HEXAGON MISSION

The HEXAGON program was a broad area medium-resolution IMINT system to collect data over the 8-million square miles of denied area during the Soviet Cold War build up. The program was conceived in 1964 and first launched in June, 1971. The final design was a 52-foot long by 10-foot diameter vehicle about twice that of the Agena-based CORONA & GAMBITs. Later versions grew to near 60-feet. Contractors: Aerospace, Eastman Kodak, General Electric, Itek, Lockheed, McDonnell Douglas, Perkin-Elmer, Raytheon, RCA & TRW.

Commands were generated on key-punch cards by a teams of four officers who worked day shifts for 12-hours each for 24-hour coverage. This was done at the Satellite Test Center in Sunnyvale, California. The Intelligence Community would provide the targets to be photographed. Weather, cloud cover and tracking data would be considered. When the commands were prepared, the contractors would verify the coded commands to be sent to the vehicle's memory during a tracking station acquisition. Six world-wide tracking stations were utilized. The SP group would monitor activities to ensure mission integrity.

HEXAGON was a long-duration satellite. It could take up to 9 months to fill all recovery vehicles that would be sequentially ejected then snared via parachute by JC-130's. The film would be processed and sent to interpreters for analysis and acted upon. All elements were on a strict need-to-know basis.

Data from HEXAGON played a critical role in our strategic defense as well as the Strategic Arms Limitation Talks (SALT) and Strategic Arms Reduction Treaty (START) negotiations & verification.

HEXAGON FACTS

- **System Operational Requirements**
  - **Initiated 1969; 20 Satellites built; flew 19; June 1971 to October 1984.**
  - **The last vehicle booster exploded during launch on April, 1986.**
  - **Achieved better than 2-foot resolution**
  - **Searched 12-million square miles semiannually**
  - **Periodically revisited key target areas to assess change**

- **Summary of Operational Service**
  - **Achieved better than 2-foot resolution**
  - **Instrumental in SALT & ABMT treaty negotiations**
  - **12 vehicles included a mapping camera module (SV 5-16)**
  - **877 Sq miles of earth surface photographed**
  - **Provided *"the best Mapping, Charting & Geodesy* support with *large scale highly-accurate contiguous imagery."***

- **Status**
  - **9/17/2011: Program declassified by the NRO**
  - **9/17/2011: Engineering vehicle displayed at Smithsonian's Udvar-Hazy Center on 50th Anniversary of NRO for one day**
  - **1/26/2012: Now on display at National Museum of the Air Force**

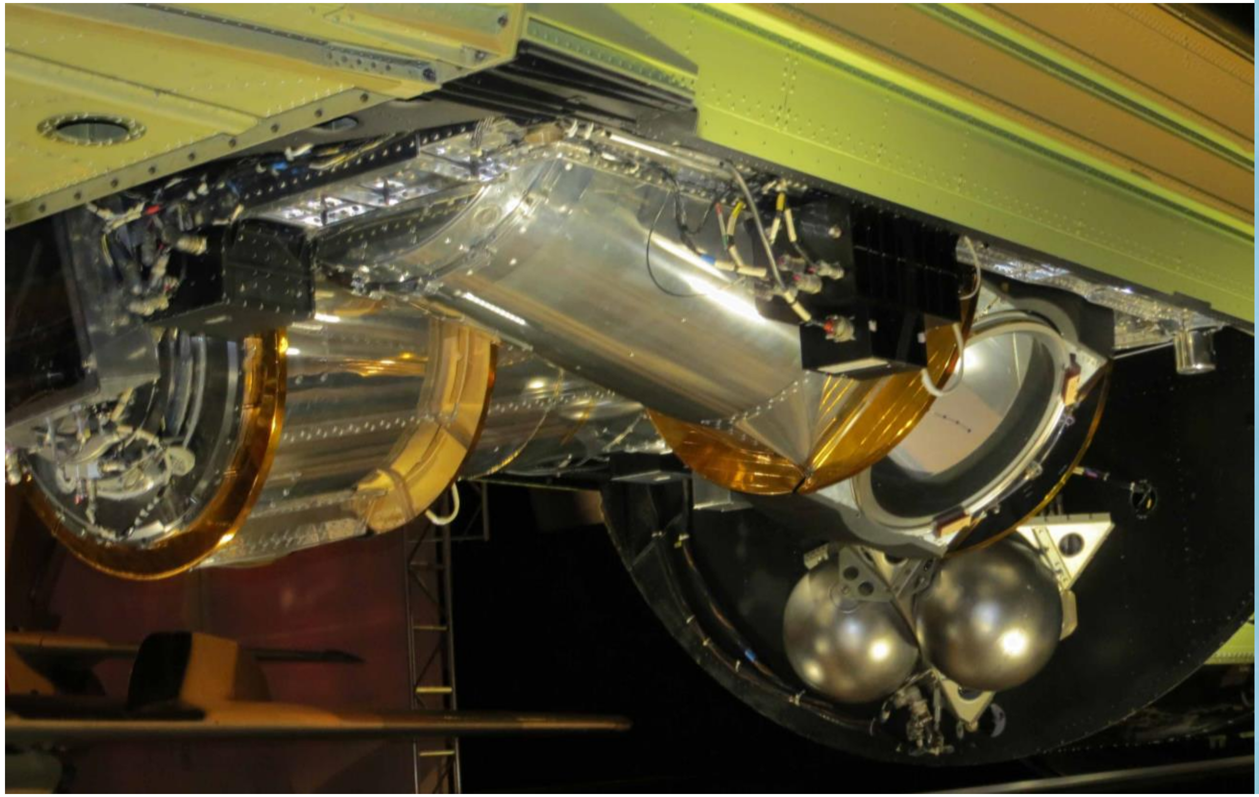
PANORAMA CAMERA SPECIFICATIONS

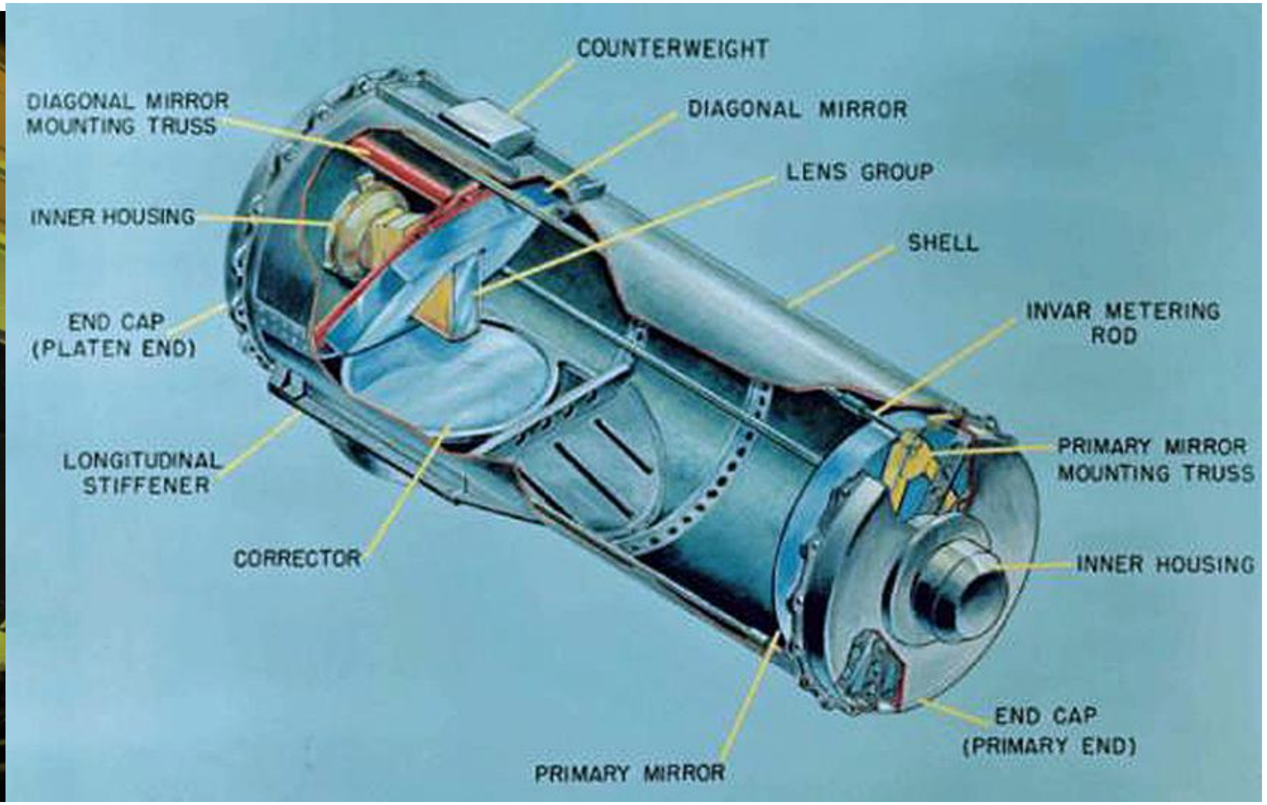
- Optics: 60” Focal length, f/3.0 Folded Wright system
- Aperture diameter: 20”
- Field Angle: 2.85 degrees
- Slit width: 0.91 to 0.08”
- Film
  - 6.6” wide in two spools
  - Supply stack diameter: 68” Weight 5,375 lbs. 30 miles per spool
  - Speed: 66”/sec from supply, 200”/sec maximum at platen
  - Frame for 120-degree scan: 125” long
- Scan Modes: 30, 60, 90, 120 degrees
- Scan centers: 0, 15, 30, 45 degrees
- Stereo coverage: 20 degrees

PANORAMA CAMERA SYSTEM OVERVIEW

The panorama camera system has two six-foot paired cameras offset 20-degrees to achieve stereo images. (The apertures were two feet across.) They could scan up to a 120-degree cross track for swaths up to 300-mi wide by 9-mi long. Scan angles and centers could be adjusted (30, 60, 90, or 120 degrees) with selectable scan offset centers. All paired camera elements rotated in opposing directions to maintain vehicle stability, reduce upsetting movement and thermal balance. No pictures were taken when the aperture pointed in.

PANORAMA CAMERA DETAILS



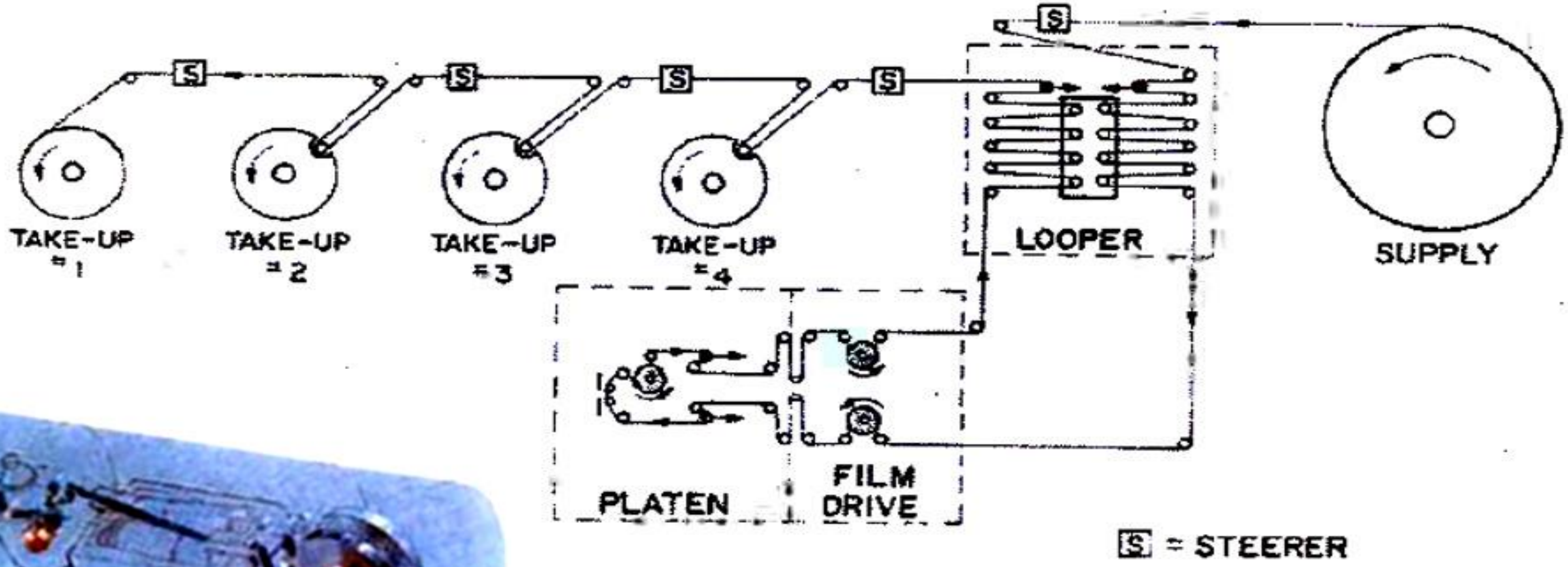


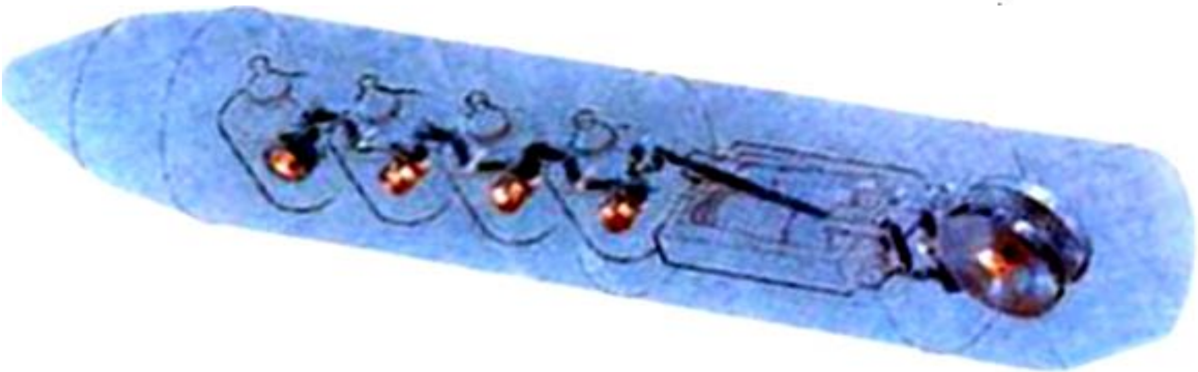
The optical bars were the key element of the camera system. They rotated rapidly to scan transverse (cross-track) to satellite direction of flight as the film passed the platen slit for exposure at a rate up to 200-inches per second for exposure. This eliminated smear due to motion. This was further complicated by the fact the platen had to oscillate; attached to the optical bar during exposure but then disconnect and reposition to begin the next scan as the optical bar rotated at a constant speed. This was done to conserve film (no pictures taken facing inward) and to balance heat conduction. They rotated in opposite directions due to momentum conservation (to avoid wobble).

PANORAMA CAMERAS ONBOARD

The optical had two paired cameras offset 20-degrees to achieve stereo images. The forward-looking camera would take a picture, then the rear looking camera activated to provide an offset to result in a three-dimensional image. Analysts could measure the heights of gantries, missiles and structures.

PANORAMA CAMERA FILM PATH





The film path within the satellite was light tight, air tight, pressurized with gaseous nitrogen and climate controlled. Each of two spools held up to 30-miles of film. Over 120-feet of film passed over more than 100 rollers and air bars between the supply rolls to the reentry vehicles. All roller alignment was precise since the film didn’t have sprocket holes like a 35-mm camera. The camera system compensated between the constant rate and the oscillation requirements of platen exposure with the “looper” that took up slack and fed film at the required rate. It passed through all reentry vehicles (RV) until the last take-up was filled. The film was then cut (between RVs) and wrapped on the next take-up when the first RV was ejected.

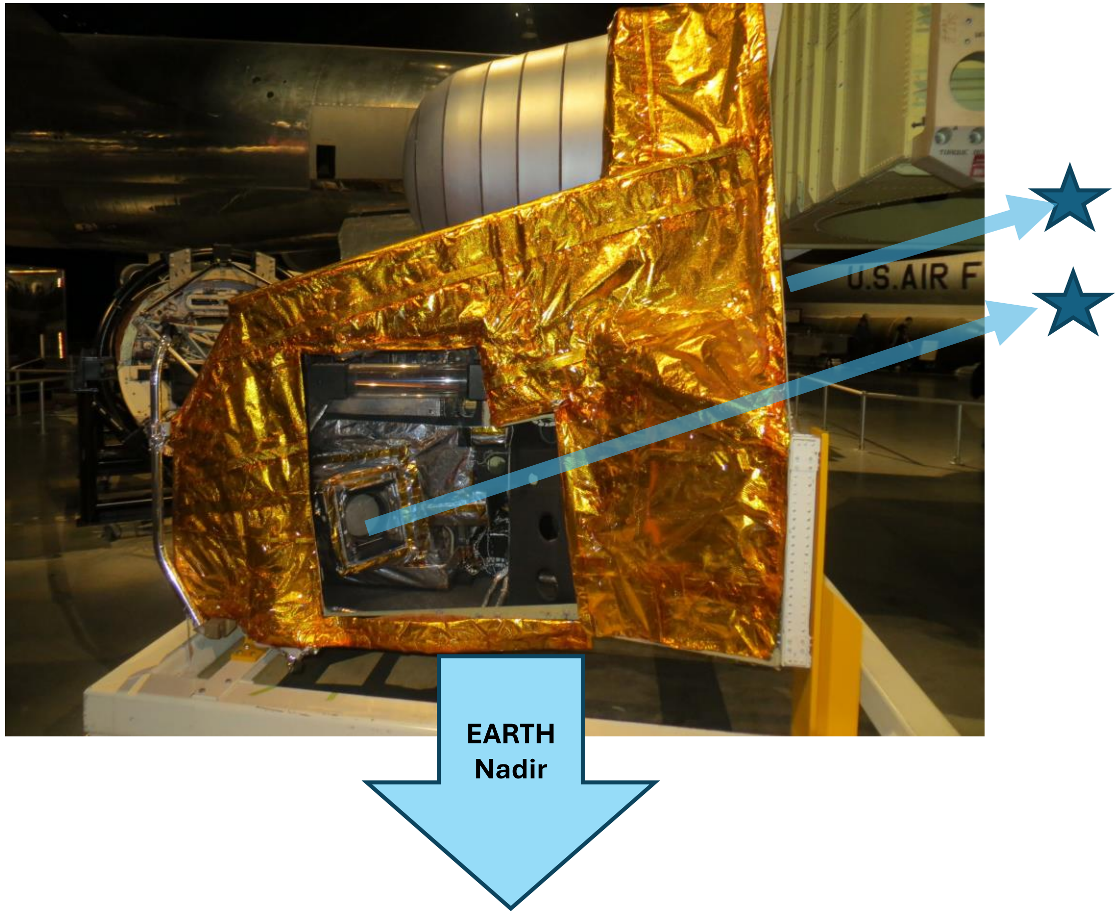
PANORAMA CAMERA INTEGRATION

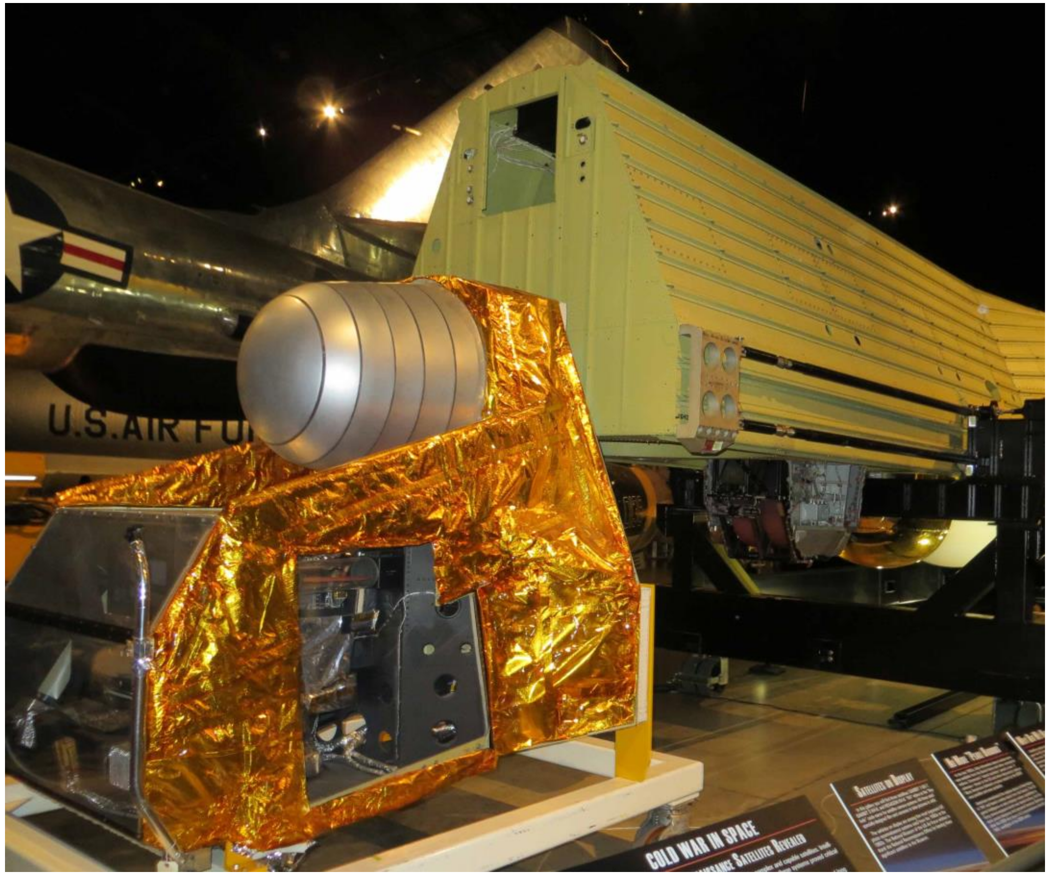
The midsection structure was transported for camera integration at Perkin-Elmer, then the camera assembly was returned to Lockheed via C-5A for final satellite assembly.

MAPPING CAMERA SPECIFICATIONS

- Optics (Ground): Focal length of 12” f/6.0 eight element lens system 9” wide film
- Optics (Stellar): Focal length of 10” f/2.0 lens 70-mm wide film
- Single Mark-V Recovery vehicle for both ground & stellar film
- The doppler beacon system improved orbit position reference
- System tested at ITEK sent to Lockheed for integration

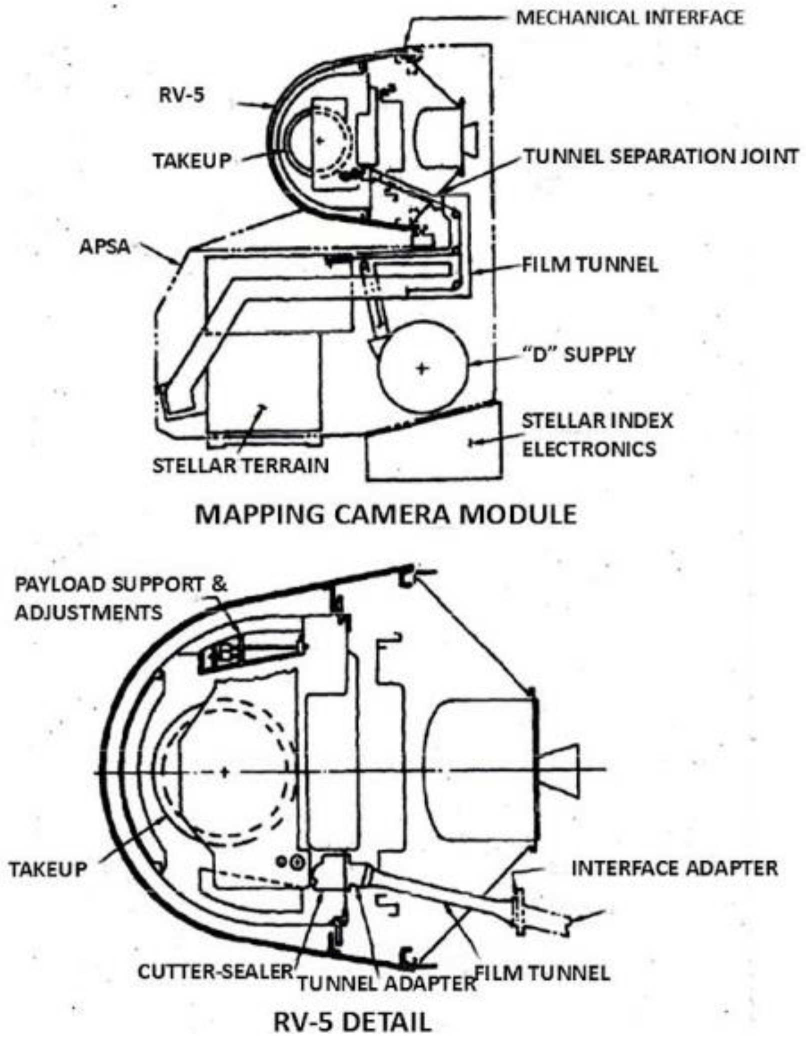
STELLAR TERRAIN MAPPING CAMERA





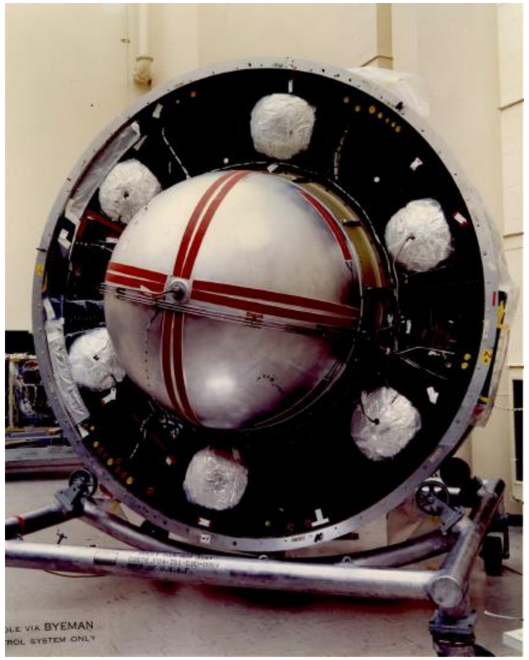
The Stellar-Terrain mapping camera flew on 12 HEXAGON vehicles (5-16) imaging 104-million sq mi. The "footprint" was 70 x 140 mi with a resolution of 20 to 30 ft providing key cartograph information. Location calculations made based on orbit position and the simultaneous imaging of star fields. This registered ground features prior to GPS

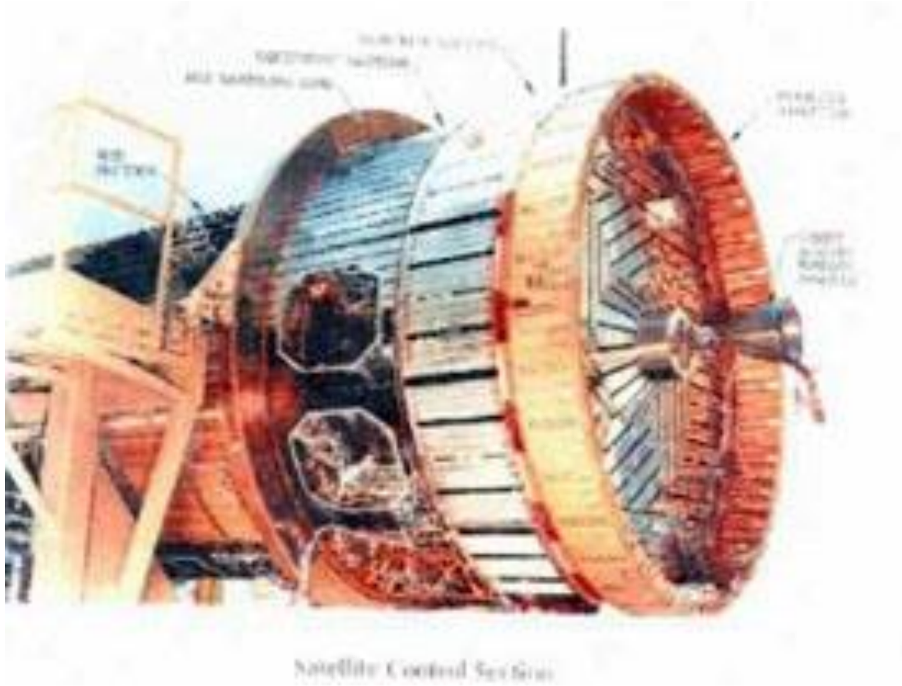
MAPPING CAMERA DETAILS



The Stellar Terrain camera was mounted on the forward HEXAGON bulkhead. It operated for 42 to 119 days by ground generated commands. It had a single RV which returned 48,000-ft of film for processing. All missions were successful in providing essential geolocation information.

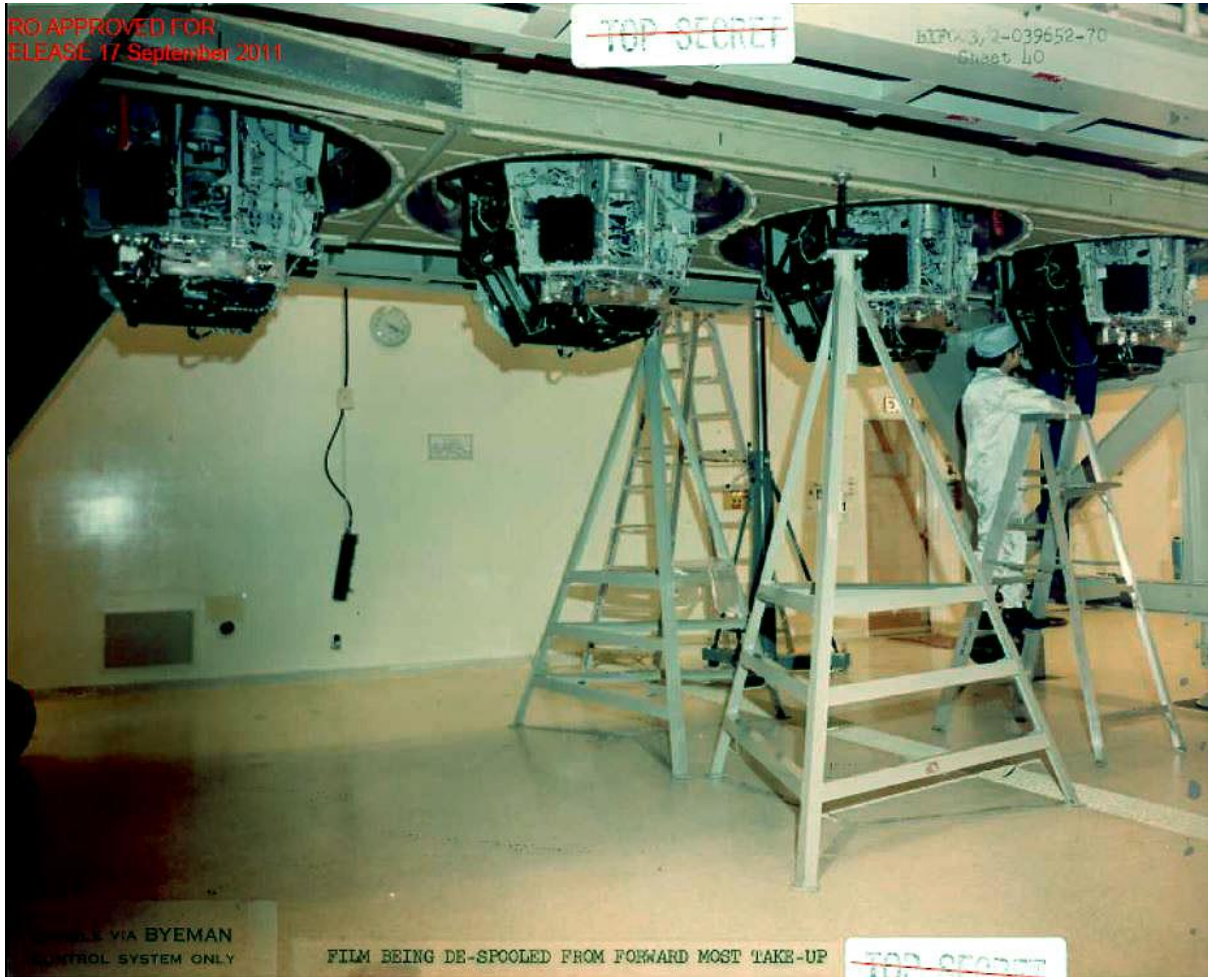
AFT SECTION SUBSYSTEMS

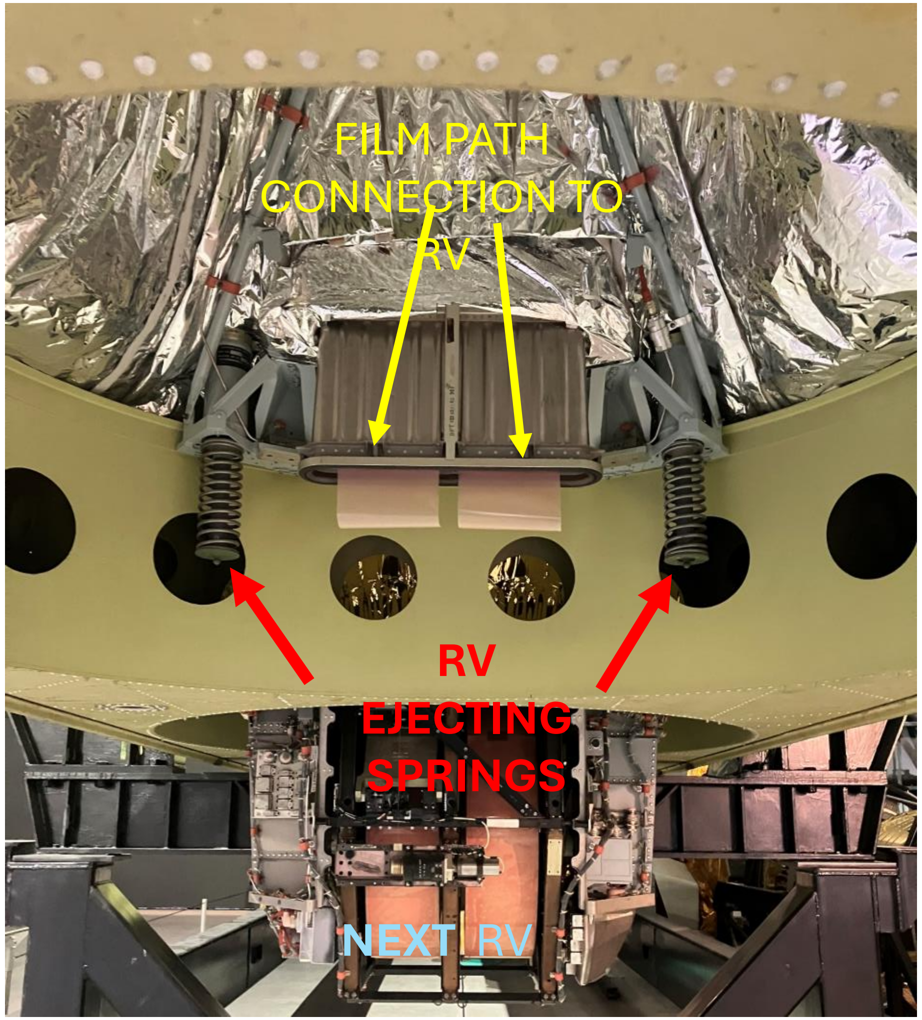




The aft section provided the essential house-keeping functions of power, attitude control, orbit adjust, communication, telemetry, tracking and commanding. Solar arrays extended from the back but cannot be shown except on orbit by graphic artists. All functions (relay, pyro, valve, servo, thruster etc.) were executed via stored program commands generated and loaded into the satellite memory from the ground when it passed over a ground station. Each command was paired with a time tag that executed when it matched the clock read-out. For example, it took a minimum of 16 precise commands to execute a single camera photo operation. Vehicle commanding is addressed in another section

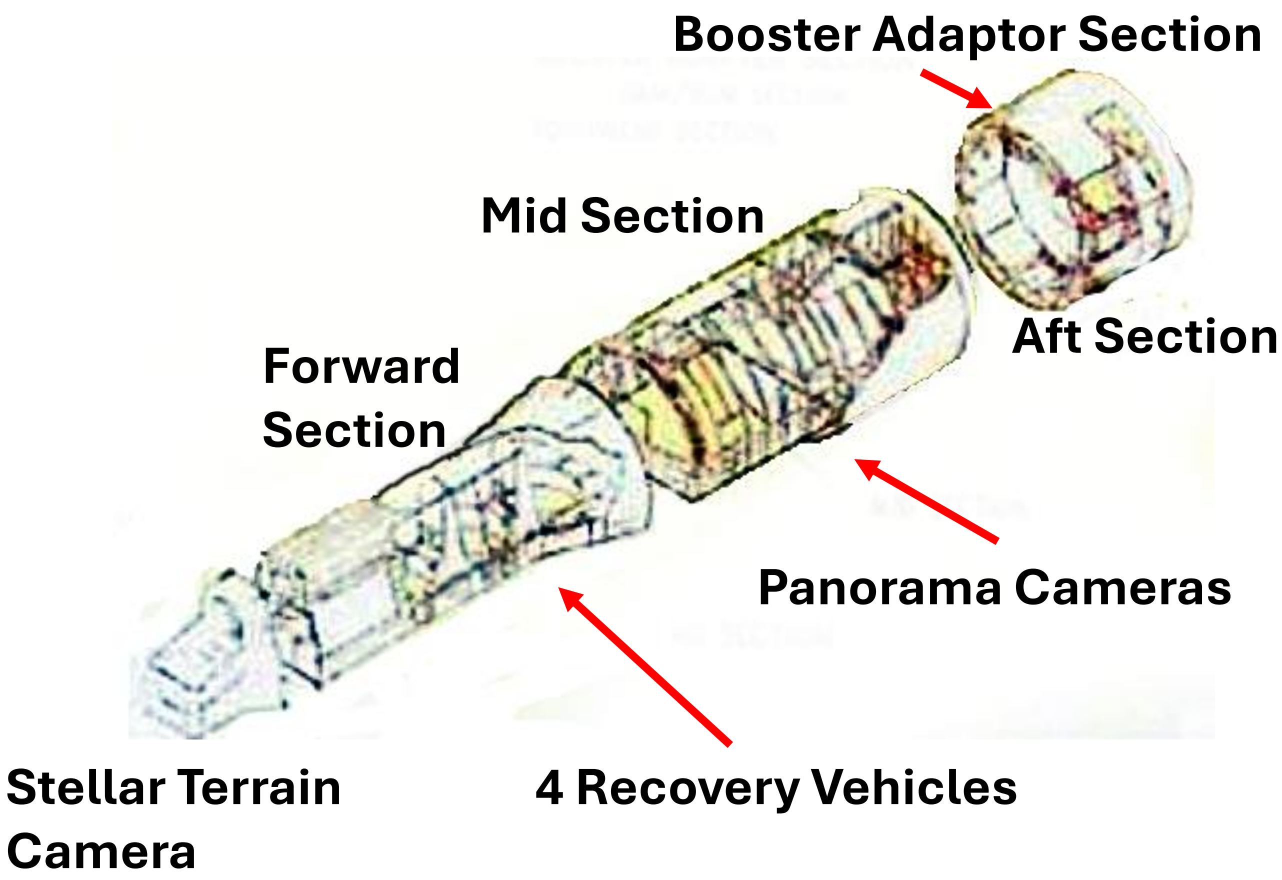
FORWARD SECTION RV ASSEMBLY

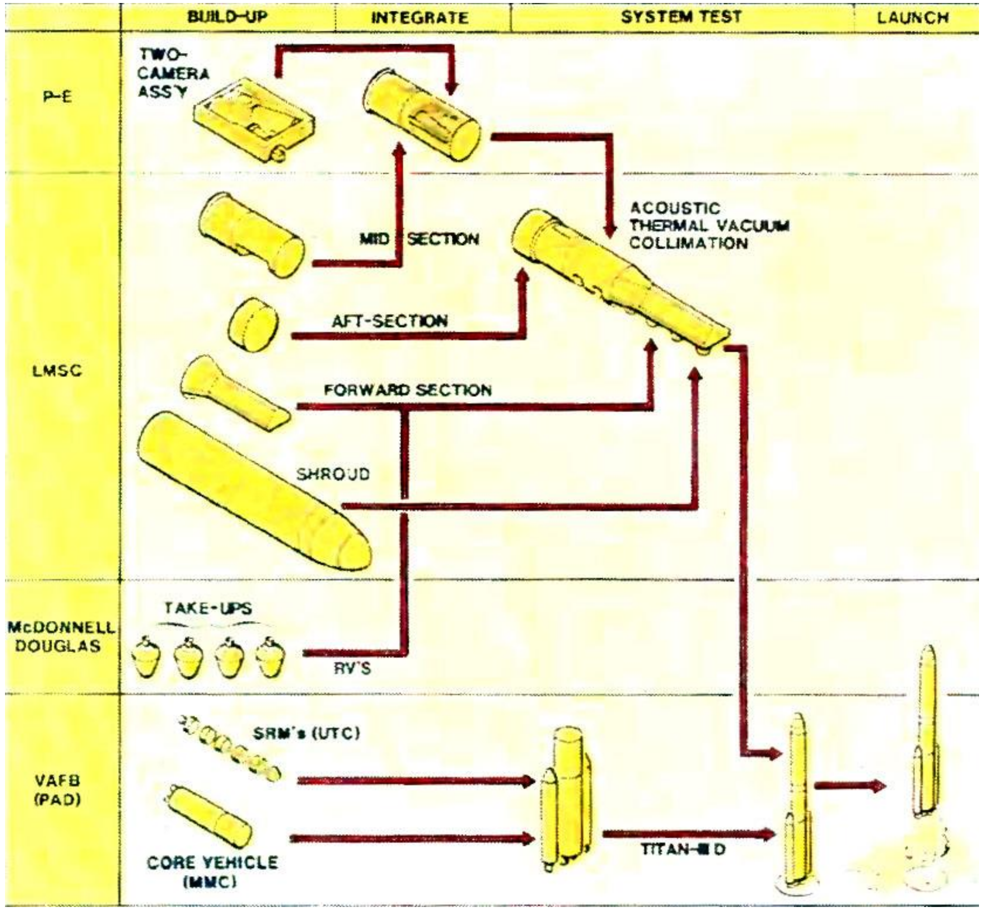




The four film reentry vehicle take-up assemblies (buckets) were installed in the forward section structure before being mating to the midsection. When an RV is deorbited with film, it is ejected and the next RV becomes the take-up device.

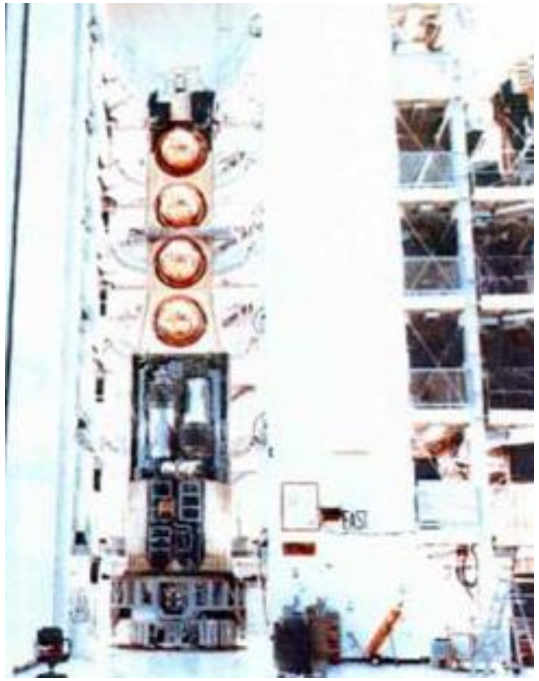
HEXAGON FACTORY ASSEMBLY & TEST





The vehicle 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 comprised the electronic and orbit modules; and the forward section contained recovery vehicles. On 12 satellites, the stellar terrain camera was mounted on the forward section. The assembly flow is indicated on the right. When complete & tested, the satellite (minus the retro rockets for the RVs) was shipped to Vandenberg, AFB to be mated with the Titan vehicle for launch.

INTEGRATED TEST

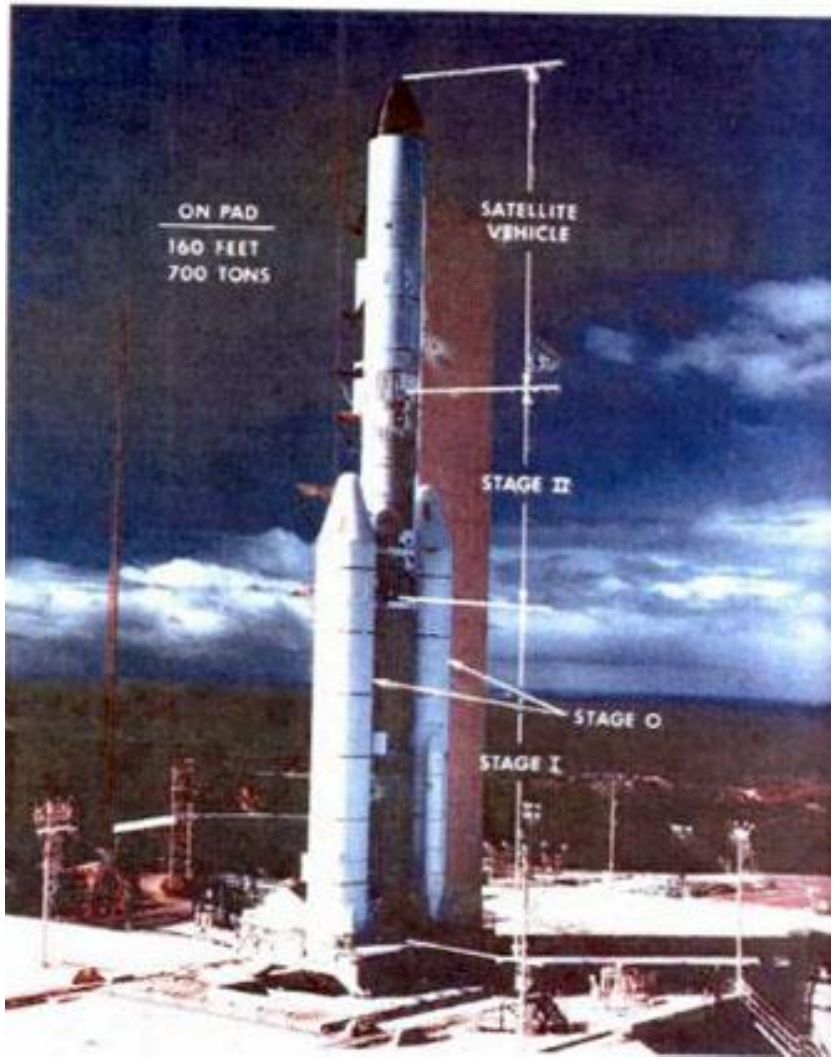


After the segments are tested as sub-units the segments are assembled for integrated vehicle testing which include ambient functional testing, acoustic, environmental and collimation. Acoustic testing subjects the satellite to vibration simulating launch to determine if anything will come apart. Environmental testing is conducted in a thermal vacuum chamber subjecting the vehicle to space conditions. Collimation verifies that the camera focus in a vacuum is correct. Final preparations include loading all flight systems for shipment to the launch team at Vandenberg. Hazards like propellent and RV rockets are handled at the launch site. The integration & test operations require repositioning the satellite both vertically and horizontally for the required assembly and test stations. The 30,000-pound vehicle was repositioned precisely to avoid damage. It’s now ready for fueling and launch.

TRANSPORT TO LAUNCH BASE

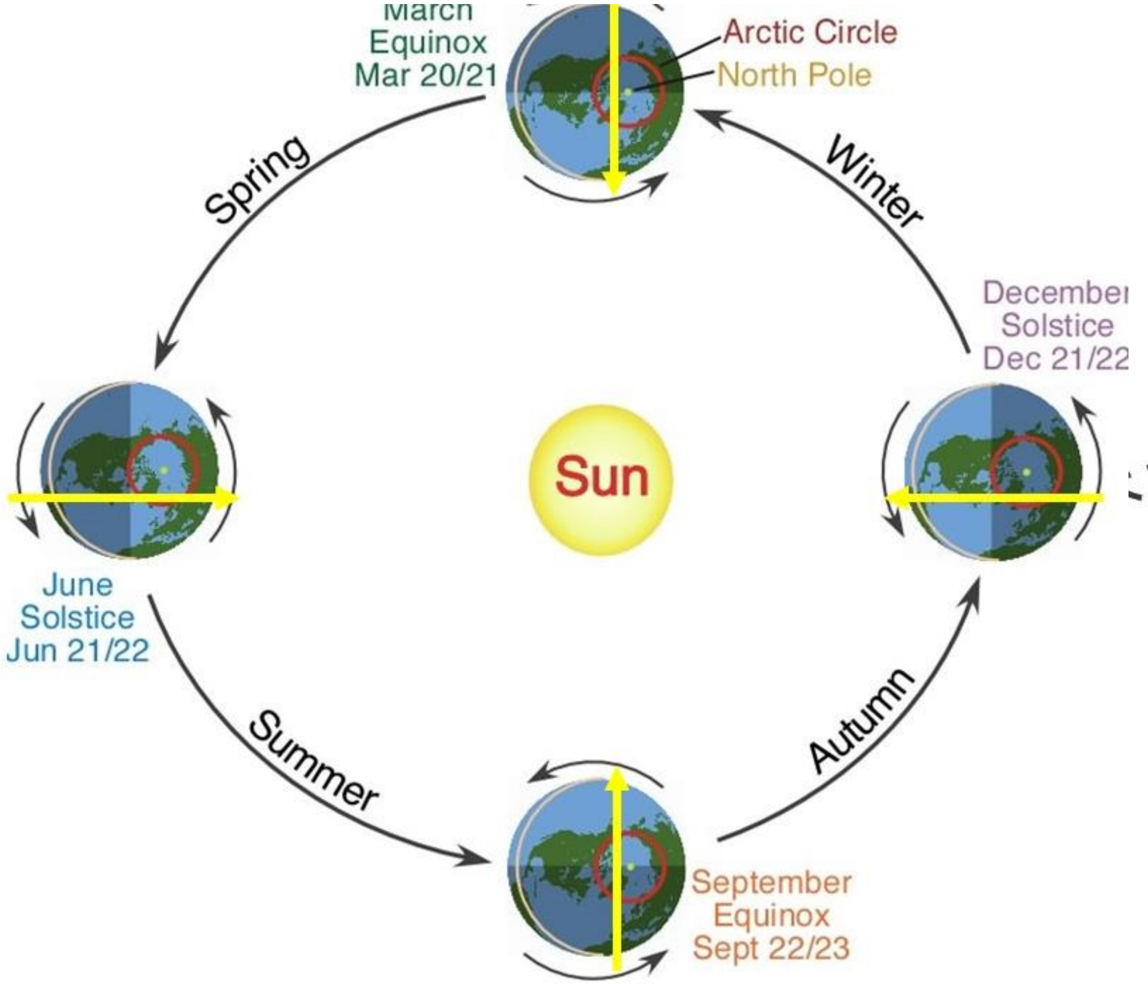
The completed HEXAGON satellite was transported 250-miles from Sunnyvale to the Vandenberg launch complex for booster integration. (Blue Cube visible in back.) Hazardous elements like propellent loading and solid rocket motors were installed at the gantry after the satellite was mated to the Titan-3D launch vehicle.

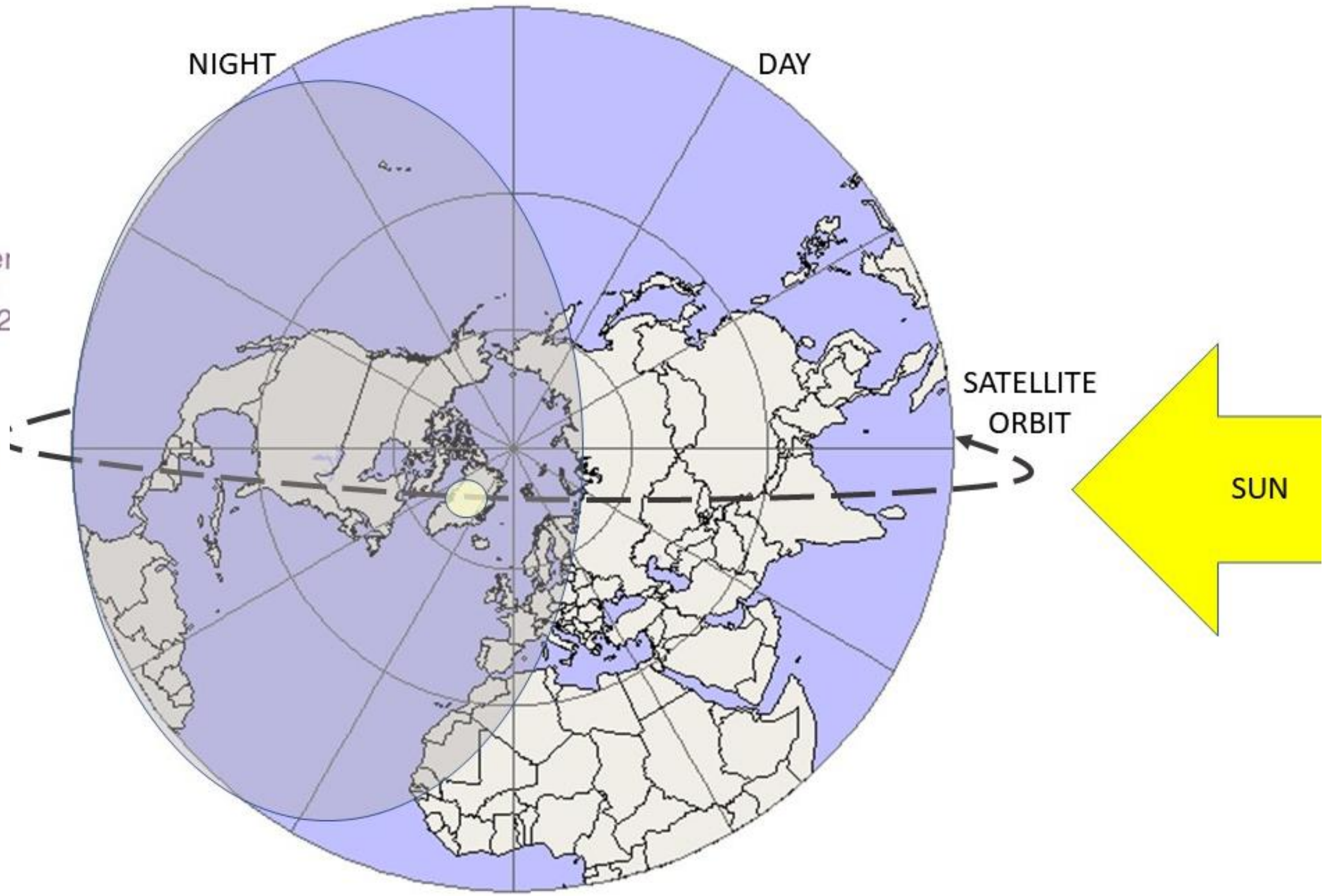
LAUNCH INTEGRATION



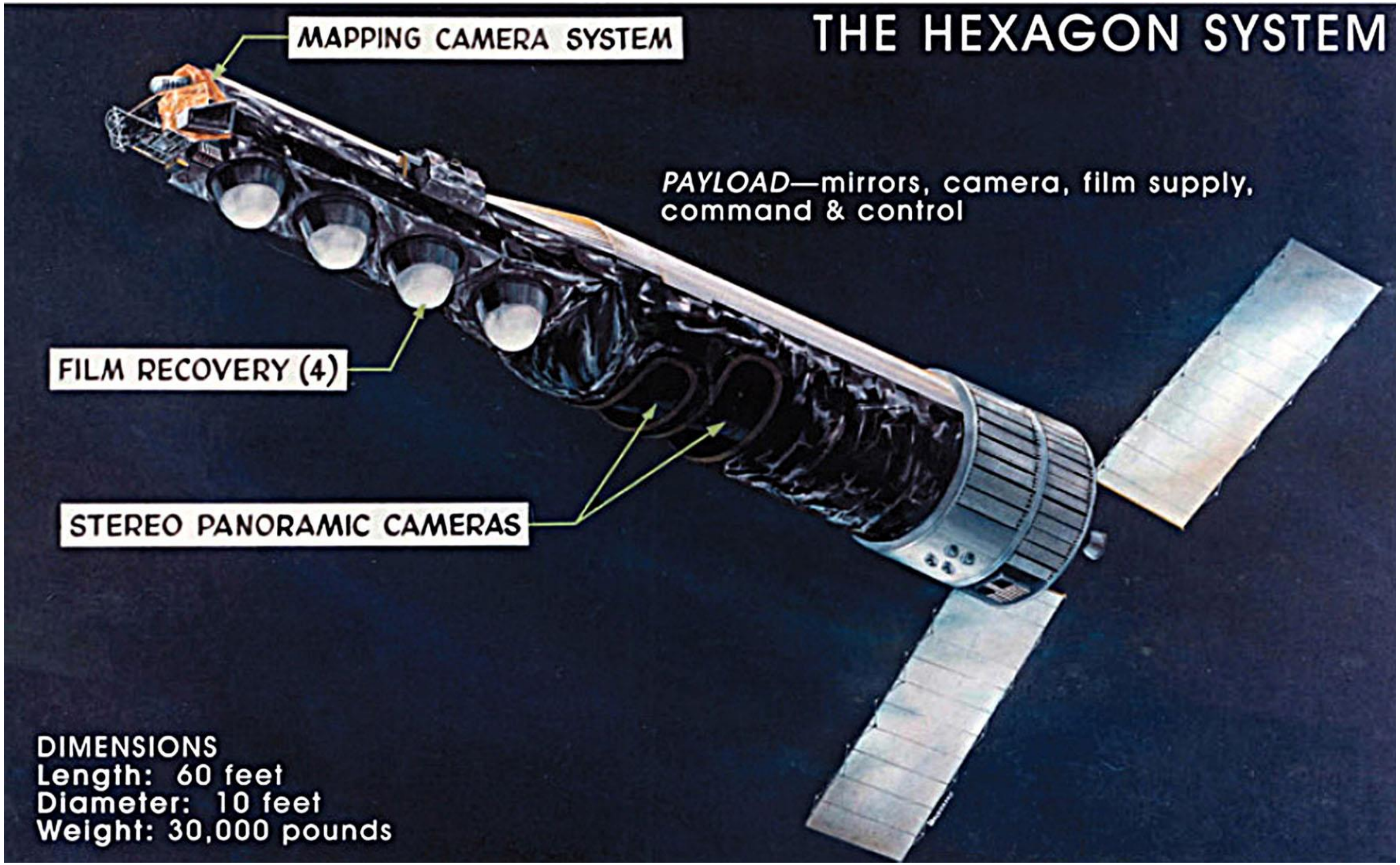
HEXAGON was launched on a Titan-3D (Larger vehicles on Titan 34-D) from Vandenberg AFB. Two solid rocket motors provide the initial thrust. Stage 1 and then 2 moved it to the desired polar orbit. The orbit was sun synchronous to enable operations over illuminated ground for long duration missions. The orbits were inclined 97 degrees and were elliptical 80-270 nm. The California coastal launch site is ideal for polar orbits.

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





FLIGHT CONFIGURATION



This drawing of HEXAGON in full flight configuration shows thermal protection blankets & reflectors, solar arrays deployed and the stellar terrain mapping system.

MISSION OPERATIONS - SATELLITE TEST CENTER

Satellite operations were controlled at the Satellite Test Center located at Sunnyvale AFS, CA.(Later renamed Onizuka AFS). Air Force & contractor teams generated the command sequences for all functions and operations as well as monitoring and managing the functional operations. Teams of four officers prepared the command messages, 24/7 for each mission duration. Commands were sent to the designated Remote Tracking Station to be uploaded during the next station pass. Commands were stored in the satellite memory and were executed later in the orbit. The generation of commands was repeated each orbit revolution, thus was repeated 16 -times each mission day.

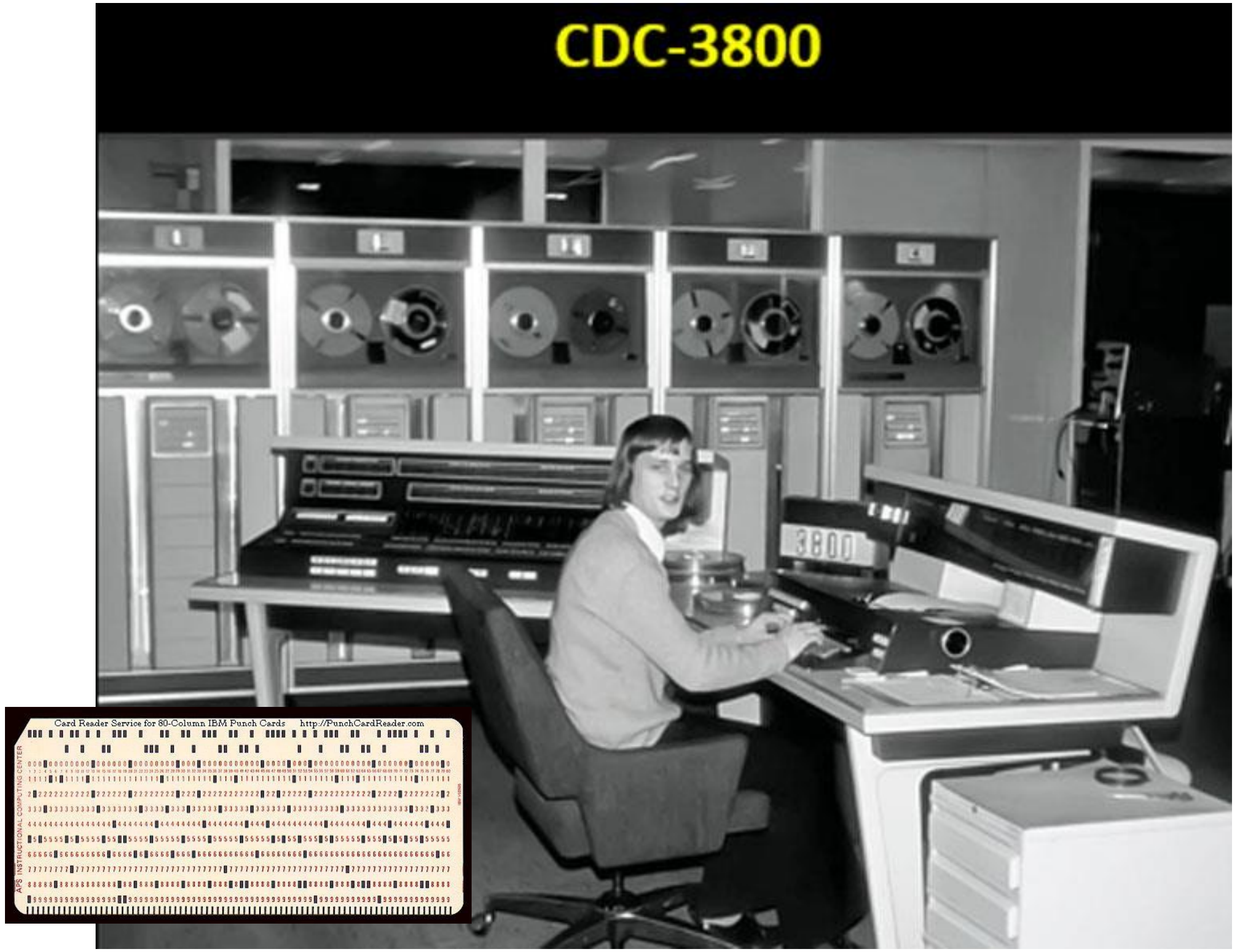
SATELITE CONTROL NETWORK OF GROUND STATIONS

Code names were: (Left to right)
HULA, COOK, BOSS,
POGO,INDI, GUAM

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!		



Computer Technology in the 70s & 80s

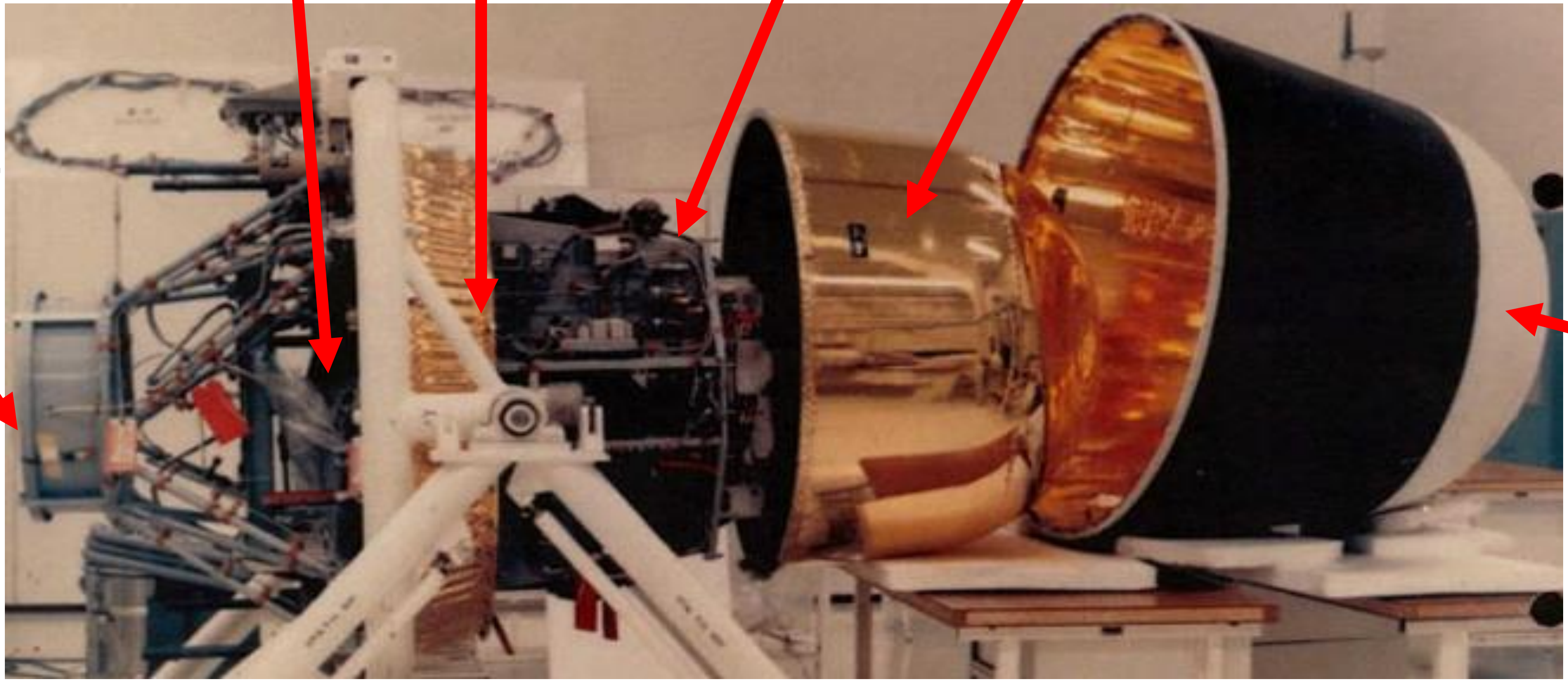
Spec	CDC 3800	Dell Inspiron Corei7	Ratio
Architecture bits	48	64	1.3
Brand Name	CDC 3800	Dell Inspiron Core i7	NA
Clock speed Hz	1,000,000	4,600,000,000	4,600
Cost	$ 1,900,000	$1,300	1,462
Graphics Coprocessor	None	Intel UHD 620	NA
Hard Drive Capacity	300,000	512,000,000,000	1,706,667
Item Weight	Tons	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 70's was primitive by today's standards. 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. Computer runs were programmed with punch cards and several runs were required to optimize the sequence. In addition, RV recovery, orbit adjust, and other functions were commanded as well as photo operations.

WEATHER SATELLITES PROVIDED CLOUD COVER INFORMATION

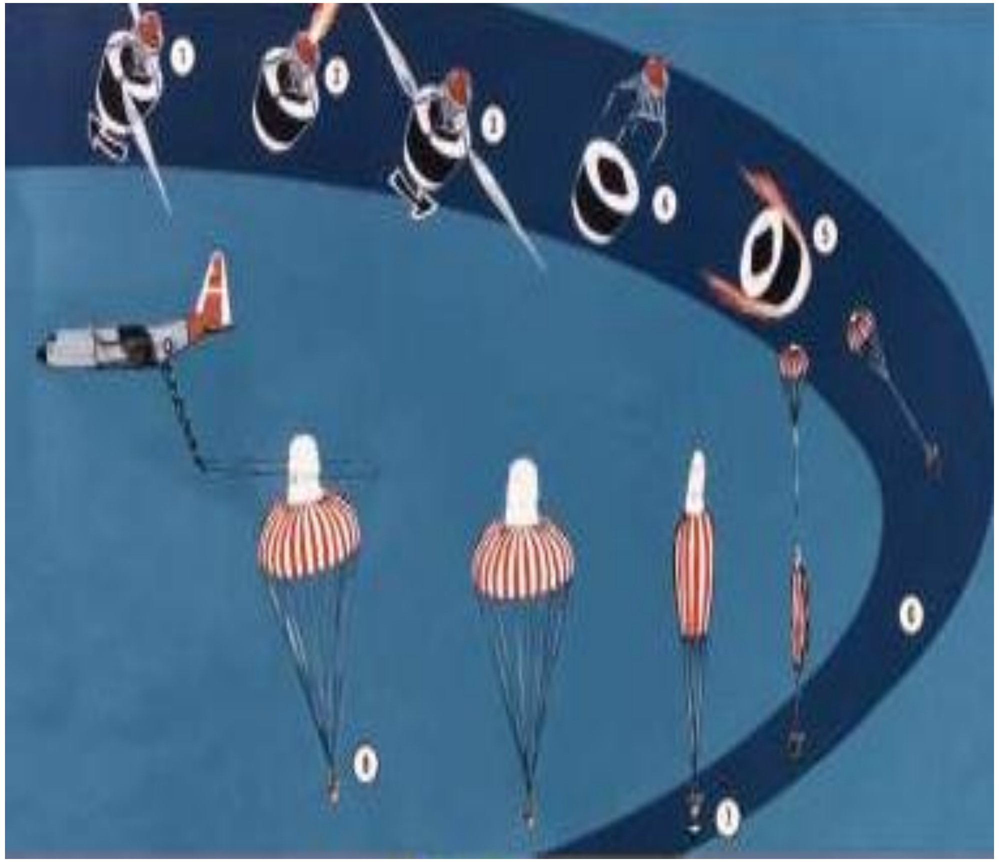
Clouds can obscure the ground, preventing detailed intelligence imagery. Weather satellites reported coverage before and after each HEXAGON pass to determine the probability that the images tasked would be clear of cloud cover. Program 417 spin-stabilized satellites flew in sun synchronous orbits (98 degree and 450 nm circular) with 1-nm resolution.

DETAILS OF REENTRY VEHICLE "BUCKETS"



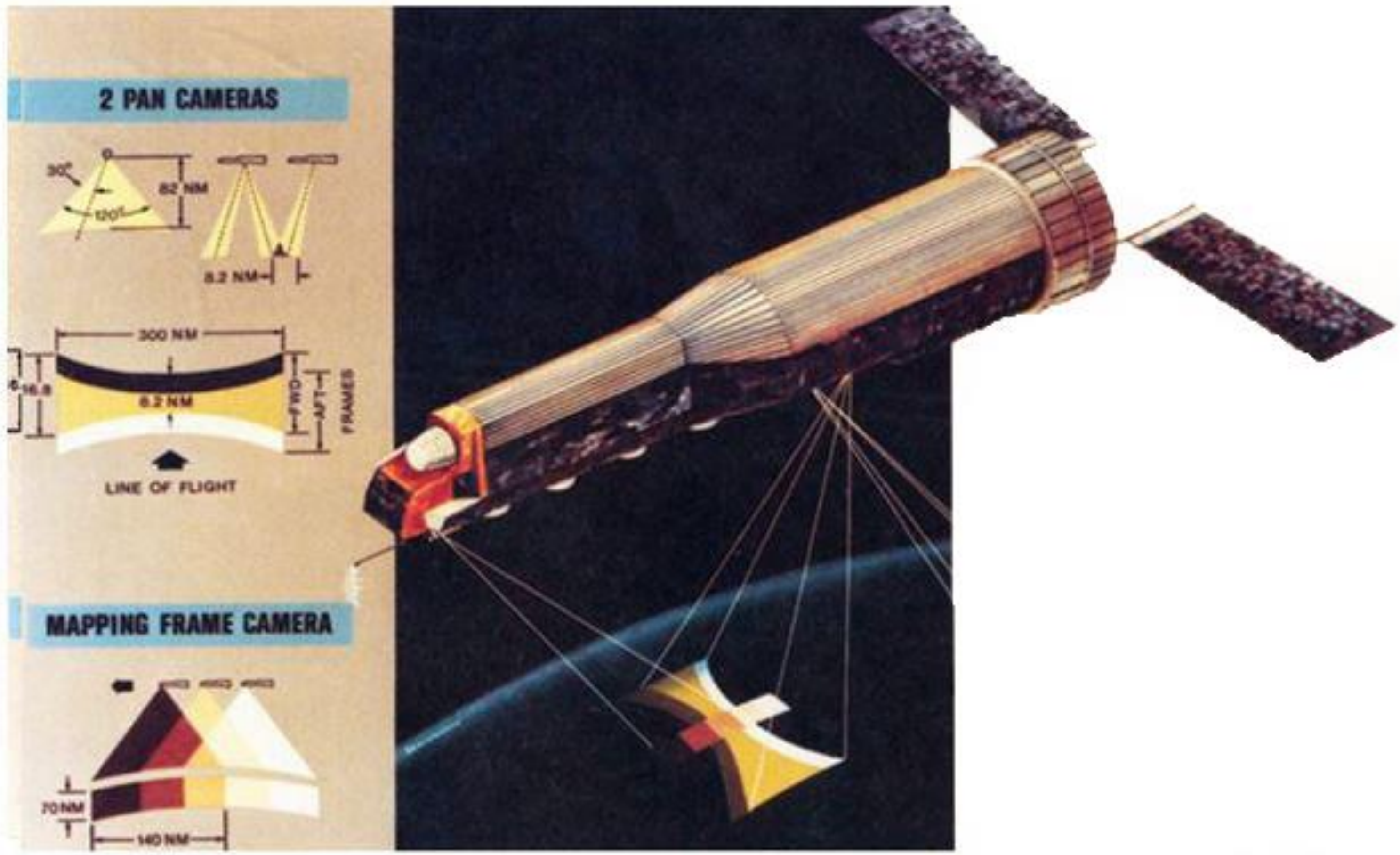
RVs protect the exposed film reels both on-orbit and during recovery. This photo shows the construct of the RV. The inner capsule & outer heat shield acted like a thermos bottle for environmental protection.

REENTRY SEQUENCE



A full RV weighed about 1,000 pounds and followed a sequence to return for processing. Springs eject the RV and a set of thrusters spin it to assure stability. A solid rocket motor fires to slow it to suborbital speed & a second set of opposing spin thrusters de-spin it. Then the thrust section is ejected. The capsule reenters the atmosphere protected by the ablative heat shield and internal (thermos bottle-like construction). After surviving the heat of reentry, the heat shield is ejected. At 50,000 feet the parachute deploys and at 15,000 a specially designed JC-130 hooks the chute & reels it in for transport to the stateside processing facility.

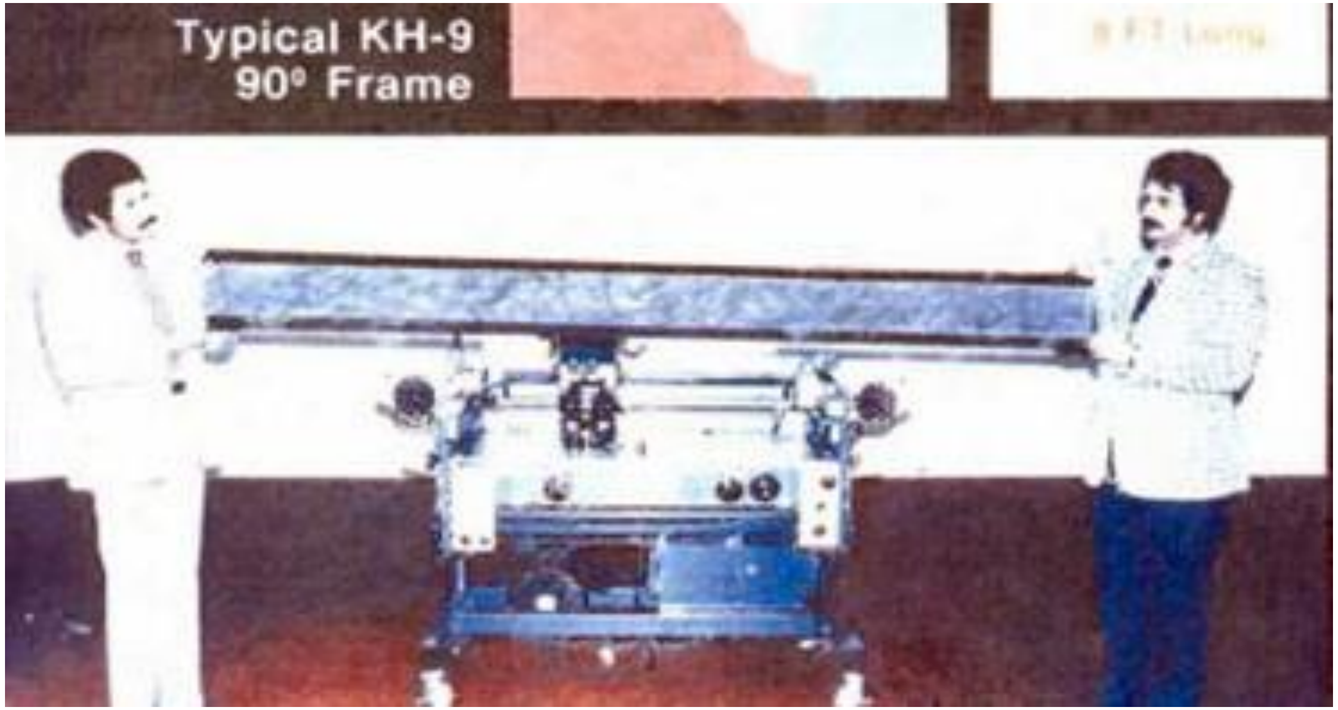
CAMERA OPERATION ON ORBIT



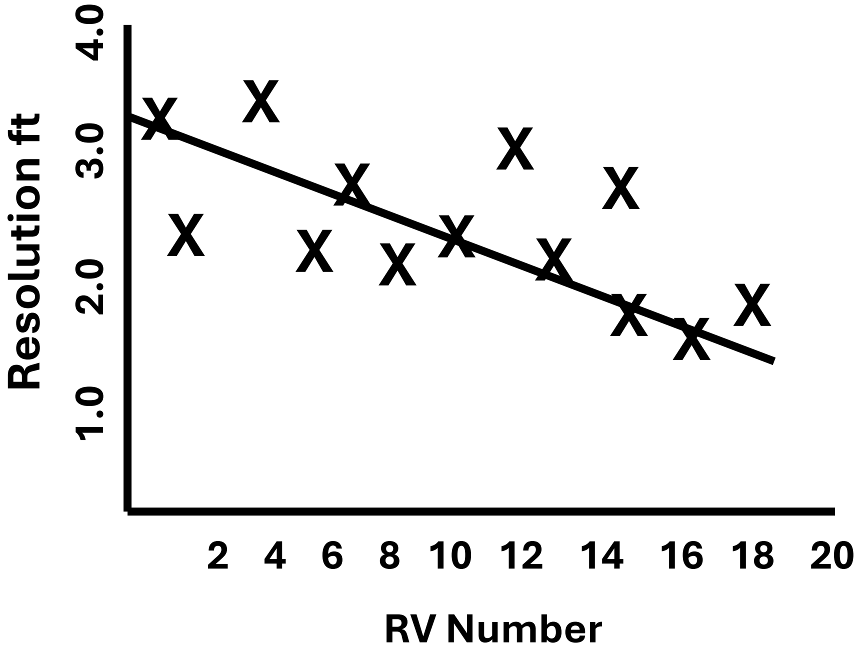
These camera “footprints” for the forward mapping camera and the main panorama camera systems depict the maximum coverage. The pan camera achieved a resolution of less than 2–7-foot resolution across its 16.8 x 300 mi footprint covering 230 million square miles on all missions. Some targets were imaged in tri-laps (3 times) in a single operation providing more detailed information.

PHOTGRAPHIC INTERPRETATION

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

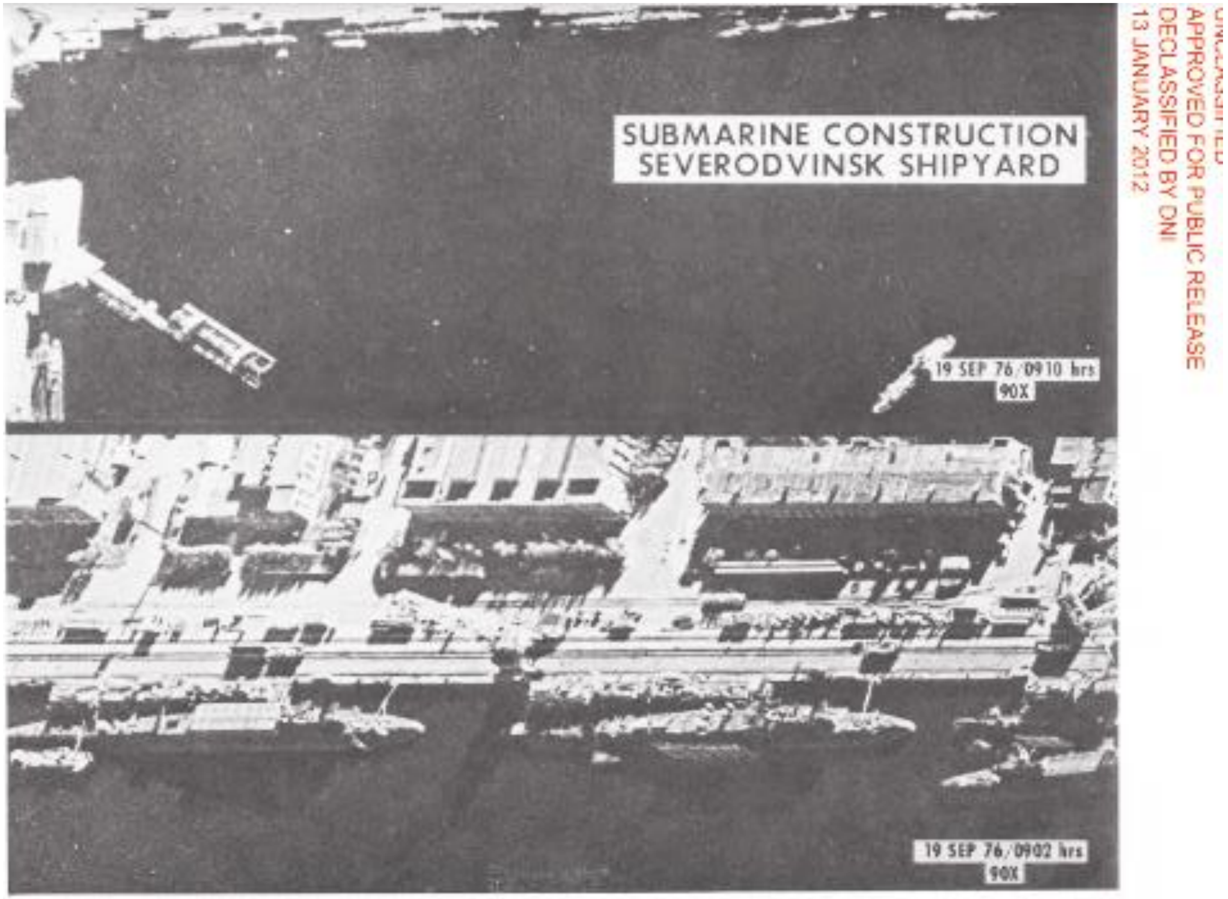


SYSTEM PERFORMANCE TRENDS



The 90-degree film strip shown is 6.5-inches wide and 8-feet long. The viewing table behind the analysts could spool film pairs from both pan cameras for stereo viewing and 3D analysis. The HEXAGON satellite integrated improved technology increasing functionality throughout its life. The graph on the right approximates how best resolution improved from 3.5 to 2-ft in the course of the program. “Broad area search at medium resolution” a half century ago was not duplicated commercially until the past decade.

DECLASSIFIED SAMPLE HEXAGON IMAGES



SUBMARINE CONSTRUCTION SEVERODVINSK SHIPYARD 9/76

MOSCOW ABM COMPLEX MISSION 1218-1 40X 1983

HEXAGON SV-20

On 18 April 1986, the 20th and planned last HEXAGON satellite exploded 9-seconds after launch on a Titan 34-D rocket. The previous 19 satellites were a 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.

This simulation below illustrates the value of strategic reconnaissance during force build-up. It is provided for illustrative purposes only using commercial satellite images (from Google Earth) of the National Museum of the United States Air Force as new hangars were built from 1994 – 2019. HEXAGON provided similar build-up intelligence during the Cold War. With two cameras, HEXAGON took 3D photos to gauge heights.

It flew in a sun-synchronous polar orbit and thus could see the same "target" with the same lighting. This allowed intelligence analysts to study any additions and modifications to points of interest. The viewer can see how a target could change over time to reveal new missile silos, launch facilities, command buildings, etc.

Note the change of seasons, time of day, image quality over years during the construction of the museum. HEXAGON could take swaths of land 300 x 9 miles on a single operation. Declassified images are now available to the public for archeological research, earth resources, climate change and agricultural studies.

Museum comprises two 800’ x 240’ buildings **March 1994**

1.

Additional aircraft displayed outside; baseball diamonds **October 2000**

2.

3rd Hangar under construction **July 2002**

3.

Museum with 3 Hangars **August 2005**

4.

Surveys for 4th Hangar **July 2006**

5.

Construction of Hangar 4

March 1994

6.

All 4 hangars visible **October 2011**

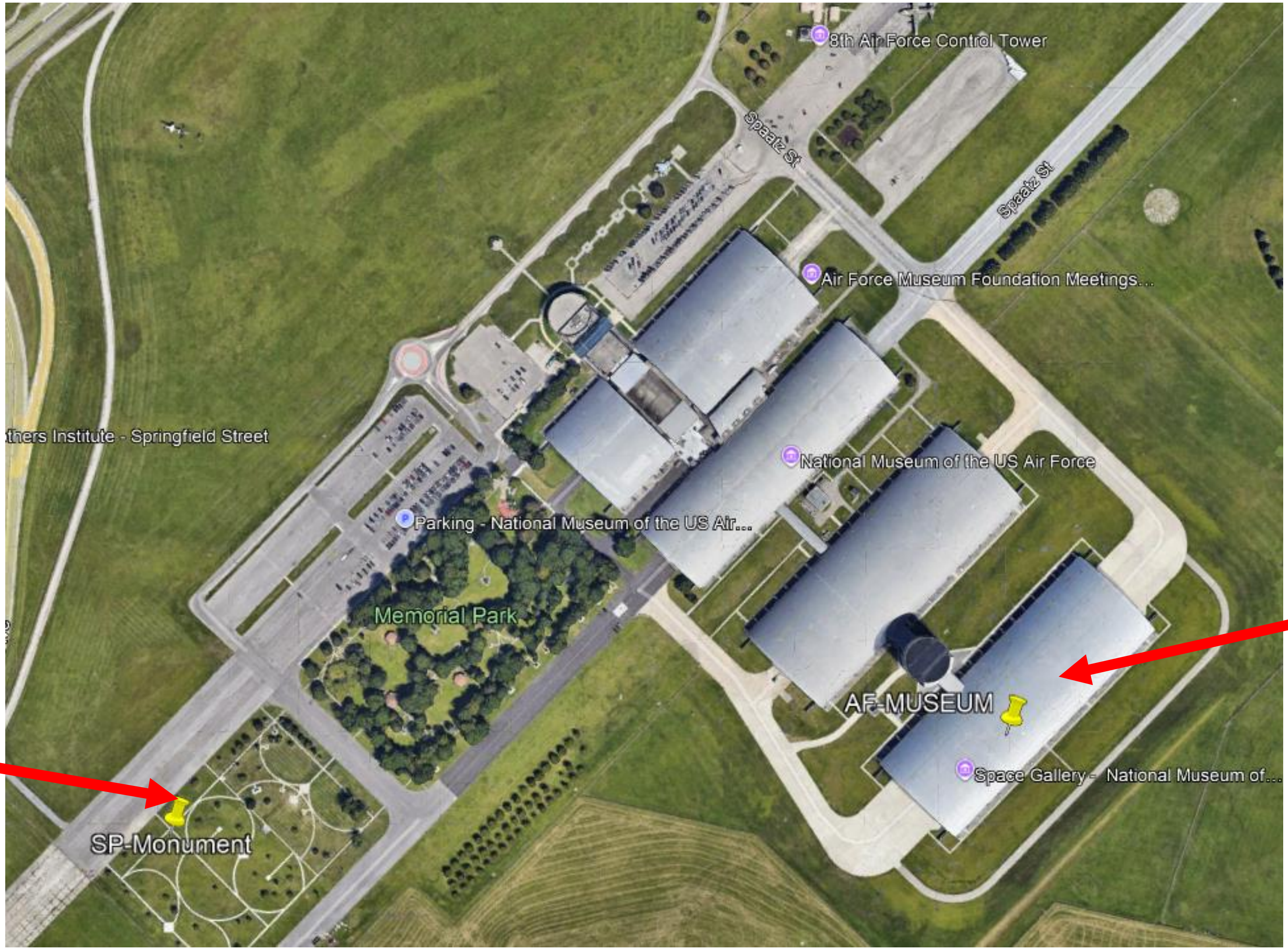
7.

Growth surrounding museum **July 2018**

8.

Current Museum configuration **April 2025**

HEXAGON DISPLAY LOCATION
National Museum of the United States Air Force



HEXAGON
In Hangar 4

SAFSP
Memorial

OPERATIONAL ACCOMPLISHMENTS

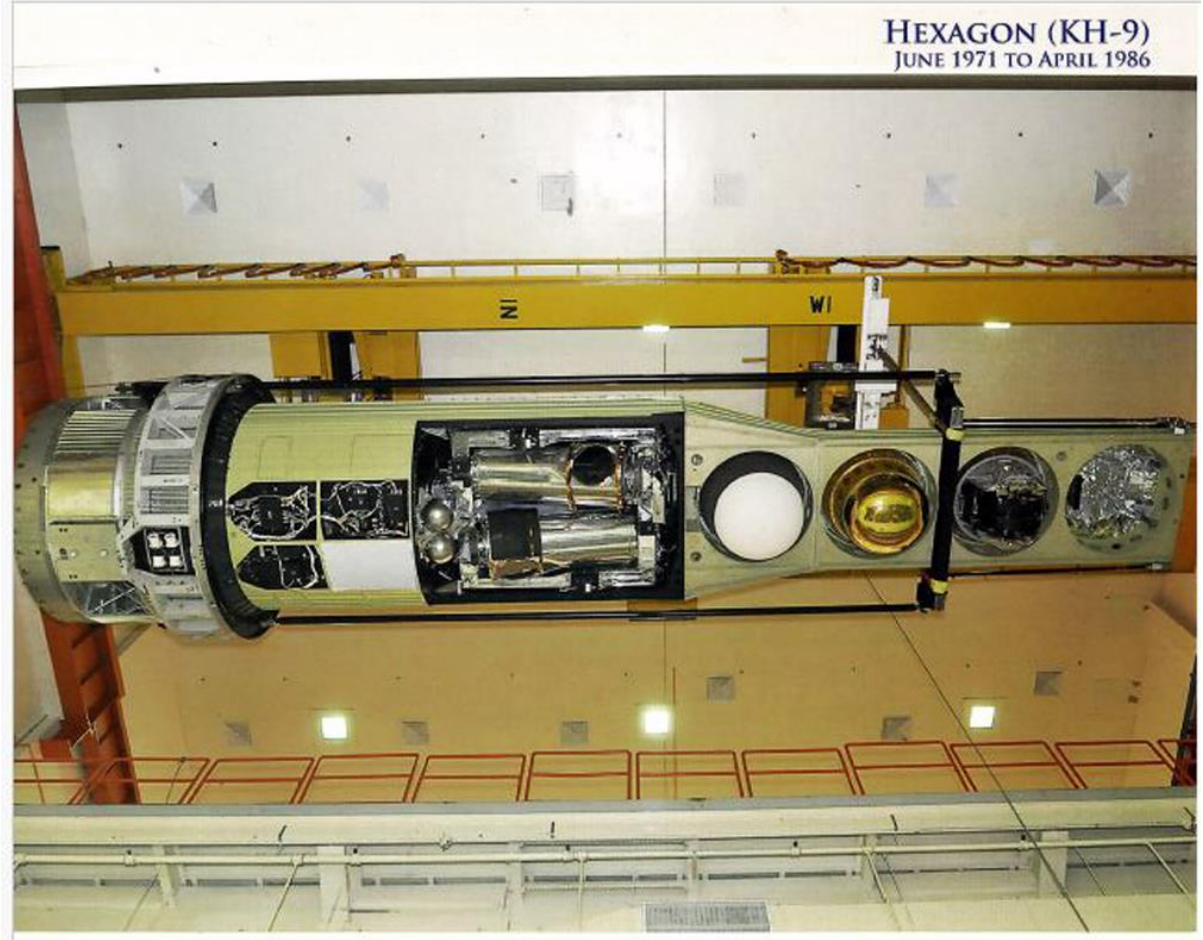
* INTELLIGENCE IS EXPENSIVE, BUT IGNORANCE IS UNACCEPTABLE!

* IF THE COLD WAR "WENT HOT," the DAMAGE WOULD EXCEED ALL WWII BOMBS DROPPED ON EUROPE; IT WOULD TAKE 40 MINS!

* CURRENT HISTORY CLASSES IGNORE 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.

On 17 September 2011 HEXAGON was declassified & displayed to the public



HEXAGON being prepared for public display.

HEXAGON at the
National Museum of the United States Air Force