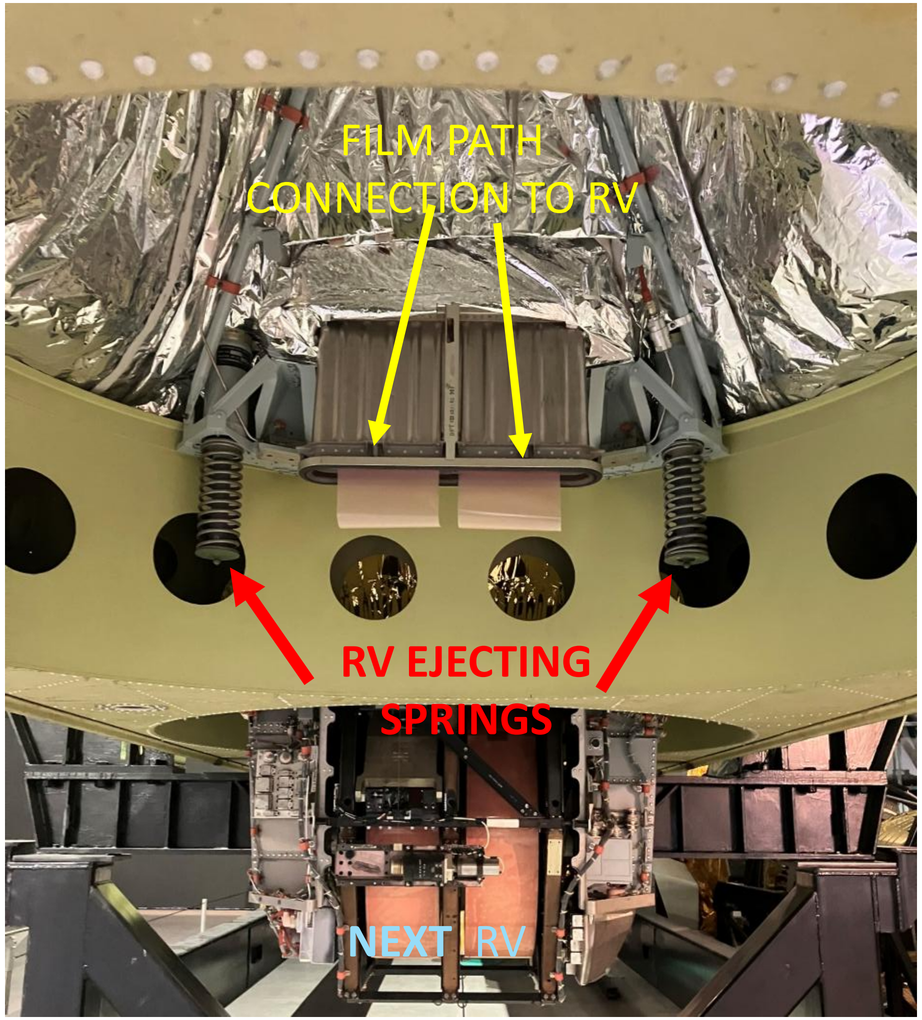
The optical bars were a key element of the camera system. They rotated rapidly to scan transverse (cross-track) to satellite direction of flight. During exposure, the film traversed the slit opening at up to 200-in/sec. After each frame was exposed the film would slowdown and backup to reduce the interframe space to 2.5-in to save film. A further complicated factor was the imaging platen had to oscillate; locked to the optical bar during exposure but then disconnected, reversed and repositioned to begin the next scan as the optical bar, supply and take-up drives continued to rotate at a constant speed.

PAN CAMERA SPECIFICATIONS

- Camera Weight less film = 5,375 lbs.
- Optics = Focal length = 60”, f/3.0 Folded Wright system
- Aperture diameter = 20”
- Field Angle = ±2.85°
- Slit width = 0.08” to 0.91”
- Film
  - 6.6” wide up to 155,000-ft/camera (weight = 1,576-lbs.)
  - Supply stack diameter 68”
  - A single frame for a 120° scan was 126” long
  - Film transport speed
    - 67-in/sec between the Supply and Take-up
    - 200-in/sec maximum at platen
- Scan Modes = 30°, 60°, 90°, 120°, within ± 60° of nadir
- Scan centers = 0°, ±15°, ± 30°, ±45°
- Stereo angle = 20°

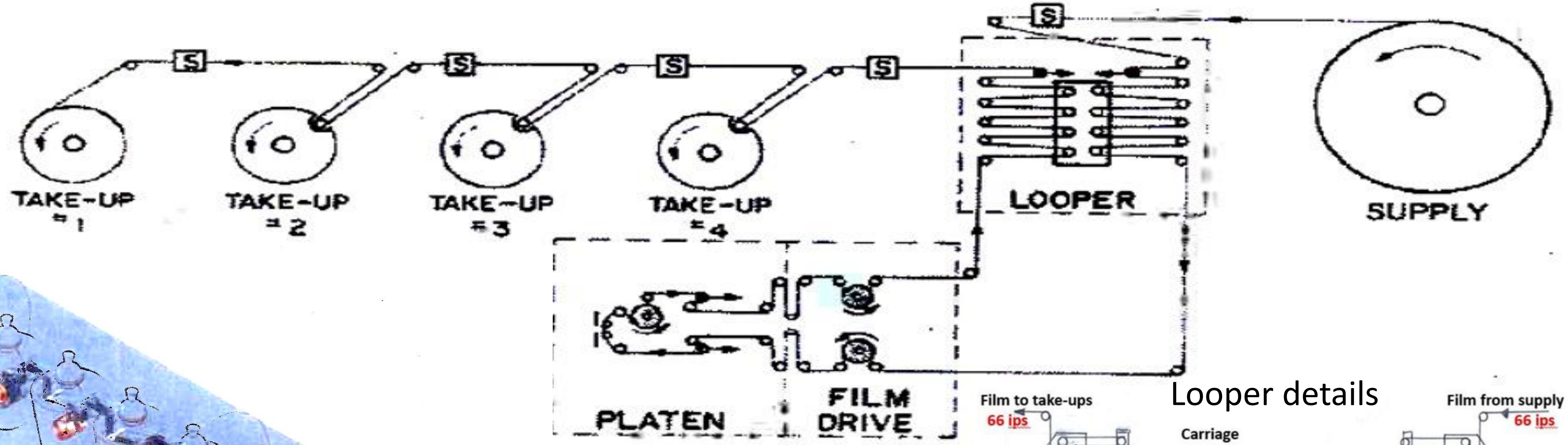
FORWARD SECTION RV ASSEMBLY

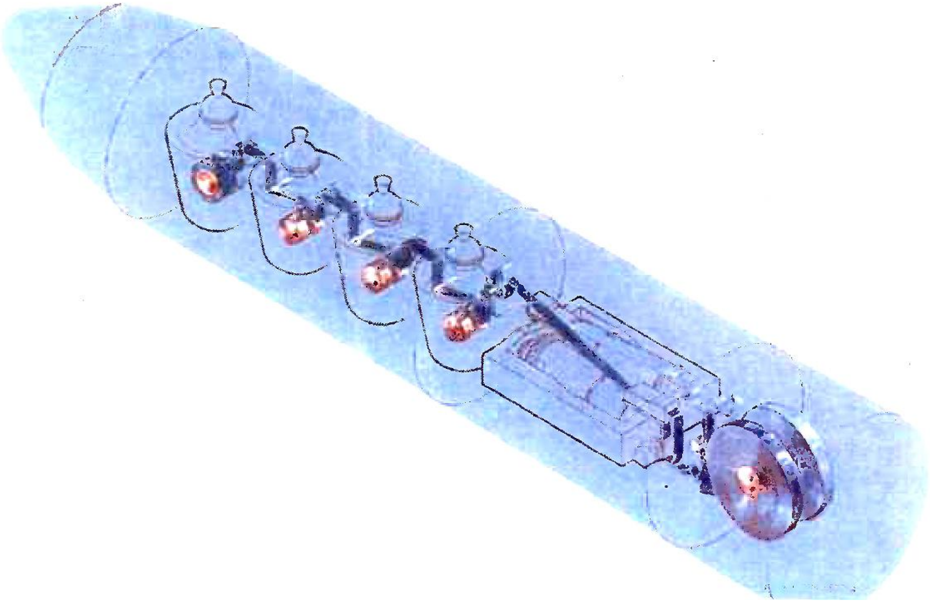


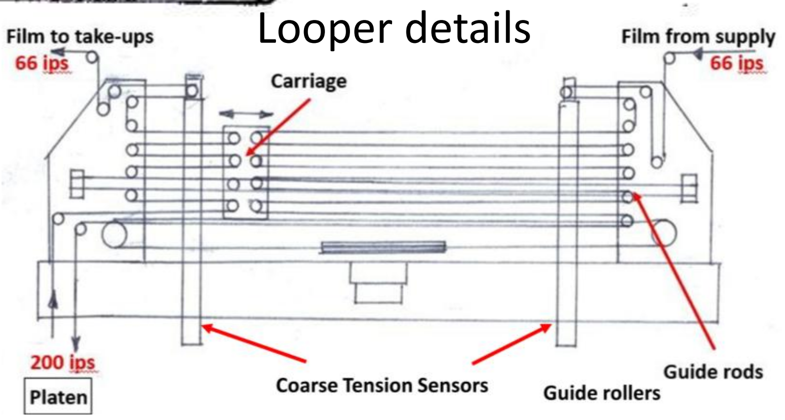


The four film reentry vehicle with take-up assemblies were installed in the forward section structure before it was mated to the midsection. Before a full RV was deorbited, the film was wrapped and cinched into the next RV and the film cut and the path sealed between RVs. The full RV was separated and the newly selected RV became the new film Take-up unit.

HEXAGON FILM PATH

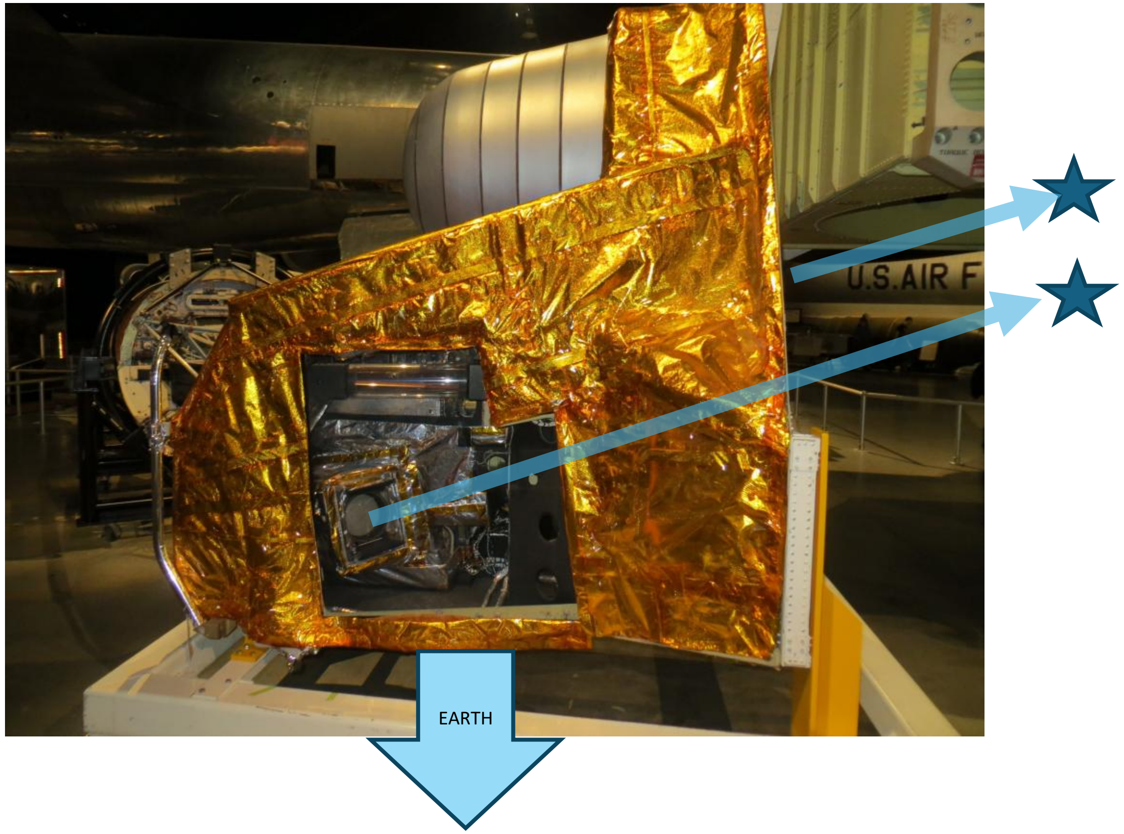


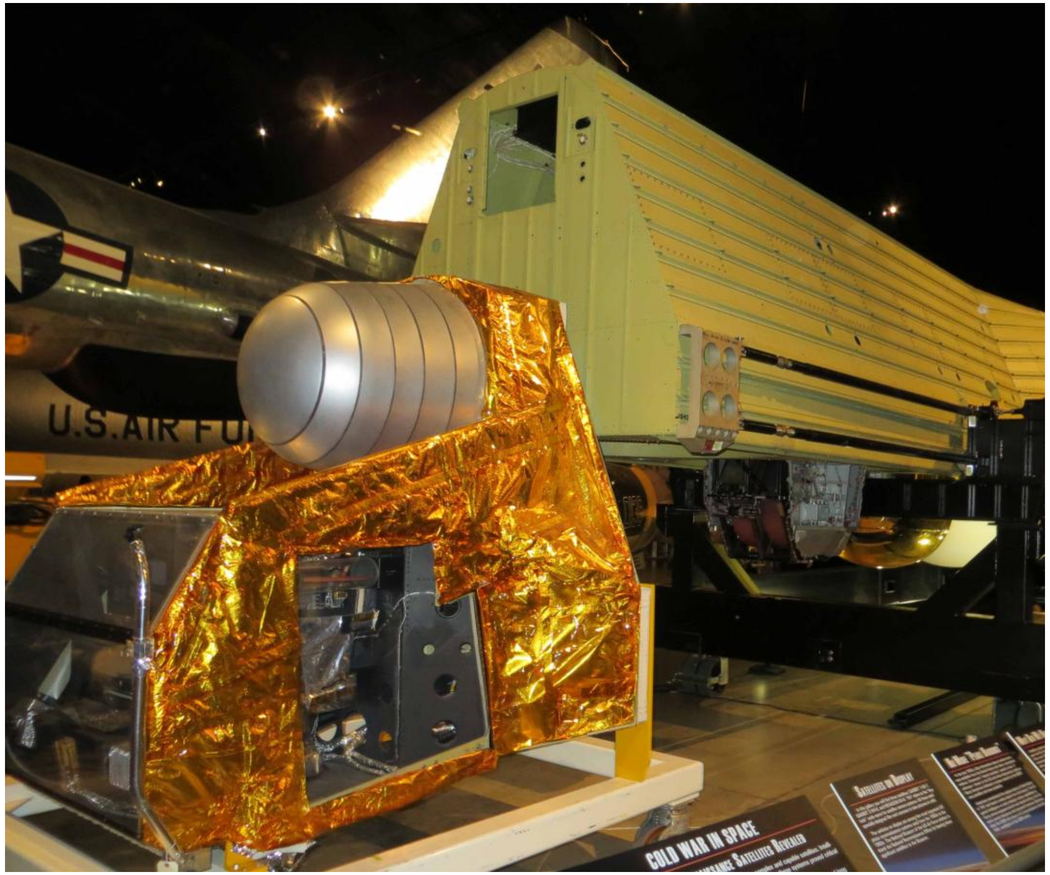




The film path within the satellite was light tight, pressurized and climate controlled. There was over 140-ft of film path between the supply unit (SU) and take-up unit (TU) with 124 to 131 rollers or air-bars. All roller alignment had to be precise since the film didn't have sprocket holes like a normal handheld camera. The film system compensated between the constant rate of the supply & take-up path velocity and the intermittent velocity of the fine path with a "looper" that acted as a "film capacitor." The film passed through all the reentry vehicles (RV) into the front-most TU.

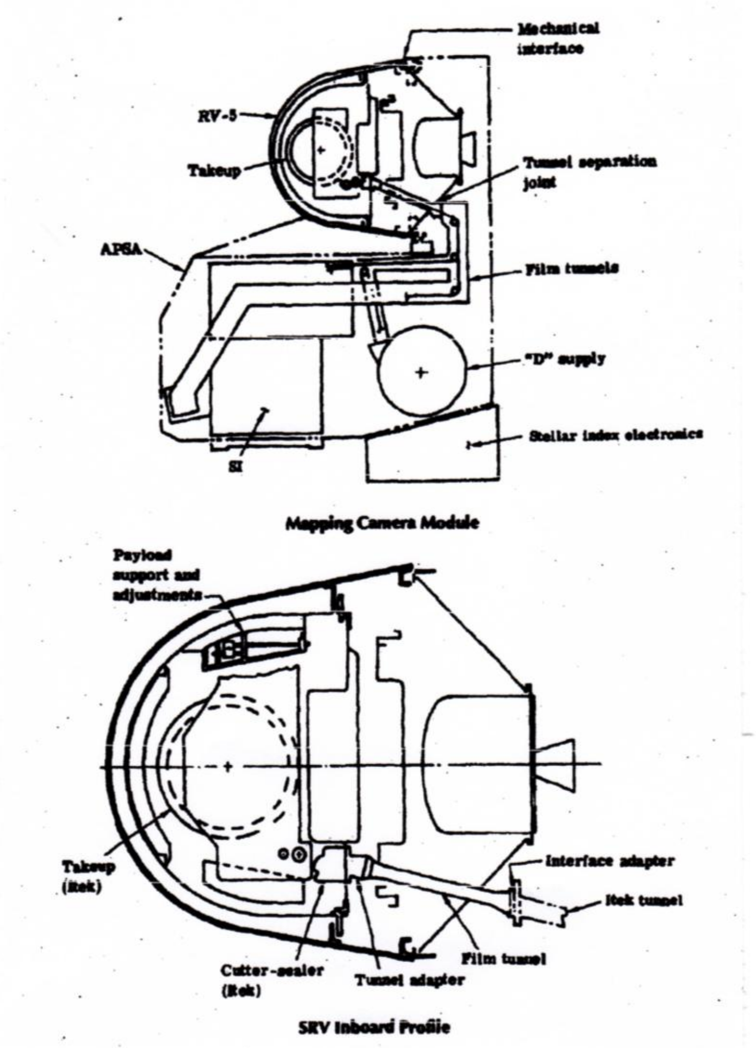
STELLAR TERRAIN MAPPING CAMERA





A stellar-terrain mapping camera was flown on 12 HEXAGON vehicles (SV# 5 through 16) imaging 104-million nm². The “footprint” was 70 x 140-nm with a resolution of 30 to 20-ft providing key cartograph information. Location calculations made based on orbit position and the simultaneous imaging of star fields registered ground features accurately prior to GPS.

MAPPING CAMERA DETAILS

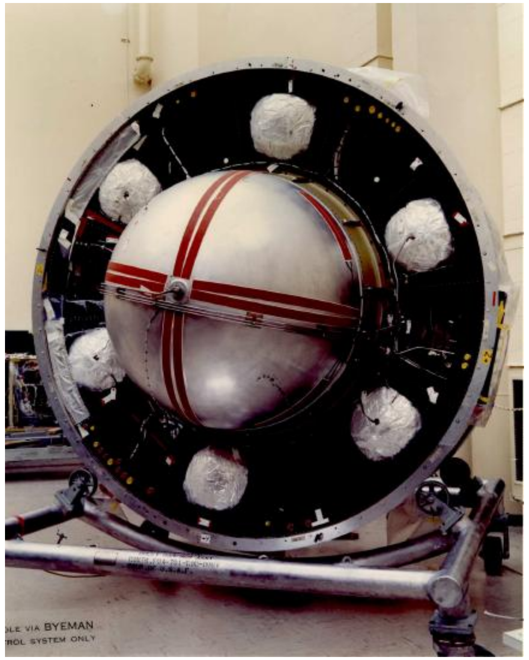


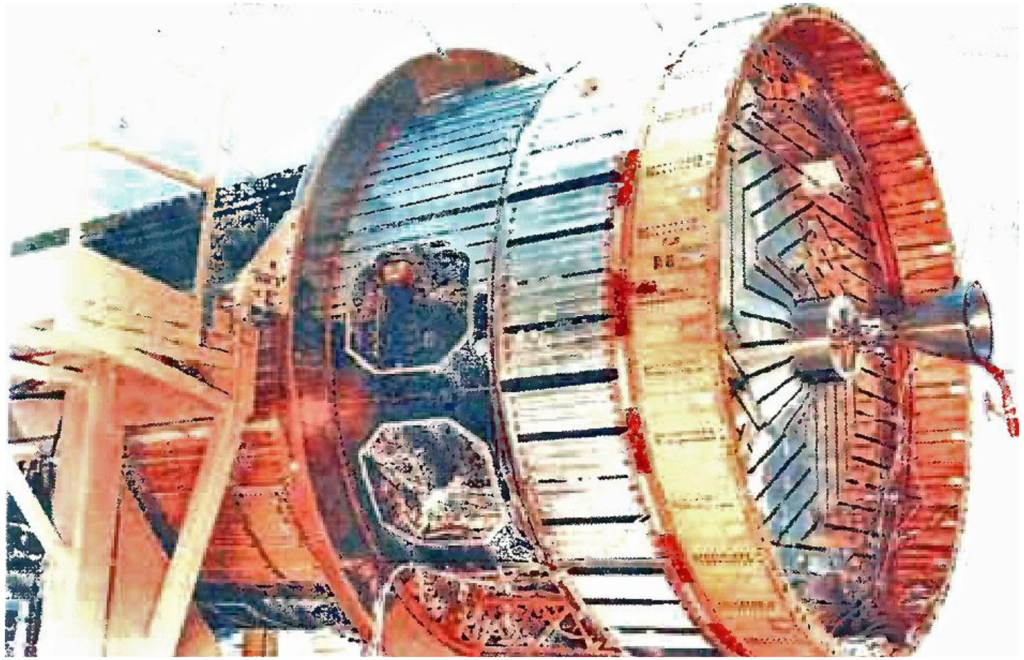
The stellar terrain camera was mounted on the forward HEXAGON bulkhead operating it mission for 42 to 119 days by ground computed commands. It had a single RV which returned 48,000-ft of film for processing. All missions were successful providing essential geolocation information.

MAPPING CAMERA SPECIFICATIONS

- Optics (Ground) = Focal length = 12” f/6.0 eight element lens system 9.5” wide film
- Optics (Stellar) (2) = Focal length = 10” f/2.0 lens 70-mm wide film
- Single Mark-V RV returned both terrain & stellar film
- The doppler beacon system improved orbit position reference.
- System tested at ITEK and Kitt Peak prior to being sent to LMSC for integration

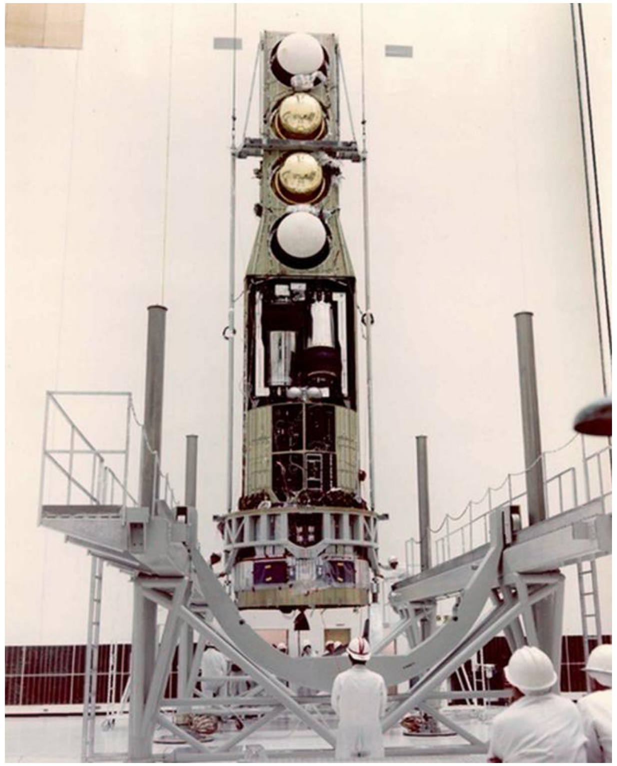
AFT SECTION SUBSYSTEMS





The aft satellite control section (SCS) contains modules to provide power (EDAP), attitude reference & reaction control (ARM) (RCM), orbit adjust (OAM), solar array (SAM) power (EPM), telemetry tracking and commanding (TTCM), and a back-up recovery system (BRAC/”Lifeboat”). Solar arrays (not shown) extended from the back. All satellite functions (relay, pyro, valve, servo, thruster etc.) were executed via stored program commands generated and loaded into the satellite programmable memory unit (PMU) when it passed over a ground station. Each stored command was time tagged to trigger execution at the appropriate time. For example, it took a minimum of 16 precise commands to execute a single camera imaging operation. Vehicle command generation will be addressed in another section.

INTEGRATED TEST



After the segments were tested as sub-units, they were assembled for integrated vehicle testing which included ambient functional testing, acoustic, environmental, collimation. Acoustic testing subjected the satellite to vibration simulating launch to detect potential mechanical failures. Environmental testing was conducted in a thermal vacuum chamber subjecting the vehicle to space orbit conditions. Collimation testing in a vacuum verified camera performance to detect focus and smear values for on-orbit operations. Final launch preparations included loading all flight systems minus those hazardous items, propellants and pyros prior to shipment to the launch site.
The integration & test operations required many vertical & horizontal repositioning operations for the assembly and test stations. The 30,000-pound vehicle was repositioned precisely to avoid damage.

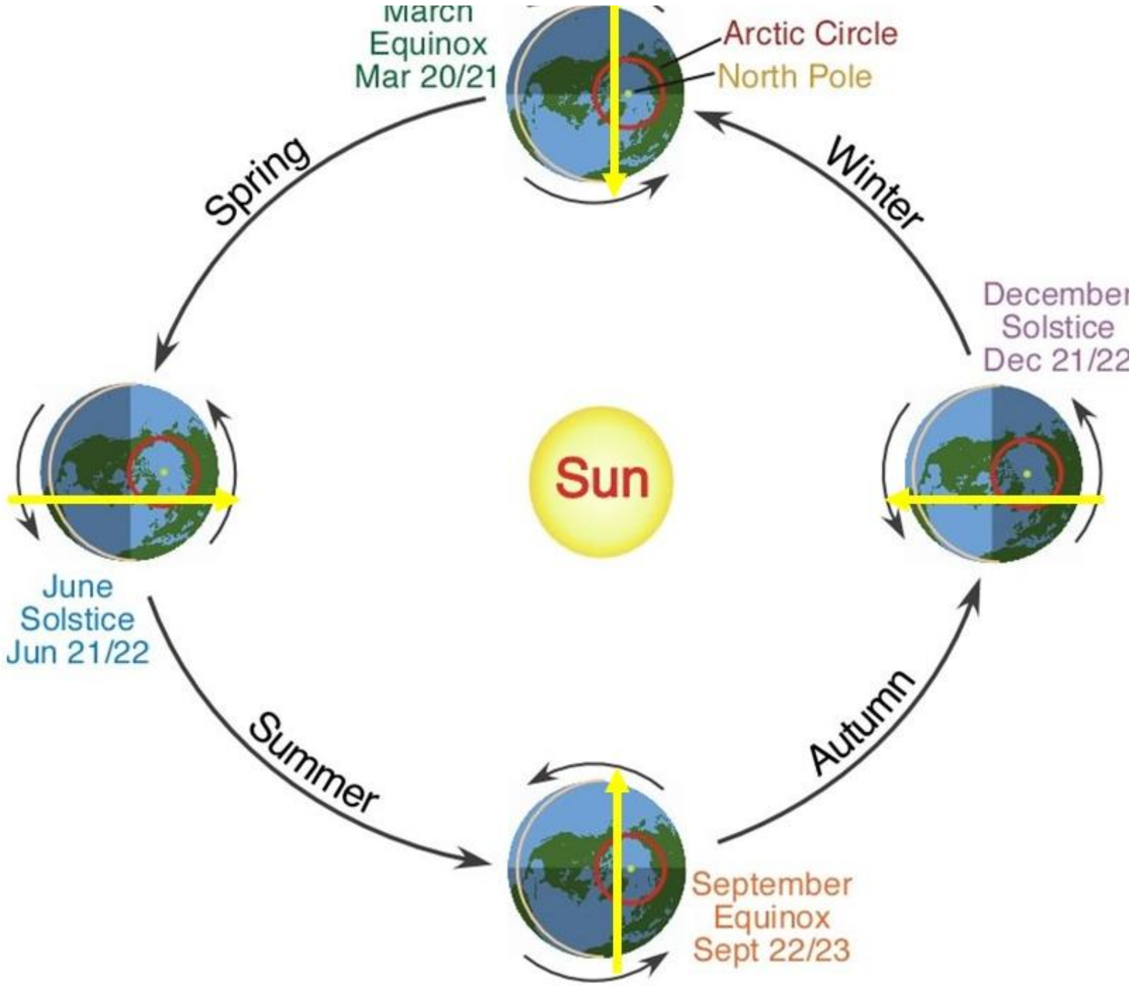
TRANSPORT TO LAUNCH BASE

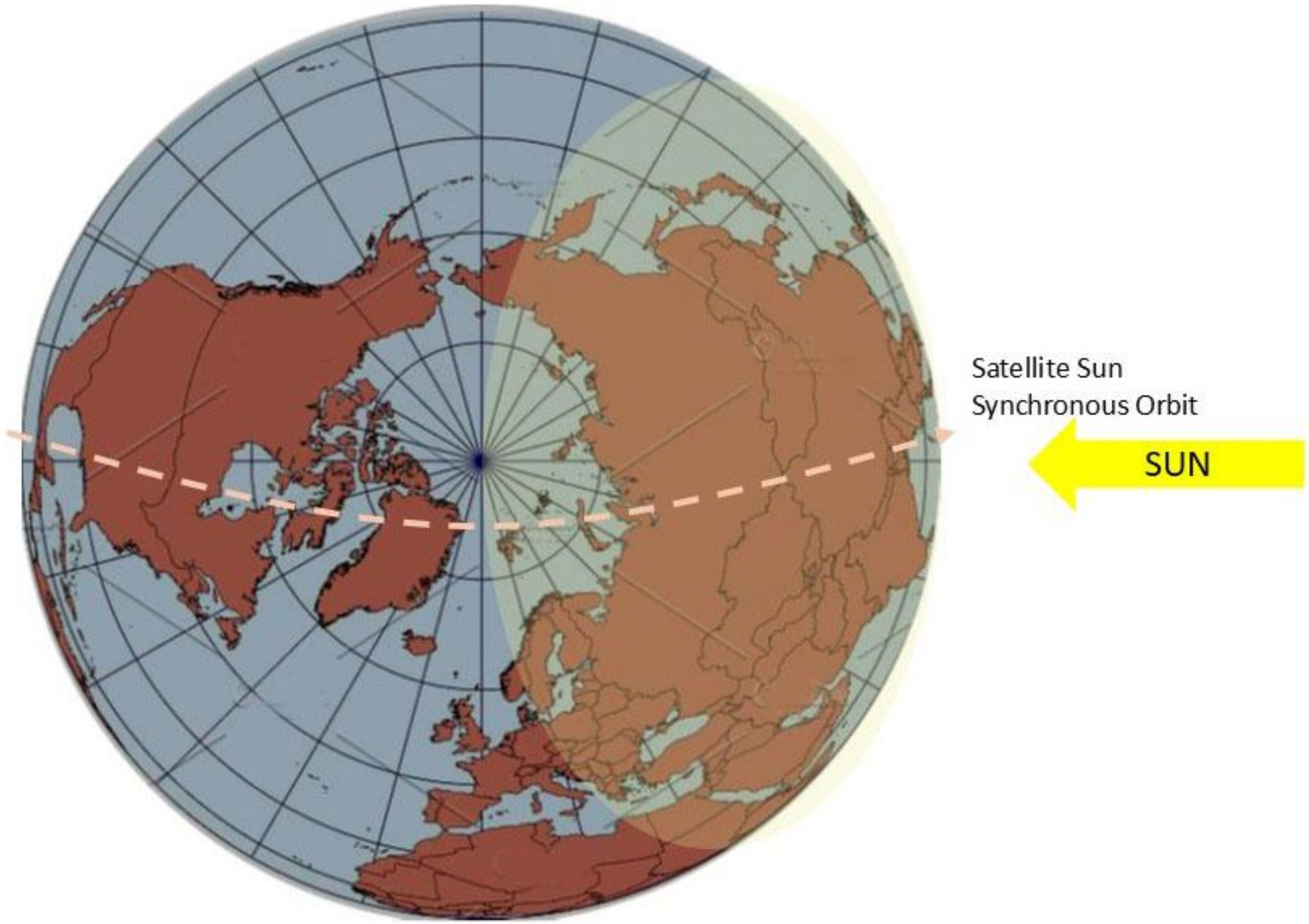
The completed HEXAGON satellite was transported 250 miles from Sunnyvale to the Vandenberg launch SLC-4E complex for booster integration. Hazardous elements like propellent loading and solid rocket motors were installed at the gantry after the satellite was mated to the Titan-3D/T-34D launch vehicle.

LAUNCH INTEGRATION

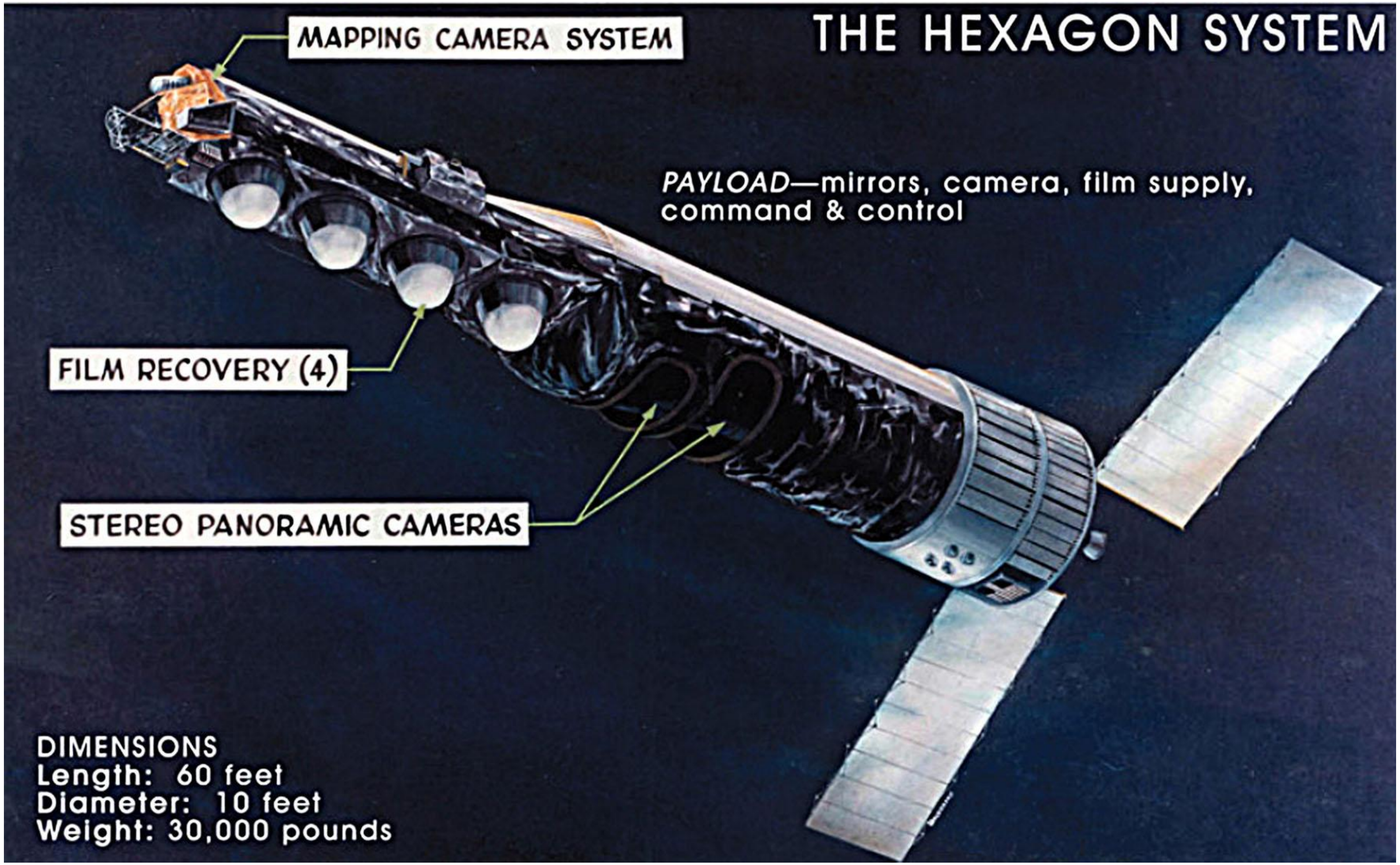
HEXAGON was launched on a Titan-3D or Titan 34-D from Vandenberg AFB, SLC-4E. The orbit was a 80 x 270 nm, 97° critically inclined sun synchronous orbit. This enabled continued operations over illuminated ground for long duration missions with minimum use of control gas to maintain the orbit and compensate for drag.

HEXAGON FLEW IN A SUN SYNCHRONOUS ORBIT
DAYLIGHT ACCESS IMAGING ALL YEAR



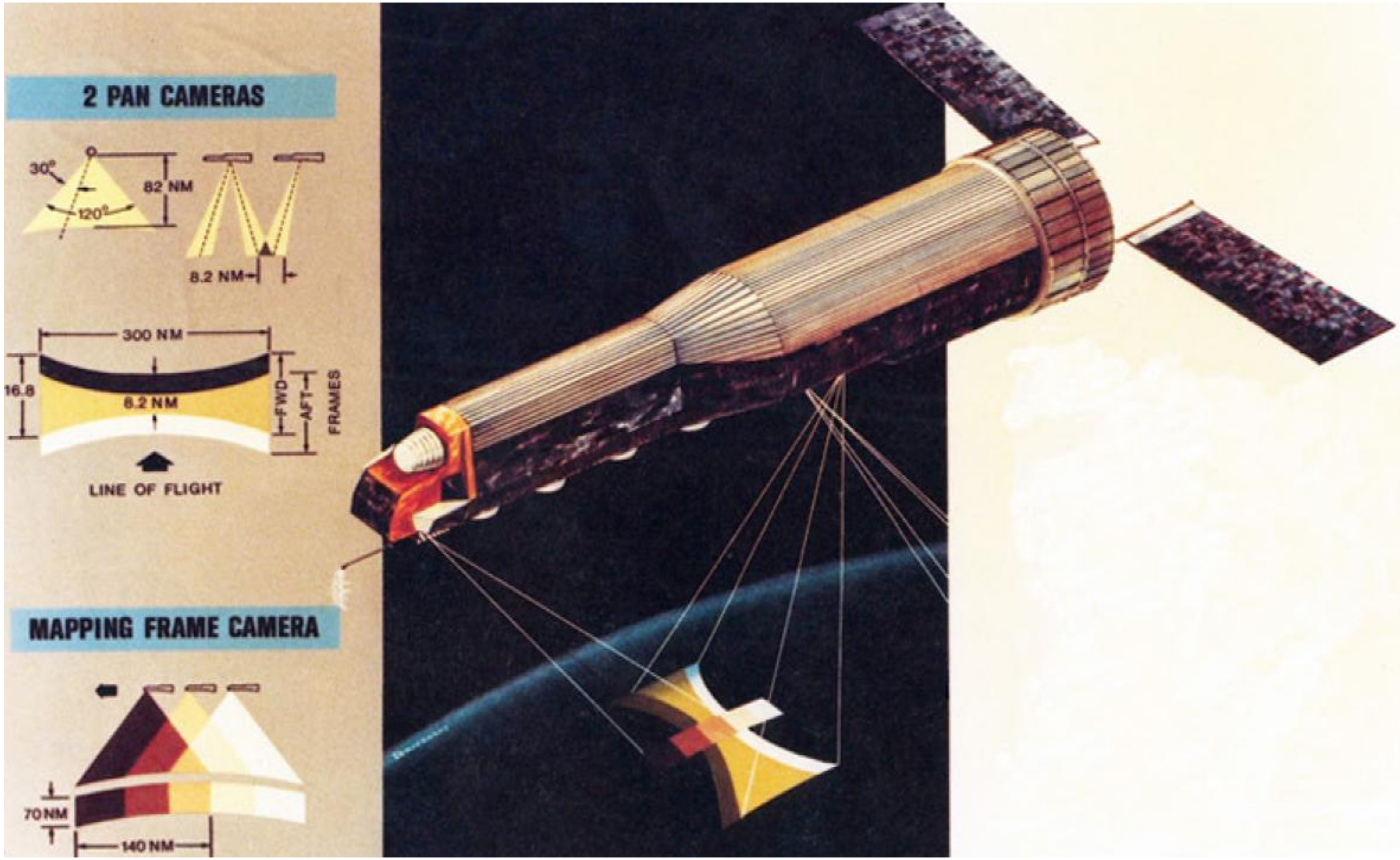


FLIGHT CONFIGURATION



HEXAGON illustrated in full flight configuration had thermal protection multi-layer insulating (MLI) blankets & reflectors, solar arrays deployed, and stellar terrain mapping system.

CAMERA OPERATION ON ORBIT



These camera "footprints" for the forward mapping camera and the main pan camera systems depict the maximum coverage. The pan camera achieved 2-7 ft resolution across its 16.8 x 370-nm footprint covering 880-million square miles over all missions, most in stereo. The mapper & pan imaged some targets in tri-laps (3-times) in a single operation providing more detailed information.

MISSION OPERATIONS - SATELLITE TEST CENTER

Satellite operations were controlled from the Satellite Test Center, Sunnyvale, CA. Air Force & contractor teams generated the command sequences for all functions and operations as well as monitoring and managing the functional operations. Command sequence messages were generated and sent to the designated network ground station to be loaded during a station pass. Commands were stored in the satellite memory (PMU) for execution later in the orbit. The command sequences were unique for each orbit revolution thus required to be generated 16 times each mission day.

SATELLITE CONTROL NETWORK OF GROUND STATION LOCATIONS

The satellite control network stations were distributed around the world. HEXAGON would be within view of a station for only 3 to 5-minutes at which time it would be checked out for health & status, read out telemetry and reloaded with the next mission operations. Tracking data was collected at every pass to calculate satellite orbit ephemeris.

GROUND MISSION OPERATIONS COMMAND CYCLE

COMMAND GENERATION OPERATIONS CYCLE

Timeline Minutes	Ground Operation Events	Satellite Operation	Comments
0	Prepare Engineering Commands		
5	Receive Predicted Weather Data		Data from previous rev weather satellite
10	Received Target Priority List		
15	Plan Image Tasking		Prioritize Target selection
20	Generate & Check Satellite Commands		All Inputs made on punch cards
25	Send Command sequence to ground station		
30	Station Pass - Communicate with & command satellite	Communicate with Ground Station	Verify health, Readout Recorder (Telemetry & Command Sequence), Load Command Sequence. Turn off Transponders (Duration 2 to 4 minutes)
35			
40	Verify Command Execution History based on telemetry		
45	Update Orbital Position based on tracking data	Satellite Imaging Operation	Engineerng operations conducted during non imaging orbits
50	Evaluate Health & Status		
55	Plan RV recovery, Orbit Adjust, Engineering Events		Engineerng operations conducted during non imaging orbits
60	Address any operational anomalies		
65	Verify imaging success based on updated cloud coverage & camera operation	Verification Weather Satellite Pass	
70			
75	Update ground simulation records with satellite data		
80			
85		Predicted Weather Satellite Pass for next orbit rev	
90			
	Repeat Sequence 16 Times a day!		

WEATHER SATELLITES PROVIDED CLOUD COVER INFORMATION

Clouds could obscured the ground preventing detailed imagery. Weather satellites reported cloud coverage before and after each HEXAGON pass to determine the probability an image tasked would be clear of cloud obscuration during an imaging operation. The Defense Meteorologic Satellite Program (DMSP) & Program 417 had sun synchronous (98° 450-nm circular) orbits providing low resolution cloud cover image information.

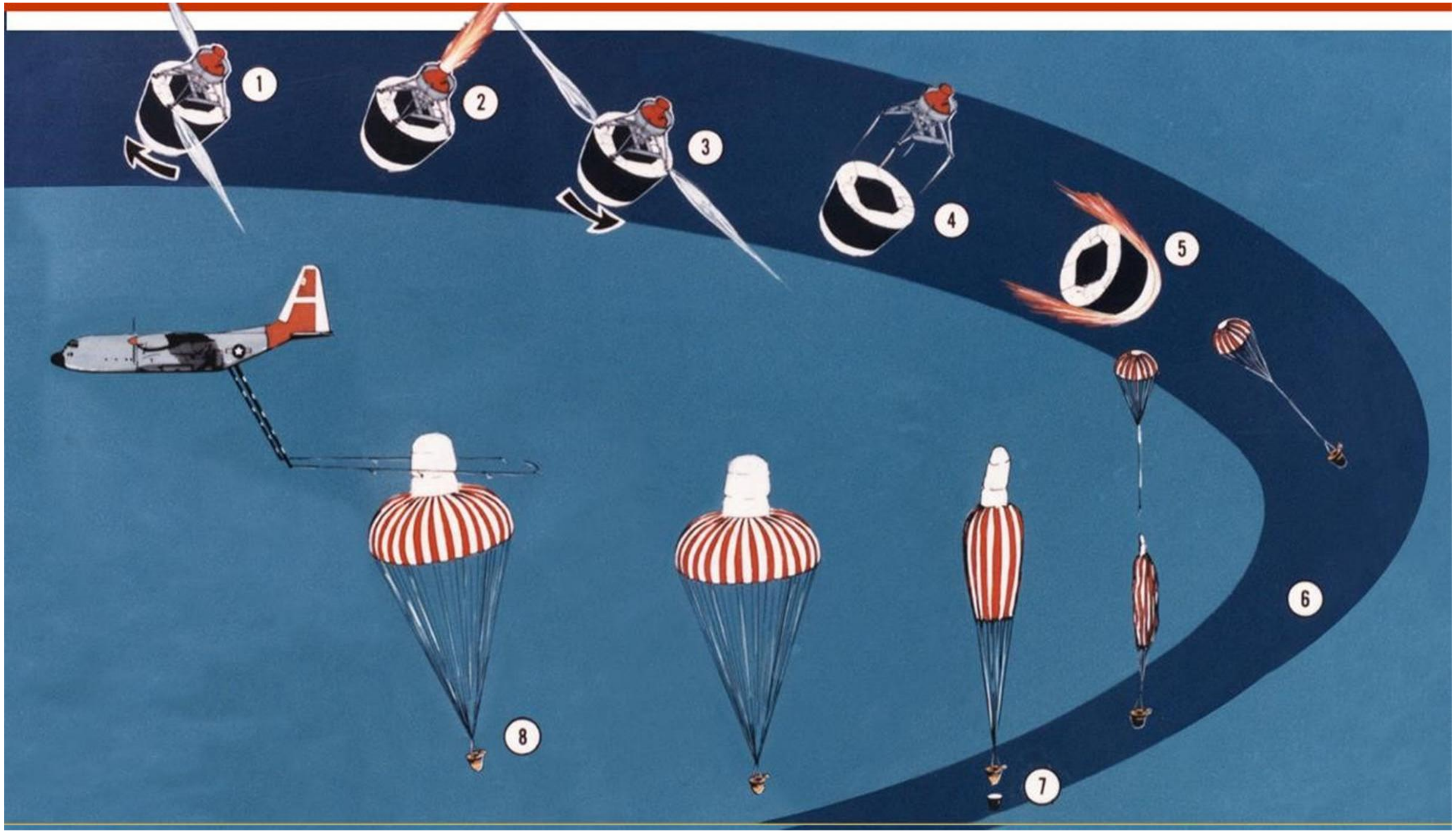
CDC-3800

Computer Technology in the 70s & 80s

Spec	CDC 3800	Dell Inspiron Corei7	Ratio
Architecture bits	48	64	1.3
Brand Name	CDC 3800	Dell Inspiron Core i7	NA
Clock speed Hz	1,000,000	4,600,000,000	4,600
Cost	$ 1,900,000	$1,300	1,462
Graphics Coprocessor	None	Intel UHD 620	NA
Hard Drive Capacity	300,000	512,000,000,000	1,706,667
Item Weight	Tons	3.86 pounds	4,000
Max Screen Resolution	None	3840 x 2160	NA
Memory	512,000	16,000,000,000	31,250
Operating System	JOVIAL	Windows 10 Pro	NA
Platform	Mainframe	Lap-top PC	NA
Power Source	Utility Powered	Battery Powered	NA
Processor Count	1	4	4
Processor Size in^3	147,600	0.5	295,200
RAM (bits)	200,000	16,000,000,000	80,000
Technology # Transistors	40	1,750,000,000	43,750,000

The state of technology in the 1970s was primitive by standards today. The CDC3800 was one of the few that could perform the complex mathematic calculation required to generate HEXAGON command instruction sequences. Each “command message” considered the satellite status, position, imaging target priority, cloud cover, and optimize use of the asset. All computer runs were programmed with punch cards and often several runs were required to optimize the command sequence. In addition, RV recovery, orbit adjust, and other flight functions were commanded as well as photo operations.

REENTRY VEHICLE (RV) SEQUENCE

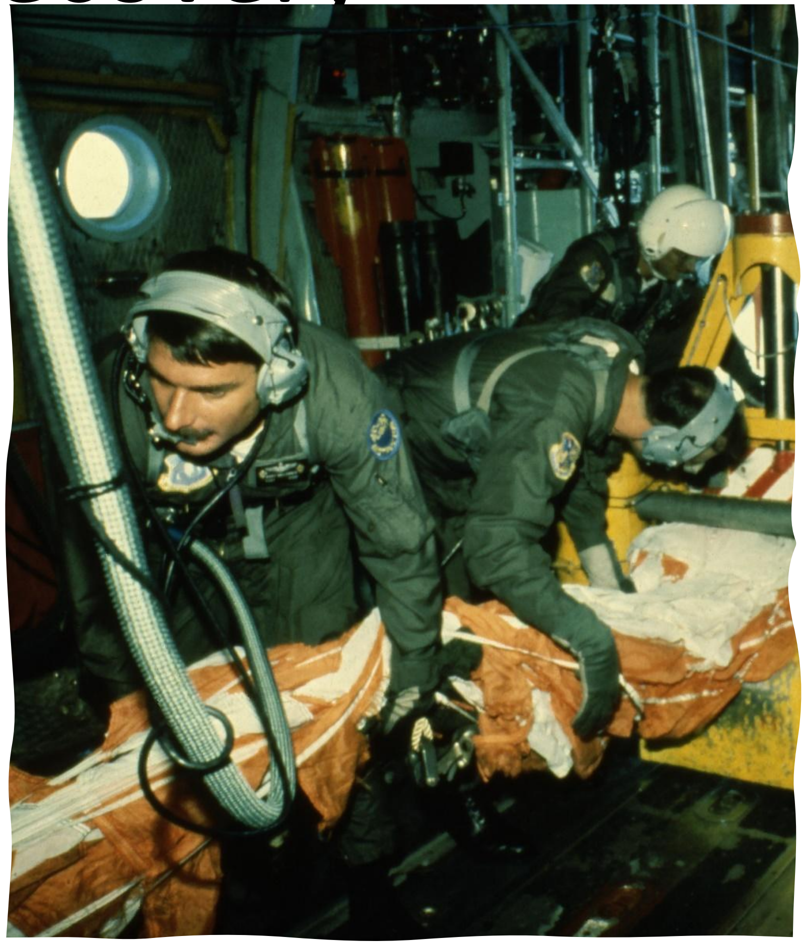


The HEXAGON pan (RV) weighed around 1,000-pounds depending on its film content. Springs ejected the RV from the spacecraft, and a set of thrusters spun it up it for stability(1). A solid rocket motor fired to slow it to suborbital speed (2) and a second set of thrusters de-spun it(3), after which the thrust section was ejected(4). The RV was protected from the extreme high temperatures of reentry by an ablative heat shield, which was subsequently ejected(5). At about 60,000-ft. the main parachute deployed (7) and at about 15,000-ft special JC-130s initiated aerial recovery maneuvers(8); typically, the recovery was made above 8,000-feet. After catching the parachute, it and the RV were reeled into the aircraft.

Film Capsule Recovery "Catch a Falling Star"

Specially modified JC-130 aircraft were used to catch the HEXAGON RV parachutes in midair. The pilot had to maneuver the JC-130 into a position about ten feet above the center of the parachute. Two poles were extended to hold recovery hooks in place below the aircraft and were attached to either nylon rope or steel cable, depending on RV weight. The rope and cable were wound on a winch that was used to slow the parachute and RV after contact, and then reel it all into the aircraft. After return to Hickam AFB, the RV was flown to the film processing facility.

RV Capsule Recovery

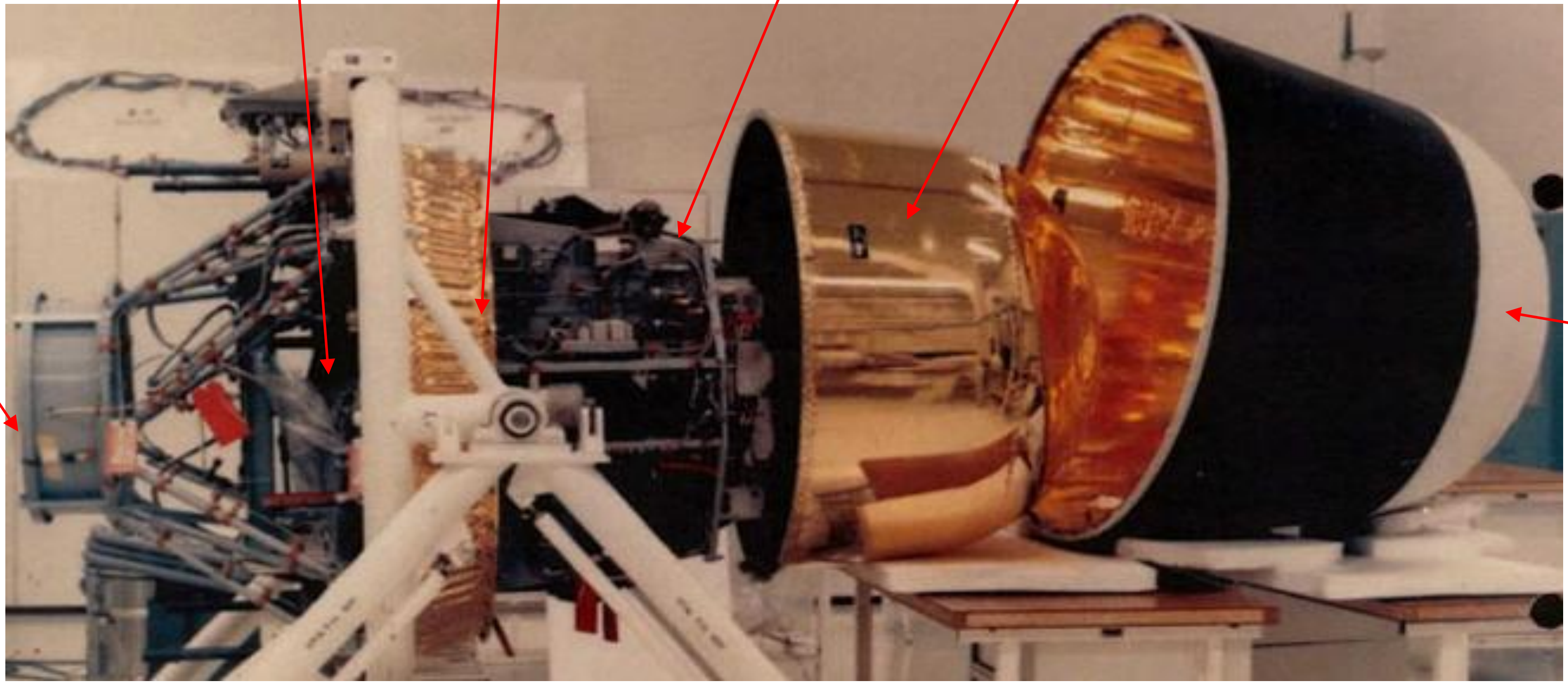


The crew in back did all the hard work deploying the recovery rig and securing the parachute and RV after recovery. The JC-130 had an Aerial Recovery Systems (ARS) installed that was used to deploy the poles, and the recovery loop and hooks below the aircraft. The ARS included a winch with a braking system that operated much like the drag on a fishing reel to slow the parachute and RV after contact. The winch was then used to reel in the parachute and RV.

Back-up Film Capsule Recovery

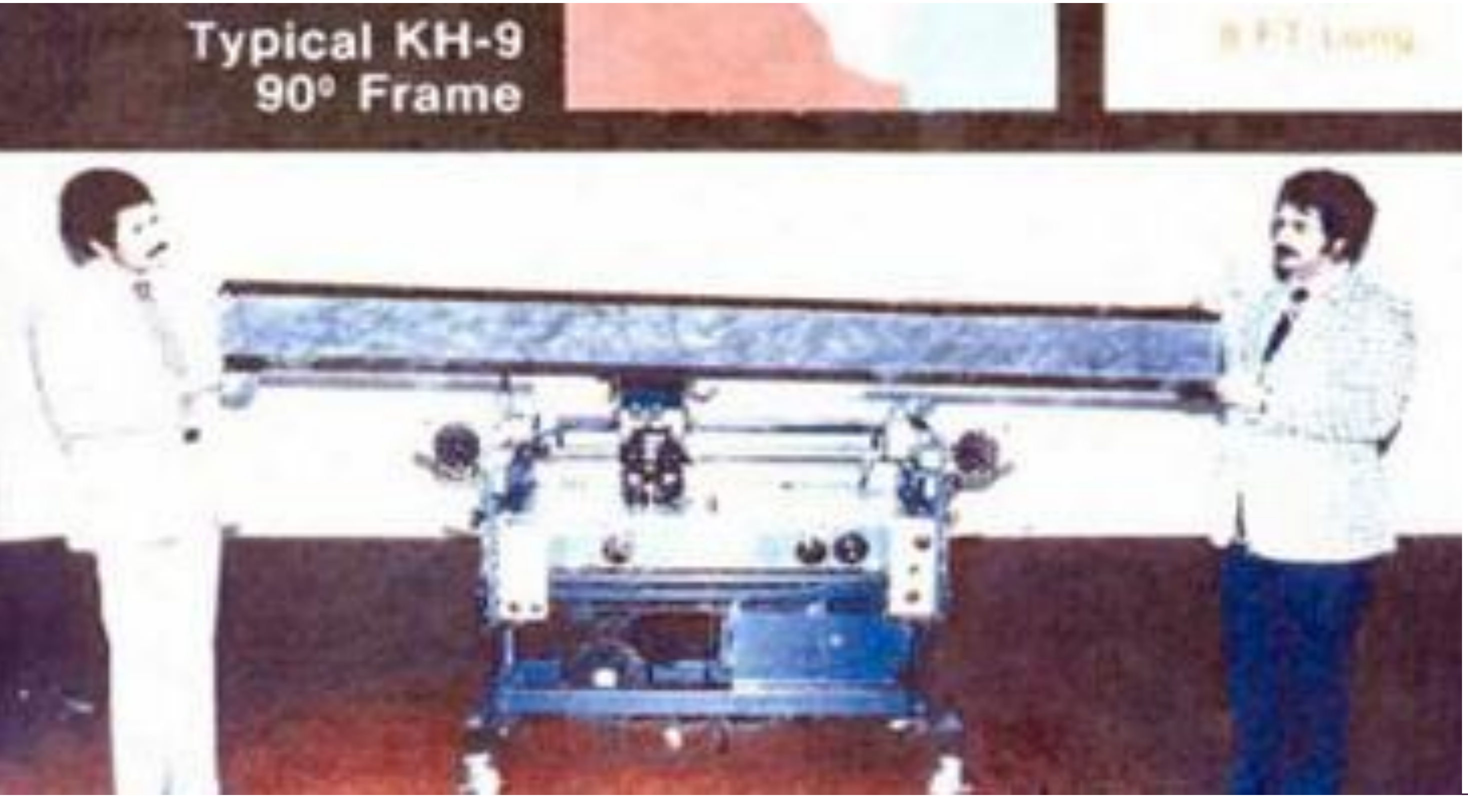
If an aerial recovery was not possible or not successful, Divers or Parachutists Jumpers (PJs) were deployed to secure the RV and prepare the RV for helicopter pickup. Initially, assigned H-3 helicopters were deployed from modified Liberty ships; later, aerial refuellable H-53's was used.

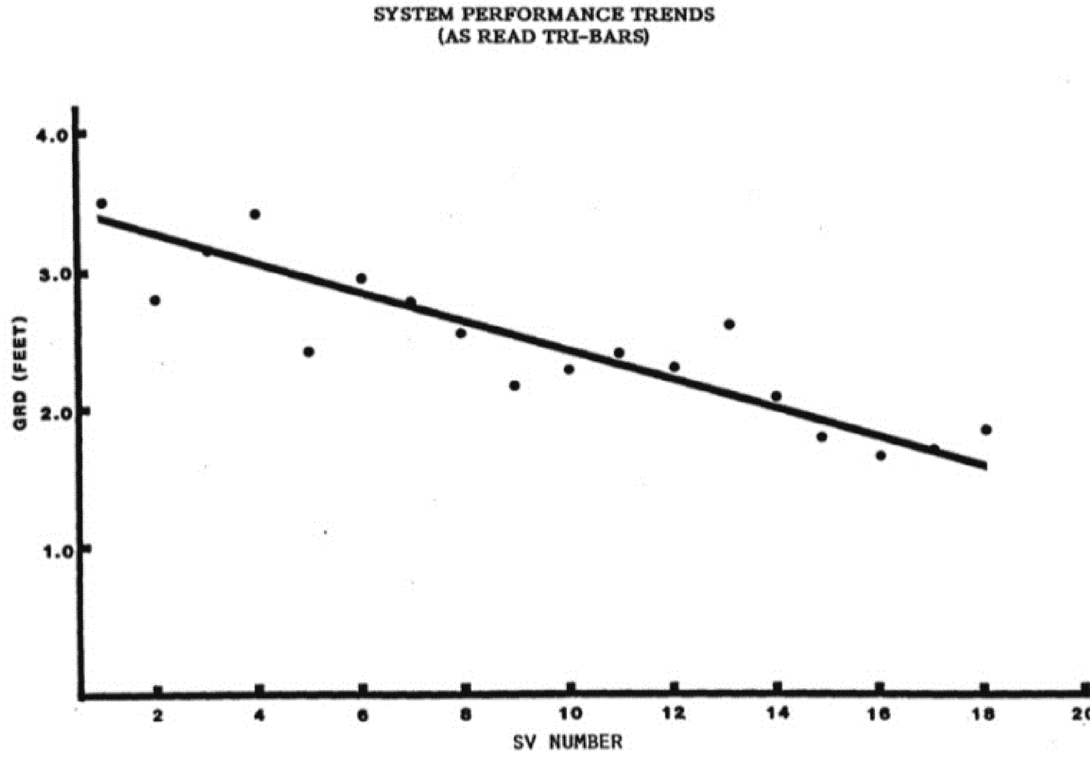
DETAILS OF REENTRY VEHICLE (RV) "BUCKETS"



RVs protect the film cargo both on orbit and recovery for processing. This detailed photo shows the construct of the RV. The inner capsule & outer heat shield acted like a thermos bottle for environmental protection.

EXAMPLE OF A SINGLE IMAGE FRAME (90 DEG SCAN @ 200"/SEC)





The 90 ° film strip shown is 6.6-inches wide and ~8 feet long. The viewing table behind them could spool film pairs from both pan cameras for stereo viewing and 3D analysis. The HEXAGON satellite integrated improved functionality throughout its 20 vehicles. The graph on the right illustrates how best resolution improved from 3.5 to < 2-ft over the course of the program. "Broad area search at medium resolution" collected a half century ago was not duplicated commercially until this past decade.

DECLASSIFIED SAMPLE HEXAGON IMAGES

1983

UNCLASSIFIED
APPROVED FOR PUBLIC RELEASE
DECLASSIFIED BY DNI
13 JANUARY 2012

Graphic 47. Submarine Construction, Severodvinsk Shipyard

UNCLASSIFIED
APPROVED FOR PUBLIC RELEASE
DECLASSIFIED BY DNI
13 JANUARY 2012

Graphic 58. Moscow ABM Complex – Mission 1218-1 40X

TEMPORAL IMAGERY MONITORS STRATEGIC BUILD-UP (SIMULATED – EXAMPLE)

This photo sequence illustrates the value of strategic reconnaissance during force build up. It applies commercial images of the Air Force Museum taken between 1994 & 2015. HEXAGON provided similar IMINT during the Cold War force build up. Once completed, the inside of buildings could no longer be imaged.

HEXAGON SV-20

On 18 April 1986 the 20th and last HEXAGON satellite exploded 9 seconds after launch on a T 34-D. The previous 19 missions were highly successful and provided critical intelligence that enabled President Nixon to sign the SALT Treaty and allowed President Reagan to “Trust but Verify” what our cold war adversaries were doing.

OPERATIONAL ACCOMPLISHMENTS

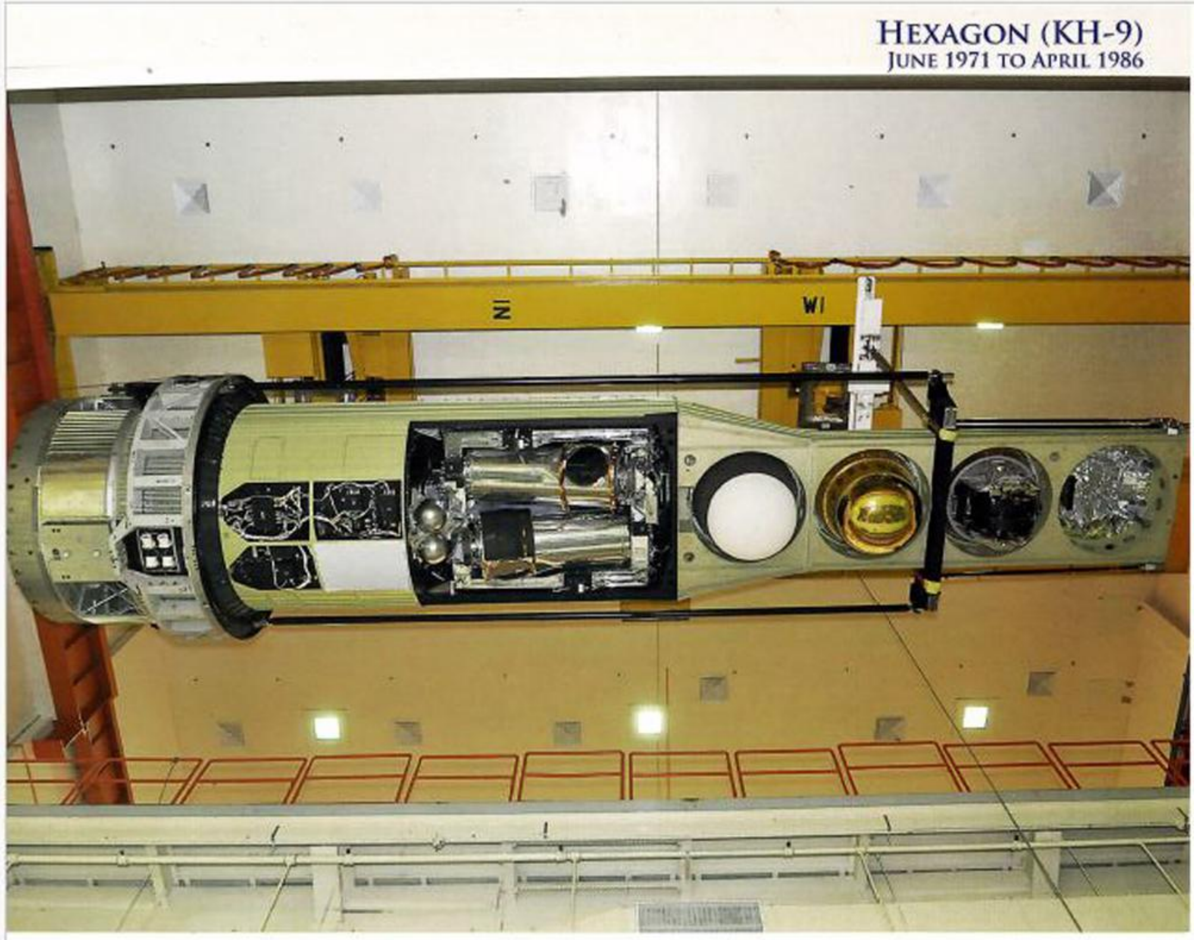
INTELLIGENCE IS EXPENSIVE, BUT IGNORANCE IS UNACCEPTABLE!

IF THE COLD WAR "WENT HOT" USA DAMAGE WOULD EXCEED ALL BOMBS DROPPED ON EUROPE IN WWII BUT WOULD TAKE ONLY 40-MINUTES!

HISTORY CLASSES OVERLOOK THE COLD WAR,
BUT IT IS ONE OF OUR MOST SIGNIFICANT VICTORIES.

THE RECONNAISSANCE SATELLITES OF SPECIAL PROJECTS ARE ONE OF THE "GREATEST STORIES, NEVER TOLD" … UNTIL NOW

17 September 2011 HEXAGON Was Declassified & Prepared for Pubic Display



HEXAGON being prepared for public display.

HEXAGON IS NOW ON DISPLAY AT THE NATIONAL MUSEUM OF THE UNITED STATES AIR FORCE

See the vehicle that made history that you could not study for over 50 years. It is in the westmost corner of exhibit hanger four.

HEXAGON Display Location
National Museum of the United States Air Force

A monument to those who supported HEXAGON and other Secretary of the Air Force Special Project (SAFSP) programs is scheduled to be built in the National Museum of the United States Air Force monument gardens by December 2025.