Recovery of the Last GAMBIT and HEXAGON Film Buckets from Space, August–October 1984

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The year 2014 marks the 30th anniversary of America's last film-return reconnaissance satellite missions.

A revolution in US intelligence quietly occurred on 19 August 1960, when a modified Air Force C-119 Flying Boxcar, commanded by Capt. Harold E. Mitchell, call sign Pelican 9, made the first successful mid-air recovery of a film capsule from a spy satellite codenamed CORONA. The capsule, ejected about 100 nautical miles over Kodiak, Alaska, on the satellite's 17th pass, made a fiery reentry through Earth's atmosphere before deploying a parachute that allowed it to descend slowly to within range of aircraft waiting in a recovery zone over the waters near Hawaii.

While the military kept the capsule's connection to intelligence a secret, the fact that Mitchell made the first midair recovery of an object from orbit quickly made national headlines. The *New York Times* ran a front-page story the next day describing how the 35-year-old Mitchell snared the 84-pound object about 8,500 feet over the Pacific Ocean on his third pass with hooks suspended from poles hanging below and behind the aircraft. Other news outlets touted the mission as another success in the nation's growing space program.

When Moscow announced the successful reentry of a Soviet capsule carrying two dogs, rats, and mice a few days later, Universal-International News broadcaster Ed Herlihy proclaimed that "dramatic strides by both sides in the space race give promise of major developments in man's efforts to actually send human explorers into the far reaches of the solar system."[1]

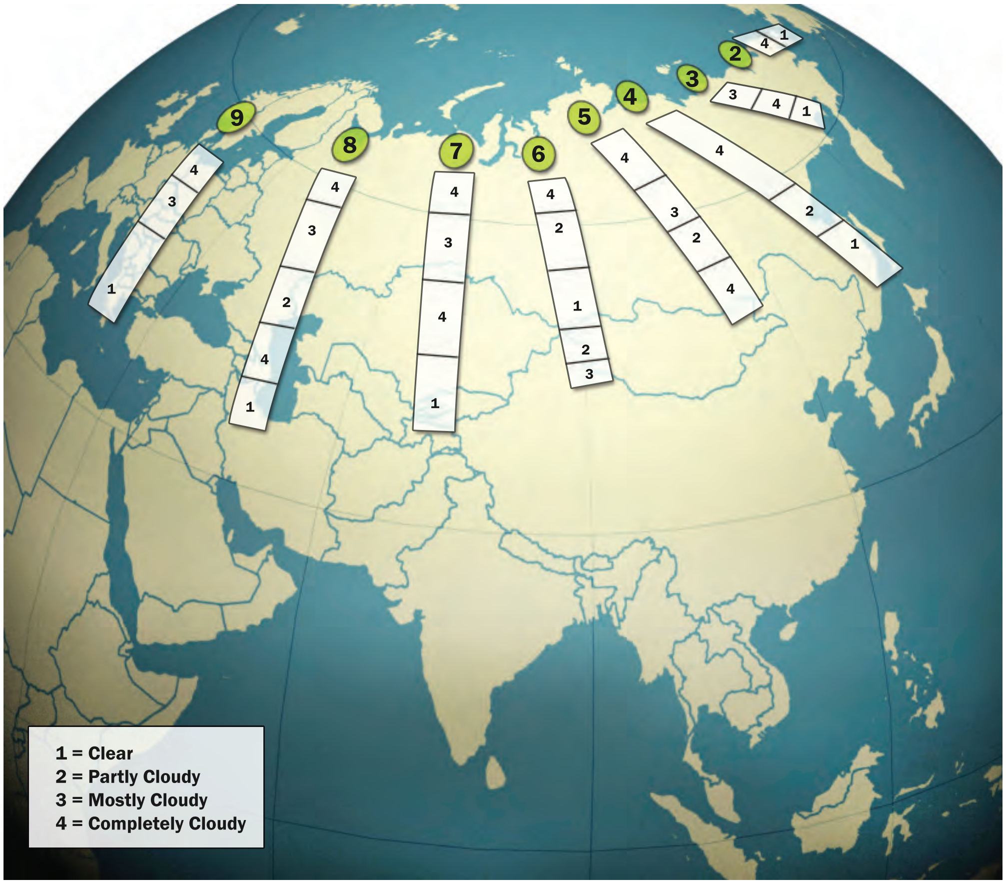
Gen. Emmett O'Donnell, commander of the Pacific Air Force, on orders from Air Force Chief of Staff Gen. Thomas D. White, awarded Mitchell the Distinguished Flying Cross and the five other members of his crew Air Medals immediately upon their return to Hickam Air Force Base in Hawaii. After an impromptu press conference, Mitchell and his crew flew to Los Angeles the next day for meetings with Maj. Gen. Osmond J. Ritland, commander of the Air Force Ballistic Missile Division and the launch officer who sent the rocket carrying the capsule into orbit. The men then made additional press appearances and taped a segment on the Dave Garroway Show in New York before briefing Lt. Gen. Bernard A. Schriever, commander of the Air Research and Development Command, in Washington, DC. Parades, hometown celebrations, and more media appearances followed. The entire unit eventually received the prestigious MacKay Trophy for the most meritorious flight of 1960.[2]

Hidden from public view, under cover of a scientific space research program called Discoverer, was knowledge that CORONA was a Central Intelligence Agency (CIA)-managed satellite program intended to photograph "denied areas" in the Soviet Union, China, and other countries. CORONA, like many early US reconnaissance satellites, emerged from a pivotal Air Force project initiated in 1956, designated Weapon System 117L (WS-117L). A primary purpose of WS-117L was to transmit electronic images of the Earth to ground-based receiving stations, but it also included a secondary system, which would return the exposed film in capsules, called buckets, ejected from the satellite.

The direct transmission function initially received priority since it offered the possibility of timely reconnaissance. In 1958, however, with the electronic transmission effort struggling and the need for accurate intelligence on the Soviet Union's strategic capabilities growing, President Dwight D. Eisenhower approved a plan reassigning the film-recovery system from the Air Force to a secret CIA/Air Force team led by CIA Deputy Director for Plans Richard M. Bissell, Jr.[3]

After 13 consecutive failures, including Discoverer Zero, Discoverer 13 finally proved the reliability of the film-return concept. The satellite, launched from Vandenberg Air Force Base, California, on 10 August 1960, carried diagnostic equipment and a hastily added American flag. Unfortunately the bucket landed in the water the next day owing to a navigation error by the recovery aircraft. Divers recovered the capsule before it sank.

A week later, Discoverer 14 (Mission 9009) achieved full success. The spacecraft entered a perfect orbit, the camera worked flawlessly, and a full 20-pound film load was exposed, placed into the recovery capsule, and successfully ejected from the satellite. Mitchell's Pelican 9 aircraft



The above schematic shows the imaging paths of Mission 9009, the first CORONA satellite to return images from space. The new imaging satellites revolutionized strategic intelligence collection on the Soviet Union. On 18 August 1960, Mission 9009 conducted eight north-south passes over the USSR and small portions of China. It imaged numerous military installations, some of which had not previously been located. (Derived from a mission map contained in *CORONA: America's First Satellite Program*.)

recovered Discoverer 14's capsule on 19 August. (See image on facing page.)

The capsule Mitchell recovered that day contained the first photographs taken from space. Over the next two-and-a-half decades, first the CIA and then the covert National Reconnaissance Office (NRO) would develop and operate several CORONA follow-on systems as well as more advanced film-return reconnaissance satellites: the ARGON and MURAL systems; QUILL, the first orbiting radar experiment; and the high-resolution GAMBIT and broad-area HEXAGON satellites.

By the end of 1984, eight years after the United States launched the first near real-time electro-optical satellite, the 6594th Test Group, the elite Air Force unit established to make these mid-air "catches," would conduct about 300 operational recoveries from the nation's film-return satellites and other systems. Without publicity, recovery aircraft commanders Capt. Randy Chang (on 11 August 1984) and Maj. Marshall Eto (on 11 October 1984) literally caught the end of an era as the aircraft they commanded made the last capsule catches from the last GAMBIT and HEXAGON missions, ending America's 24-year era of film-return space reconnaissance.

Eto and Chang Join the 6594th Test Group

The 6594th Test Group traces its lineage to the 6594th Recovery Control Group. This Air Force organization, activated on 1 November 1959, had two subordinate commands: the 6593rd Test Squadron (Special) at Hickam Air Force Base, which actually made the aerial recoveries, and the 6593rd Instrumentation Squadron responsible for the acquisition, tracking, and command of the satellites. On 10 March 1966, the Air Force redesigned the 6594th Recovery Control Group as the 6594th Test Group, and on 1 July 1972, started a reorganization that removed the Instrumentation Squadron from the Test Group's control. From that point until its deactivation in 1986, the 6594th Test Group would have the single mission to plan, direct, and execute the recovery of capsules ejected from space-orbiting satellites.[4]

Eto and Chang, both Air Force officers from Hawaii, came to the 6594th Test Group with similar experiences flying large transport aircraft. Eto joined the US Air Force after graduating from the University of Hawaii Reserve Officer Training Corps in 1964. He completed a Masters in Engineering and pilot training before starting active duty in 1966 and eventually saw service in Vietnam as a C-130 pilot.

The aerial recovery process required great coordination—after extensive training—between the pilot and copilot, who could see the descending parachute and bucket, and the aft crew, who would have to act to reel it in. Here a crewman is bringing in a film bucket. (Undated photo courtesy of Al Blankenship.)

Chang recalled an instance when a training chute that came too close to the airplane knocked the antenna off the bottom of the fuselage, forcing the crew to land at Hickam without radio assistance.

On Eto's return to Hawaii two years later, he consulted a friend at Hickam Air Force Base about joining the base's Air Rescue Squadron, but the friend suggested he apply to the Test Group. The unit screened most of its approximately 600 members before they received an assignment to the group. Most pilots had to be qualified aircraft commanders with more than 1,200 flying hours. To Eto's delight, the highly secretive unit offered the young lieutenant a position. "[The Test Group was] hesitant to take a person like me at that time because I was very junior; I just made aircraft commander while I was in Vietnam," Eto recalled.[5]

Eto soon began learning the fine art of making mid-air recoveries. Pilots normally flew morning and afternoon training missions every day (about six practice flights a week) to make the 100 successful catches needed to become a recovery aircraft commander. The modified Air Force C-130 Hercules (C-130 aircraft had replaced the underpowered C-119 by 1962) would rise to an altitude of about 18,000 feet, drop a training capsule filled with sand and gravel to simulate the necessary weight, descend to the falling capsule's altitude, and attempt to "catch" the item. "You actually dropped the system [capsule] to yourself, take the airplane, circle around, and then make the catch and bring it on board," explained Eto. The young pilot soon mastered the difficult high-speed runs, which required flying at maximum speed to reach the rapidly falling object, marking a capsule that had accidently landed in the water for helicopters with ParaRescue jumpers to recover, and flying search patterns looking for the object.

When not in training, Eto and the other less experienced pilots flew as copilots under veteran aircraft commanders. "If you were lucky you would maybe get your training done in three months," said Eto. "Usually it took longer…Once you started the program you were usually checked out by six months at the latest."[6]

After four years with the Test Group, and earning the coveted recovery aircraft commander designation, Eto left Hickam in 1972 on a routine reassignment to the Air Force Satellite Control Facility (AFSCF) at Onizuka Air Force Station in Sunnyvale, California. In that position he actually experienced operating the nation's reconnaissance satellites. Eto began a second tour with the Test Group in 1976, before leaving again in 1980 for an assignment to an Air Rescue Squadron in Okinawa, Japan.[7]

While Eto was in Okinawa, Randy Chang was nearing the end of an assignment flying C-130 transports out of Yokota, Japan. The 1976 Air Force Academy graduate joined the service to see the world and quickly developed a love of flying. He heard about the 6594th while in Yokota. Although he believed his Hawaii residence gave him a good chance of receiving a posting to the exclusive unit, like Eto, he feared he might not qualify. "The group was an elite squadron where you had to have a lot of high time [many flight hours] and then someone usually had to 'will it' to you, or somebody had to die for you to get into that squadron," said Chang.

Accepted into the 6594th in 1981, he began the same training as Eto to meet the unit's rigorous flying standards. "We had to pay our dues, for over a year we were just sitting in the right [copilot] seat watching and learning about what was going on." The unit filmed and graded every catch, which increased the already severe competition among pilots. "There was a pecking order in the lineup," recalled Chang, "to stay in the line up and move up to the next catch required a 90-percent success rate…It could be your turn [to recover a bucket] but if you weren't at 90 percent then you had to step out."[8]

Pilots who experienced a mishap during training received a nasty, worn out, old piece of parachute called the Rag, which remained in the pilot's office until another unit member had a problem. Since the 6594th used repaired training parachutes an average of six times, practice chutes tended to have torn panels or other defects that would cause the descending buckets to fly sideways or act unpredictably.[9]

Chang recalled an instance when a training chute that came too close to the airplane knocked the antenna off the bottom of the fuselage, forcing the crew to land at Hickam without radio assistance. On other occasions parachutes could become wrapped around the engine's propellers, or buckets would hit the recovery rig trailing behind the aircraft, sending debris into the horizontal stabilizer and rudder. As Chang summarized, "Lots of things could go wrong."[10]

Eto was still serving in Okinawa when Chang joined the Test Group, but he left Japan in 1983 for his final tour with the 6594th. At this point, he and Chang began serving together in the elite unit. Planning for the last GAMBIT and HEXAGON missions would begin about a year later.

Planning for the last GAMBIT and HEXAGON missions started long before the spacecraft took off into space.

The Last GAMBIT and HEXAGON Missions – A Tale of Two Satellites

Planning for the last GAMBIT and HEXAGON missions started long before the spacecraft took off into space. In addition to building the satellites and procuring boosters and scheduling launch facilities, the defense and intelligence communities had to submit requirements for targets the satellites would photograph. The responsibility for compiling this information fell to the Committee on Imagery Requirements and Exploitation (COMIREX). Its creation on 1 July 1967 reflected the growing need for imagery from space and the fact that agencies often had competing intelligence needs that needed prioritization.

On 26 March 1984, Harry C. Eisenbeiss, chairman of the COMIREX, forwarded a six-page memo to Edward C. Aldridge, Jr., Director of the NRO (DNRO), with guidance for the last GAMBIT mission. "The primary community requirement for Mission 4354 [designation for the last GAMBIT mission]" he wrote, "is to acquire the highest possible resolution imagery to support intelligence shortfalls associated with Science and Technology intelligence problems and other high priority problems worldwide."

A secondary objective was to obtain imagery in the southern latitudes not normally associated with activities in the Soviet Union, Eastern Europe, and Asia. He requested that NRO launch the spacecraft into a 70 to 75 nautical-mile orbit at position 45 to 60 degrees north latitude. He listed ballistic missile submarine forces, intercontinental and intermediate range ballistic missiles, bio-warfare, and Strategic Arms Limitation Treaty monitoring in the Soviet Union and other denied areas as standing intelligence problems. He identified film requirements for the detection of narcotic and grain cultivation, camouflage, concealment, and deception activities. He provided a prioritized list of the types of targets for photographing and at what resolutions on 30-day, 15-day, or daily bases.[11]

After verifying the requirements, NRO forwarded COMIREX's guidance to the AFSCF, which used it to create an executable mission plan, telling the satellite what to photograph and when.[12] The AFSCF, part of the Space Systems Division, Air Force Systems Command, was the hub of a far-flung network of command, control, tracking, data acquisition, and space recovery activities. It included tracking stations from California to New Hampshire, north to Alaska and Greenland, and west to Hawaii; the national launch ranges supporting Cape Canaveral Air Station, Florida, and Vandenberg Air Force Base, California, and US Navy telemetry ships at sea.

AFSCF operators actually "flew" the satellites from banks of consoles inside a large, blue building known as the Blue Cube. The consoles faced enormous screens, which permitted the controllers to call up visual presentations of maps, weather conditions, orbit traces, telemetry, and other data.[13] To maximize their ability to fulfill COMIREX's guidance, the controllers would upload commands to the satellite each day to account for changes in weather and spacecraft performance.

With preparations complete, the last GAMBIT satellite containing two recovery capsules took off from Vandenberg Air Force Base at 10:54 AM Pacific Standard Time on 17 April 1984 for a 120-day mission, and entered its planned 75-nautical mile orbit with extra fuel due to a "hot booster." Despite minor problems with the vehicle's film take-up mechanism, viewport door, and nine-inch camera, good weather at the target areas enabled imagery operations to proceed ahead of schedule.

The mission proceeded so smoothly that on 14 May, NRO lowered the satellite's orbit to 73 nautical miles to increase image quality. The higher drag owing to the denser atmosphere at the lower orbit increased the number of orbital adjustments the satellite had to make, but the extra fuel onboard was sufficient to complete the mission. A 1 June status report on mission day 45 reported no long-term effects from the anomalies, noting only that the last frame of film might have some trailing edge distortions because the viewport door was

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closing improperly. On 11 June, on its 897th orbit, the spacecraft ejected its first bucket about a week earlier than planned. Pilots from the 6594th Test Group caught it in mid-air.[14]

That same month, the Defense Mapping Agency (DMA) issued mapping, charting, and geodesy requirements for the upcoming HEXAGON mission. Those requirements called for 90-percent or better cloud free coverage over 14.1 million square nautical miles (MSNM), plus 0.8 MSNM for the US Geological Survey. Exceptions to the 90-percent cloud free constraint were data for the maintenance of hydrographic coastal charts and the positioning of islands, which only required 80- and 50-percent cloud-free imagery, respectively.

Areas in the Soviet Union and several denied regions topped DMA's priorities. One country experiencing economic and social turmoil particularly concerned the DMA, which noted a lack of adequate maps available for the evacuation of US citizens or for the evasive evacuation of downed pilots if the US intervened in that country. The DMA also required imagery over several US missile ranges to support weapons tests in those areas and outlined Geological Service needs along Alaska's North Slope, Brooks Range, Alaska Range, Mackenzie Mountains, and the Alaskan/Canadian border.

A modified JC-130 Hercules captures a GAMBIT film bucket with hooks trailing behind and below the aircraft. (Undated photo courtesy of Randy Chang.)

Following the same process used in the last GAMBIT mission, Eisenbeiss sent DMA's and other agency requirements to DNRO Aldridge on 12 June, explaining "The primary Intelligence Community objectives for this medium resolution search mission are to support worldwide intelligence search requirements, and mapping, charting, and geodesy production and mapping requirements." He requested that NRO satisfy broad-area search needs in several denied areas and identified 19 special intelligence needs, which included nuclear proliferation, narcotics activities, missile developments, and order of battle monitoring. He also listed film requirements for the collection of imagery against various forms of camouflage, concealment, and deception activities.[15]

The NRO reviewed and forwarded COMIREX's guidance to the AFSCF in the process of planning the next HEXAGON mission. With preparations complete, the satellite, with four recovery capsules, took off from Vandenberg on 25 June 1984 for a 302-day mission. Unlike the well performing GAMBIT, however, the new HEXAGON developed mechanical problems shortly after launch.[16]

The first of the Block-IV series, it contained a new type of extended command system (ECS) to control the satellite.[17] A software problem in the programmable memory began causing anomalies in one of the two sides of the ECS (each side provided redundant maneuvering thruster and camera control on the vehicle's left or right side). Since the anomaly appeared similar to a problem corrected on a previous HEXAGON mission, the AFSCF applied a software fix on 30 June with mixed results.

Another memory error two days later triggered a complete emergency shutdown of the satellite, an automatic safety measure that points the satellite's solar arrays towards the sun to preserve power before deactivating the entire spacecraft. Ground controllers were able to resume operations early on the evening of 2 July, but by 9 July, one side of the ECS—the B Side—was completely inoperable. Photographic operations were only being conducted with the remaining functioning A Side.

Since making orbital adjustments with a partially functioning ECS was unacceptably risky, on 11 July, Brig. Gen. Ralph H. Jacobson, director of the Secretary of the Air Force Office of Special Projects, NRO's Air Force (Program A) element, ordered the satellite placed into a higher, 115 nautical mile, elliptical orbit. The new orbit allowed the satellite's trajectory to decay gradually to a more circular trajectory over a 30-day period. Instead of making orbital adjustments every three days as standard procedures called for, the new flight plan would essentially allow the spacecraft to coast in space.

Although the ECS A Side was experiencing minor anomalies affecting its maneuvering thrusters, at the time, this problem was not disrupting imagery operations, and ground controllers believed that carefully

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modifying the vehicle's operations during the first 14 days of each orbital adjustment would still permit them to satisfy all mission requirements.

Despite the promising outlook, Jacobson accelerated photographic operations on the first recovery bucket "to include active requirements in good weather areas normally reserved for collection later in the mission." This change increased the daily film usage rate and filled up the first bucket more quickly than the pre-mission plan had anticipated. In a 17 July message to DNRO Aldridge, Jacobson pledged to "continue to assess the command system anomalies to determine the extent of the problems and seek corrective action," but explained, "At this point in time…I believe it prudent to increase the film use rate and effect an earlier RV-1 [film recovery vehicle one] recovery."

DNRO Aldridge sounded positive when he reported the next day to Secretary of Defense Caspar W. Weinberger, Jr. and Director of Central Intelligence William J. Casey that the satellite "is fully operational and, with one exception, all systems are functioning normally. That exception is a hardware problem associated with the satellite vehicle command system's programmable memory. Until this anomaly is resolved we are adjusting the system's operation to insure that a recurrence does not unnecessarily jeopardize vehicle safety."[18]

The Last Catches

Since the 250-pound Mark 5 GAMBIT bucket and the much larger 1,100-pound Mark 8 HEXAGON bucket had different amounts of film and staggered deorbit times, the 6594th Test Group had to alternate between recovering the two types of buckets. The Test Group had already recovered the first bucket from the last GAMBIT mission on 11 June 1984, leaving the second GAMBIT bucket and all four HEXAGON buckets to recover.

The first bucket on the last HEXAGON mission returned from space with a 97-percent film load at 6:29 PM Eastern Daylight Time on 5 August 1984, 24 days earlier than its planned 66 days, owing to the accelerated collection strategy Jacobson had ordered for that satellite's first bucket. Pilots from the 6594th Test Group sent to recover the object reported a "gore" in the parachute during their first pass. On their second pass, the lead aircraft accidently tore through the parachute; it did not reinflate, causing the item to fall into the ocean.

Although divers retrieved the bucket before it sank, pressure to avoid a similar incident was intense when six days later, Chang and his copilot, 39-year-old Air Force Maj. Michael Frueh, prepared to recover the final bucket from the last GAMBIT satellite. "Everybody was looking toward us to not screw up," Chang joked, "It's not supposed to go in the water."[19]

All aspects of an operational recovery, from the time of crew briefings, to engine start, take off, and arrival on station depended on the estimated time of parachute deployment.[20] The AFSCF would provide the Test Group with the parachute's estimated time and location of deployment and alert the unit of pending recoveries.

Late on the evening of 10 August, members of the Test Group began calling a special coded phone number at Hickam Air Force Base. While the mysterious recorded message, "Status Forces Report for Duty," would mean little to anyone who inadvertently called the number, for the Test Group the instructions were clear: mission a 'GO!'[21]

Stars filled the cloudless predawn sky as aircrews and support personnel began arriving on base early the next morning. Each aircraft crew consisted of a pilot, copilot, navigator, flight engineer, electronic direction finder operator, telemetry operator and recorder, hydraulic winch operator, four recovery rig personnel, and an inflight photographer. Each member had clearly identified jobs and, because they had to operate harmoniously as a team, would often spend months training as a single unit.

Chang, Frueh, and the other pilots assembled in the Hanger Two Operations Center to receive their aircraft assignments, file flight plans, and prepare for briefings. At the recovery section in Hangar 11, backend crews prepared poles, lines, and hooks for delivery to the appropriate aircraft. Meanwhile, on the normally busy flight line, now devoid of all but the Test Group aircraft, crews readied five specially configured JC-130 Hercules cargo planes, a C-130P refueling tanker, and two highly modified HH-53C Super Jolly Green Giant helicopters for the long overwater journey. About 6:00 AM, the aircrew met for a final preflight briefing before reporting to their aircraft and fitting a personal parachute for use during the recovery.

At around 8:00 AM, Chang took off. En route to the recovery zone, called the Ballpark by the Test Group, backend riggers installed a new nylon line on a massive hydraulic winch in the aircraft's cargo area and readied a large dolly assembly housing two 34 foot long metal poles, tapered from four inches at the top to two inches at the bottom. They attached half-inch thick mountain climber rope between the poles to create a loop, and connected six four-prong brass aerial recovery hooks (brass prevented static electricity build up as the hooks dangled violently behind the aircraft) at places specially arranged to entangle the bucket's parachute load lines. This trapezoid-like assembly, trailing behind the aircraft at about a 45-degree angle, allowed the parachute and film bucket to come in-trail behind the aircraft.

Communication between the pilots at the front of the aircraft and the riggers in the back was critical for making a successful catch. Once the bucket went under the aircraft, only those in the back watching from the open rear ramp could report the bucket's location relative to the airplane, so the pilots could properly line up the aircraft to make the next recovery attempt. "It was very much a crew effort," stated Chang.[22]

The squadron of recovery aircraft neared the Ballpark after about a 90-minute flight and assumed positions along a 100- by 600-mile pattern down the bucket's projected reentry path as high above the last GAMBIT bucket was plummeting earthward. In the high atmosphere, it resembled a shooting star streaking across the Northern Pacific sky. The bucket's parachute opened at an altitude of about 55,000 feet. The shock of the opening ejected the heat shield, and the ultra high frequency (UHF) telemetry and direction locating beacon beginning transmitting.

Chang's aircraft, flying at the highest altitude in the prime recovery position, would have the first attempt to catch the bucket. If he failed or was out of position, the other JC-130s would attempt to make the recovery as the bucket descended into their lower altitudes. If all five aircrews missed the bucket or the parachute appeared severely damaged, helicopters would deploy ParaRescue jumpers into the water to attempt to retrieve the bucket before it sank.[23]

Chang and Frueh spotted the bucket at an altitude of around 40,000 or 45,000 feet. At 25,000 feet, Chang called out over the intercom, "Inbound pass," signaling the crew he was beginning the initial "look see" run to establish a matching descent rate and determine if it was safe to make the recovery. When he inspected the condition of the parachute, shroud lines, and capsule, he saw a perfectly deployed orange-and-white chute above a golden bucket glistening in the sunlight.

Chang banked slowly left in a 20-second teardrop pattern, maneuvering around for a straight in approach. Forty-five minutes before the estimated time of parachute deployment, Chang and the other recovery crews began breathing pure oxygen to prevent bends when at 18,000 feet the backend crew depressurized the aircraft, opened the rear cargo ramp, and deployed the recovery rig into the streaming wind. Moments later, at 15,000 feet, the highest altitude he could make a recovery attempt, Chang called out, "Inbound hot," alerting the crew to prepare for recovery.

After receiving a final "Ready" from the crew, Chang and Frueh started their first run. Bringing the top of the bucket's parachute, which was approximately one to two miles away from the start of their run, to within about six feet of the bottom of their 97 foot long JC-130, while flying between 120 to 125 knots (138 to 144 mph) and matching the bucket's 1,500 feet a minute descent rate, left little room for error. "You're looking at an object that's going about 200 feet a second, coming right at you," said Frueh. "When you're actually making an approach you only have a few seconds to get lined up. The actual final corrections are only about three seconds before the thing hits."[24]

As his aircraft approached the bucket, Chang called out a 10-second warning to the crew, which immediately braced for contact. "In the back, we don't get to see very much," explained former Test Group instructor rigger Frank Adams, "so we're just playing over in our heads our checklist, our training, what do we do if [there is a problem]." The backend crew had to be ready in case there was a tear-through of the parachute, a line breakage, any other type of emergency. "You're just in a ready state," said Adams.[25]

Perhaps the most alarming contingency was the last second pull off, which entailed tipping the aircraft's nose down sharply in an effort to snap the recovery rig up and over the chute without making contact, a maneuver that would leave the backend crew momentarily weightless. As Adams explained, "Usually when we went inbound hot, we made ourselves part of the aircraft. We were holding onto something because we know if they had to do a pull-off, it was going to be a real violent maneuver, and if you weren't hanging on, you were going to get hurt."[26] Frueh echoed the comment. "It's a pretty abrupt maneuver if you have to pull off," he said. "If you make a decision you're going to be too close, you immediately stick power to the airplane and try to pull yourself across the top [of the parachute] and not catch something."[27]

There was, however, no need to pull off. On his first pass, at 2142 Zulu on 11 August 1984, at an altitude of about 13,000 feet, Chang's JC-130 flew over the parachute.

The crew felt a soft bounce, similar to driving over a speed bump, caused by the disturbed air over the parachute.[28] Chang instinctively applied engine power before feeling the distinctive backwards tug of a good catch as the recovery loop, entangled in the parachute, snapped clear of the poles.

"Contact!" the aft rigger yelled into the intercom over the scream of the winch line playing out into the sky behind the aircraft. After about three seconds, the winch slowed the line to a stop. The aft rigger reported "In trail," indicating a solid catch and the winch operator began reeling the bucket into the aircraft: first, the recovery loop with the entangled parachute, followed by the shroud lines, and finally the gold foil skinned bucket. Once it was on board, either the navigator or electronic direction finding operator walked back to connect a plug into the bucket to turn off the UHF homing beacon. Chang too walked back, leaving Frueh to fly the airplane, and with satisfaction, touched what would be his only recovered bucket. Touching the bucket was a small break in protocol, but as Chang explained, "I just had to touch it."[29]

When Chang's aircraft returned to Hickam Air Force Base, crews quickly placed the bucket with its precious film onboard a heavily guarded Starlifter cargo airplane for transport to film processing facilities in the United States. "They just opened the back of [our aircraft] and whisked [the bucket] away," Chang said. "We never saw it again."[30]

A routine message later that day reported, "The end of an era! GAMBIT 54 is the last film-based high-resolution photoreconnaissance mission."[31] The next day, the AFSCF placed the satellite, now devoid of film, into an unstable orbit designed to destroy the spacecraft. Any pieces that might have survived their fiery plummet through the atmosphere would fall into the deep ocean, beyond the reach of undersea salvage.[32] The Test Group later cut up the recovered bucket into small pieces as mementos for its members.[33]

Emergency orders quickly went out to the Test Group on 11 October 1984 to undertake an unscheduled recovery of the last HEXAGON bucket.

Chang's textbook catch was a fitting conclusion to a near flawless mission. In a 27 August memo to DNRO Aldridge, Eisenbeiss congratulated those involved in the mission calling them "essential to the successful acquisition and satisfaction of various Intelligence Community collection problems." Their never-failing spirit, flexibility, and high satisfaction record resulted in the "appreciation of the entire Intelligence Community for their efforts... the team deserves special recognition from all who benefited from their professionalism and expertise."[34]

Two months later, the National Photographic Interpretation Center (NPIC) also issued a report praising the last GAMBIT mission. NPIC rated the quality of cloud and haze-free black-and-white imagery from the second bucket as fair to excellent, with the majority of the frames judged to be in the good to very good category. The color imagery was very good and camera operations were anomaly free.

As Chang was making the last GAMBIT bucket recovery, conditions on the ailing HEXAGON spacecraft were deteriorating rapidly. On 17 August, six days after Chang's historic mission, Jacobson reported to DNRO Aldridge, "We are continuing to analyze the command system anomalies and develop possible corrective actions. However, the situation is serious." He continued the accelerated collection strategy on HEXAGON's second bucket to include "active requirements in good weather areas worldwide."[35] Events would soon prove his caution warranted.

Eighteen days later, a mechanical problem in the take-up brake—needed to keep tension on the film from the aft looking camera as it entered the second bucket—caused an emergency shutdown of the aft looking camera. With only the forward-looking camera operational, the AFSCF began signal camera operations on 6 September, which prevented the satellite from obtaining the all-important stereoscopic imagery capable of detecting elevations on the ground from flat photographs. Single camera operations continued until 8 September when another command system anomaly again shutdown all satellite functions. Single camera operations resumed a day later, but it quickly became clear that the malfunctioning camera brake was not repairable: the spacecraft received commands to apply the brake, but it would not engage. Since the failure appeared limited to the second bucket, Jacobson ordered single camera operations to continue until the second bucket returned from space, at which time, he hoped, the satellite could resume dual camera operations. The plan worked: two camera operations resumed after the Test Group recovered the second bucket at 5:45 PM Eastern Daylight Time on 24 September.[36]

Despite the good news, the larger problem of HEXAGON's ailing command system with one side inoperable and the other side only partially functioning, was a serious concern. On 1 October, Jacobson reported that the nonfunctioning ECS side was unrecoverable, explaining, "There are no further risk-free tests which we can pursue" to fix the problem. Convinced he had "taken every reasonable precaution to maximize the mission success under the existing ECS conditions," he ordered the satellite returned to its normal orbital position.

The installation of commands to protect the partially functioning ECS side from the inoperable side's aliments and the presence of the Minimal Control System, which provided backup control, were adequate safeguards in his estimation.[37]

However, nine days later Jacobson suddenly reported to DNRO Aldridge that the partially functioning ECS side had experienced further anomalies and was no longer usable. "[Previous] anomalies were benign or workarounds were possible," he explained, "the most recent problems were fatal." With the Minimal Control System providing the only link to the satellite, he determined that the safest course was to recover the third bucket and deorbit the satellite as soon as possible.[38]

Emergency orders quickly went out to the Test Group to undertake the unscheduled recovery. As Chang had done on the last GAMBIT mission, Major Eto would fly in the prime recovery position. With few exceptions, the mechanics of recovering a HEXAGON and GAMBIT bucket were identical. Instead of installing the half-inch thick mountain climber rope used to snare the 250-pound GAMBIT bucket, riggers readied a stronger plastic coated half-inch thick steel cable capable of recovering HEXAGON's 1,100-pound bucket, and used eight instead of six recovery hooks, each of which was about 70-percent larger and heavier than the MK-5 GAMBIT hooks. The backend crew also placed transparent, bulletproof Lexan protectors, called Doghouses, over the cable along the rails in the floor of the aircraft's cargo area to prevent the line from ripping through people and the aircraft if the high tensile strength cable snapped.[39]

Eto's aircraft rendezvoused with the descending object about 17 miles from its predicted impact point, possibly owing to the difficulties of controlling the satellite with only the Minimum Control System. Unbeknownst to Eto at the time, the bucket contained just a 36-percent film load because of the mission's early termination, but he immediately knew something was different. "The descent rate was slower," Eto recalled. "I remember I had to carry more power than I normally would to actually make the recovery. When it hit, it didn't have the same jerk that you normally would get. Even a number of the backend group said something about it was a little different…This is just a perception, but I kept thinking, maybe this thing wasn't really full."[40]

Despite the lighter-than-normal-bucket, Eto made a successful mid-air recovery on his first pass at 6:15 PM Eastern Daylight Time on 11 October 1984 at an altitude of 12,800 feet.

Less than an hour later, the AFSCF deorbited the satellite, along with its fourth unused bucket, into the Pacific Ocean.[41] Unlike Chang, who knew he had recovered the last GAMBIT bucket, NRO still had one more HEXAGON mission scheduled. That mission, however, ended spectacularly when the Titan rocket carrying it into orbit exploded nine seconds after liftoff on 18 April 1986. The event left Eto with the distinction of commanding the aircraft that recovered the last bucket from the last ever American film-return photoreconnaissance satellite.[42] "It is nice to know that you did the last one, but at the time I didn't realize it was the last one; that never dawned on me until the next one blew up," said Eto.[43]

While most applauded the effort that went into nursing the ailing HEXAGON spacecraft along, evidence as to the damage the mission's early termination caused varies. On 11 October, the same day he ordered the third bucket's early recovery, Jacobsen reported that while the three buckets returned 57 percent of the spacecraft's total film load, the mission satisfied 70 percent of COMIREX's collection plan.[44]

NPIC, however, was less generous in a memo about six weeks later. They reported that the satellite's early termination "impacted heavily on NPIC's abilities to address worldwide search responsibilities and national-level intelligence issues." Only 25 percent of collection over Moscow and Eastern Europe was usable. The satellite failed to image 40 to 50 percent of one critical denied area, provided little useful imagery of SS-11 deactivation targets, and

The last capture, on 11 October 1984, of a HEXAGON bucket went especially smoothly. It was less than half full owing to problems with the satellite's control system. Within an hour of the recovery the troubled satellite was deorbited into the Pacific Ocean. (Undated photo courtesy of Randy Chang.)

left 50 percent of bomber dispersal airfields unimaged. NPIC criticized the limited imagery against SS-20 base construction, found collection of one nation during the restructuring of its ground forces wanting, predicted a two-year hiatus against another denied area, and concluded that the satellite only imaged 12 percent of missile search areas in another country.[45]

A preliminary damage assessment issued by the Defense Mapping Agency around the same time also concluded that the last HEXAGON's premature end negatively affected the agency's ability to fulfill mapping, charting, and geodesy needs. Since the planned operations in December and February, historically the best weather times to image certain areas, did not occur, DMA reported it lacked the accurate geodetic positioning for many products, including those used for targeting cruise missiles.

Eisenbeiss, on the other hand, struck a positive note in a 14 January 1985 letter to DNRO Aldridge. He praised the HEXAGON team for "planning, operating, managing, and nursing the ailing" satellite. "Community requirements for the mission were demanding," he wrote, "over 21.2 million square nautical miles for intelligence search and 14.1 million square nautical miles to support mapping." Modifying the collection strategy to image active targets in good weather areas at an accelerated rate called for the "dynamic interaction on a revolution-by-revolution basis to focus on a myriad of decisions impacting daily imaging operations." This collection substantially satisfied COMIREX requirements "despite the hardware problems encountered and the shortened mission length." The 57-percent film load, he concluded, "produced approximately 14.1 million square nautical miles of unique cloud free imagery, which resulted in the satisfaction of 53 percent of the total search requirements, 54 percent of the total ad hoc requirements, and 29 percent of the total mapping requirements."[46]

DNRO Aldridge, too, offered his own tribute in a 6 February 1985 note to Jacobson. "The command system anomalies experienced at the beginning of the mission were regrettable," he wrote. "However, without the superb efforts of the HEXAGON team, the impact on the nation's intelligence collection would have been far more severe. Due to the extraordinary dedication of this team, significant intelligence collection accomplishments were achieved."[47]

Epilogue

On 18 July 1986, 22 months after Eto's last HEXAGON catch, current and former Test Group members gathered in Hawaii to attend the unit's formal deactivation ceremony. During its years of operation, the unit made exactly 40,000 mid-air recov-

GAMBIT and HEXAGON Factsheet

KH-7 GAMBIT

Total Program Cost:	$651.4 million
Years of Operation:	1963-1967
Missions:	38 (28 successful)
Mean Mission Life:	6.6 days
Camera Developer:	Eastman Kodak
Image Resolution:	2-3 feet
Buckets per Mission:	1

KH-8 GAMBIT

Total Program Cost:	$2.3 billion
Years of Operation:	1966-1984
Missions:	54 (50 successful)
Mean Mission Life:	31 days
Camera Developer:	Eastman Kodak
Image Resolution:	Better than 2 feet
Buckets per Mission:	1-2

KH-9 HEXAGON

Total Program Cost:	$3.26 billion
Years of Operation:	1971-1984
Total Missions:	20 (19 successful)[a]
Camera Developer:	Perkin-Elmer (panoramic camera), Itek (mapping camera)
Image Resolution:	2-3 feet (panoramic camera), 30-35 feet (mapping camera)
Buckets per Mission:	4 (5th mapping camera bucket added on 12 missions)
Aerial Recoveries:	80
Water Recoveries:	7[b]

a. HEXAGON mission 20 was lost on 18 April 1986 due a Titan booster failure nine seconds after liftoff.
b. Including the attempted underwater recovery of a bucket that crashed into the Pacific Ocean on reentry in 1971. See David Waltrop, *An Underwater Ice Station Zebra: Recovering a KH-9 HEXAGON Capsule from 16,400 Feet Below the Pacific Ocean* (CIA, Historical Collections Division, 2012).

Since electro-optical technology offered timely reconnaissance without the weeks needed to deorbit and develop film from space, satellite imagery increasingly was able to support rapidly changing tactical operations.

eries. Most occurred during training missions, but about 300 were operational recoveries from NRO's film-return satellites, and other national security and scientific projects.

In addition to this primary assignment, since 1975 the unit's long-range aircraft, helicopters, and ParaRescue jumpers participated in 105 search-and-rescue missions throughout the Pacific, receiving credit for saving 89 lives and assisting in the saving of nine others. In commenting on the Test Group's search-and-rescue contribution, US Coast Guard Capt. William F. Roland, speaking at the deactivation ceremony, called these rescues "the most difficult 89 cases there were." The rescues included a nonstop, over water rescue on 5 January 1985, requiring a round-trip flight of more than 1,400 nautical miles to rescue a crewmember who had suffered chemical burns on a ship far out to sea. All seven members of another Test Group helicopter died on another rescue mission 10 days later.

The Test Group's last aircraft left Hickam Air Force Base on 22 July 1986; the Air Force officially deactivated the unit on 30 September.[48]

Marshall Eto retired from the Air Force in May 1986. He would continue to fly commercial aircraft until he reached 60, the mandatory retirement age, in 2002. Michael Frueh also retired from the Air Force and flew commercially. Randy Chang retired from the Air Force in 1996 as a lieutenant colonel, but he continues to fly charter aircraft today.

At 7:34 AM Eastern Standard Time on 25 September 2009, nearly 23 years to the day after the Test Group's official deactivation, NRO produced the last hardcopy film, completing the final transition to digital imagery. In a ceremony intended to symbolize the path that more than 140,000 miles of film had followed on its way from NRO to the National Geospatial-Intelligence Agency (NGA), a grandfather, father, and son team from NRO's Photography Production Facility inspected and certified the last roll of film. The ceremonial roll then made its way to the NRO and NGA. After the transfer, DNRO Bruce Carlson remarked in a recorded congratulatory message, "A picture may be worth a thousand words, but the pictures you processed saved lives and changed the course of the world."

The evolution from film-return to near-real-time space-based imagery, which began with the launch of the first electro-optical satellite in 1976, dramatically expanded the users of imagery systems managed by the NRO. Since electro-optical technology offered timely reconnaissance without the weeks needed to deorbit and develop film from space, satellite imagery, traditionally a provider of strategic intelligence for the president and senior policymakers, increasingly was able to support rapidly changing tactical operations.

In 1977, Congress funded the creation of the Tactical Exploitation of National Capabilities (TENCAP) program within the Department of Defense to exploit and distribute for military use products from NRO systems originally created to meet strategic needs. "This was a very useful step, but not a game changer," said Robert J. Herman, who served as DNRO from 1979 to 1981.[49]

Three years later, Secretary of Defense Harold Brown established the Defense Reconnaissance Support Program as a single office to meet the unique needs of both the director of central intelligence and secretary of defense with NRO systems. The difficulty of supporting the increasing amount of military and other non-traditional users of NRO systems from a covert organization led to the appointment of the first NRO Deputy Director for Military Support in 1990, followed two years later by the declassification of NRO's existence. "The open secret of the NRO made it corrosive to our real security needs by trying to maintain this fiction [that the NRO did not exist]," explained Martin C. Faga who served as the DNRO during the declassification. "How are you going to operate with people in the field from a covert organization?"[50]

Retrieval of the last buckets from the final GAMBIT and HEXAGON missions was a critical point in the nation's transition to near-real time imagery from space. The Test Group was part of complex system that

a. The author would like to thank Randy Chang, Mike Frueh, Marshall Eto, Frank Adams, Al Blankenship, and Dr. Jeffrey Charlston, for assisting with this article. All errors are those of the author.

included the building, launching, tasking, and control of the satellite; and the retrieval, dissemination, assessment, and exploitation of the imagery product. Today the unit's historical significance parallels that of the Wright Brother's first flight or Chuck Yeager's breaking the sound barrier. A plaque honoring the unit rests near the flagpole in Atterbury Circle on Hickam Air Force Base, placed there on the 50th anniversary of Harold Mitchell's historic first mid-air catch.

Col. Sam Barrett, commander of the 15th Wing, Joint Base Pearl Harbor-Hickam, praised the unit's unique mission during the plaque-laying ceremony: "What a mission you had—catching free-falling objects from outer space is no small feat, in your day. The Test Group was the only organization in the free world to accomplish such a mission. The stakes were high; our national security depended on it." DNRO Carlson, also speaking at the ceremony, echoed the Test Group's intelligence contribution to the United States. "What you did was give us an incredible advantage, an asymmetric advantage, over our enemy," he said. "Your pioneering work in overhead reconnaissance gave us the confidence we needed."[51]

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Endnotes

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