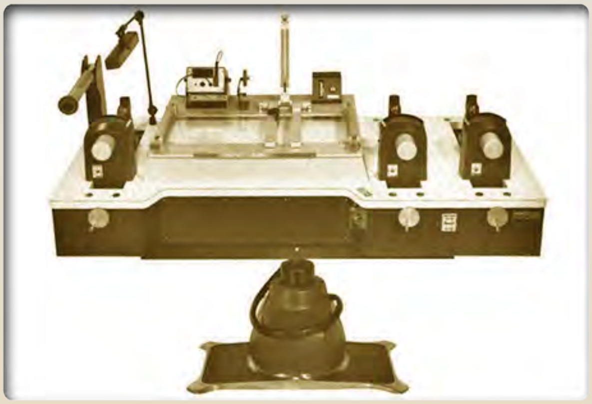
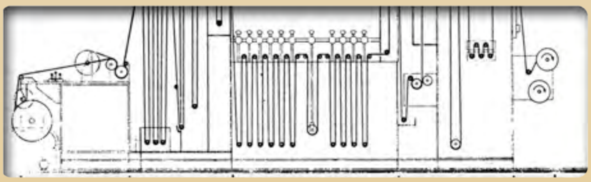
IN THE WORDS OF THOSE WHO SERVED



BRIDGEHEAD:

EASTMAN KODAK COMPANY'S COVERT PHOTORECONNAISSANCE FILM PROCESSING PROGRAM



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BRIDGEHEAD:

EASTMAN KODAK COMPANY'S COVERT PHOTORECONNAISSANCE FILM PROCESSING PROGRAM

CENTER FOR THE STUDY OF
NATIONAL RECONNAISSANCE

JULY 2014

Center for the Study of National Reconnaissance

The Center for the Study of National Reconnaissance (CSNR) is an independent National Reconnaissance Office (NRO) research body reporting to the NRO Deputy Director, Business Plans and Operations. Its primary objective is to ensure that the NRO leadership has the analytic framework and historical context to make effective policy and programmatic decisions. The CSNR accomplishes its mission by promoting the study, dialogue, and understanding of the discipline, practice, and history of national reconnaissance. The CSNR studies the past, analyzes the present, and searches for lessons-learned.

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TABLE OF CONTENTS

FOREWORD

The success of the Cold War photo-reconnaissance missions during the pre-digital age of the 20th century, was dependent on the magic of photochemistry. The core of that magic—with its latent images, silver halide crystals, gelatin, acetate, and ESTAR—was located in a highly secretive film processing and camera development facility, run by Kodak, and operated behind the cover name of Bridgehead. Six former Kodak employees—Dick Stowe, Don Schoessler, Dick Sherwood, Joe Russo, Tom Havens, and Rand Warner—engineering managers who worked behind the Bridgehead security curtain, have documented their recollections of what that facility did and how it supported photographic missions of the National Reconnaissance Office (NRO). This book, *Bridgehead: Eastman Kodak Company's Covert Photoreconnaissance Film Processing Program,* is the second unclassified story in our series, In the Words of Those Who Served.

This book, from the perspective of participant observers, tells the history of Bridgehead's most critical support efforts in early years of national reconnaissance. Both airborne and satellite photoreconnaissance programs became essential sources of intelligence by the early 1960s, and it was Bridgehead that converted the film of those reconnaissance missions into a source for imagery intelligence. First there were the U-2, A-12, and SR-71 high altitude aircraft platforms. For a time, the U-2 proved a reliable means for collecting badly needed photoreconnaissance, but the downing of the Francis Gary Powers' piloted U-2 in May 1960 brought to a close the use of high altitude aircraft for collecting intelligence over the Soviet Union. In parallel to the high altitude aircraft, the United States defense and intelligence communities actively were developing satellites for collecting intelligence. The CIA and the Air Force launched and operated the nation's first successful photoreconnaissance satellite, known as Corona. The authors tell much of their story within the context of the Corona program.

The Corona photoreconnaissance satellite was, by late 1950s standards, a complicated, technological marvel. The CIA and USAF, and later the NRO, designed it to carry a camera system that utilized Kodak film to take images of the earth's surface from space. The film was then transferred to a film-return capsule, enabling the film to re-enter the earth's atmosphere. The next challenges were to retrieve the film and process it so the images could be evaluated by photo interpretation analysts.[1] Eastman Kodak was responsible for the on-ground processing of the film. Kodak developed the technology and machines that allowed for film development, the production of film prints, and the transfer of images for photo-interpretation. This is the story of the triumph of that ground processing, which was critical for allowing the Corona system to succeed, and for the success of the NRO film-return reconnaissance satellites that followed, known as the Hexagon and Gambit systems.

There are several vantage points from which this history could be read. This history could be read as a technology history. The reader will come away with a greater understanding of how technology was developed and applied for satellite film processing. The authors of the history are careful to describe the technological achievements necessary to enable film processing and distribute images for photo interpretation. This evolution of technology story can be useful to readers who are challenged with developing their own technological solutions to today's challenges.

The development of any new technology almost always has secondary benefits beyond those for which the technology was developed. A reader of this history will discover how Kodak's embrace of

1 See the CSNR book, *Intelligence Revolution 1960: Retrieving the Corona Imagery That Helped Win the Cold War*—another in the CSNR series*, In the Words of Those Who Served*—for first-hand accounts of the challenge of retrieving the film capsules returned from space.

photoreconnaissance ground processing strengthened the company. Kodak employees supporting the projects associated with photoreconnaissance developed skills and abilities that exemplified the best in Kodak and thereby strengthened the company. The investments into people and technology provided Kodak with unique, unparalleled capabilities that resulted in a firmer corporate foundation.

A reader of the Bridgehead story also might take away management and leadership lessons from reading the history. Any new challenge requires imaginative management and strong leadership to succeed. This history illustrates not only what management and leadership efforts were developed, but more importantly how they were developed to assure program success. The how of leadership and management is a readily transferrable set of lessons for any new and challenging program.

Finally, a reader of this history will find that passion for the highly secret processing of photoreconnaissance intelligence drove the program. In any project, the more passion, the more likely it is that challenges can be overcome and critical breakthroughs accomplished.

Now in 2014, after many years of silence, this former Kodak team of engineering managers, publicly can tell this important story. Unlike the man behind the curtain in the *Wizard of Oz*, where he had no magical powers, the men and women behind the curtain at Bridgehead had the magical powers of photochemistry. This is the story of that magic. We all can benefit from the telling in the ways I have described above.

Robert A. McDonald, Ph.D.
Director, Center for the Study of National Reconnaissance

PREFACE

In 2008, a group of retired Eastman Kodak engineering managers began to document their story about "Bridgehead,"—the codename for the covert location and operation that researched and developed ground handling equipment and film processing and reproduction technologies for the United States overhead reconnaissance programs. The story began with a group of men who shared a unique bond, which endured into the golden years of life, where "good company" replaced the descriptor "professional colleague." Because of the sensitive nature of their work and a pledge to maintain secrecy, they shared a bond that outsiders, including their own families, were not privy to until the President of the United States declassified their operation. As they met once again during their periodic luncheons, they decided to capture the story of this remarkable piece of history before it became too late to do so. Other motivations included the fact that they were on the front lines of photoreconnaissance and possessed the collective memory to describe the details of their critical role in making reconnaissance missions successful. After a lifetime that necessitated separating a secret world of work from families and friends, the authors wanted to share the details of their past working experiences. They always longed to talk about the unusual circumstances that existed over many years of living double lives, such as the long, demanding work hours and travel to undisclosed locations.

This core group of authors consisted of six retired Eastman Kodak Company employees who spearheaded the writing, compilation, and formatting effort, which included the memories and recollections of many former Bridgehead colleagues. ITT Exelis (formally ITT's Geospatial Systems Division—Kodak's successor in the government systems area), also provided access to unclassified archives. While documenting 45 years of history, the authors took appropriate precautions not to violate security restrictions still in effect. The writing included specifics of Bridgehead's involvement in the U-2 high-altitude photoreconnaissance aircraft and the Corona film-return reconnaissance satellite, which the U.S. Government declassified in the 1990s. The story more recently evolved with information surrounding Bridgehead's involvement in the recently declassified film-return reconnaissance satellite systems, Gambit and Hexagon. The official declassification announcement for Gambit and Hexagon occurred on 17 September 2011, as part of the NRO's 50th Anniversary Commemoration celebration in Washington, D.C.

The authors created their document as a labor of love and submitted the work to the National Reconnaissance Office (NRO) for review and comment. Because of that review, the NRO indicated interest in adding it to its library of publications. Accordingly, in late 2010, the NRO assigned an editor (MSgt Lorraine M. Jacobs, USAFR Historian) to help prepare the document for publication by the Government Printing Office (GPO). At a regional celebration in Rochester, NY—hosted by ITT Exelis—the authors distributed unofficial copies of this book to guests in attendance at the event. These hardcopies served as a memento of that 30 September 2011 event and as a dedication to all the personnel who worked on the various overhead reconnaissance programs at that location. The authors and editor have since expanded on that original version to be more inclusive of the Gambit and Hexagon operations at Bridgehead.

Dick Stowe
Don Schoessler
Dick Sherwood
Joe Russo
Tom Havens
Rand Warner

INTRODUCTION

Historians and scholars of national reconnaissance have written extensively about the marvels of technology that flew at high altitudes or orbited the earth to capture critical Cold War photoreconnaissance. The authors of *Bridgehead: Eastman Kodak Company's Covert Photoreconnaissance Film Processing Program* add important insight into a critical effort for assuring success of both airborne and satellite photoreconnaissance that has received less attention from scholars. They reveal in this history how Eastman Kodak Company developed, built, and operated the infrastructure for processing film from photoreconnaissance collection systems. The authors affirm Kodak as an essential partner in the complex effort to gain intelligence from new heights—intelligence that proved essential for helping win the Cold War.

At the onset of the Cold War between the Soviet Union and the free world after World War II, the United States found it essential to learn more about activities behind the Iron Curtain. Clandestine overhead photography became one of the most effective ways to monitor that activity. The U.S. Government and its contractors conceived, designed, and built both the U-2 winged aircraft and the Corona reconnaissance satellite for the primary purpose of carrying sophisticated camera systems at either high altitude or in space orbits, to acquire imagery that was unattainable by any other means.

Specifically, the U-2 program began in 1955 with the development of an aircraft capable of carrying aerial cameras at very high altitudes over denied areas, most notably the Soviet Union. From 1956 until 1960, this reconnaissance system was the only reliable source of very high altitude photography over Sino-Soviet territories available to the U.S. However, the downing of Gary Powers' U-2 aircraft over Russia on 1 May 1960 terminated these U-2 over-flights. The Powers incident dictated the rapid advancement of covert satellite technology to peer over the Iron Curtain.

President Eisenhower had foreseen the need for satellite photoreconnaissance and assigned Project Corona to the Central Intelligence Agency (CIA) to manage in early 1958. This film-return satellite reconnaissance system was not without its failures. After thirteen attempts, the United States finally realized success on 10 August 1960, when Navy divers retrieved from the Pacific Ocean a test return recovery vehicle (RV) carrying a U.S. flag. A week later, the U.S. successfully launched another Corona satellite, which returned film of some 1.5 million square miles of the Soviet Union, more than all the previous U-2 missions combined. Between 1960 and 1972, Corona's 145 launches used two million linear feet of 70mm camera film and millions of feet of duplicate film, which were distributed to numerous government agencies. For that decade, the Corona system was one of the workhorses of this country's overhead reconnaissance efforts.

During the same period, the U.S. Government and other collaborators diligently worked toward developing other systems. Where Corona provided broad area coverage, the evolving Gambit satellite system provided a narrower view with higher resolution. Eastman Kodak developed the camera for Gambit's very high resolution targeting system. Its first launch and mission on 12 July 1963 provided the best imagery to that point for a photoreconnaissance satellite. The Gambit system's high-resolution performance would go on to complement the new Hexagon system with its broad area coverage and improved resolution over Corona. Hexagon, first launched in June 1971, incorporated Perkin-Elmer's camera and, like the Gambit satellites, used the latest high quality Kodak films available at the time.

With the declassification of all these systems, the Eastman Kodak authors were eager to document the Bridgehead operation, which played an essential role in these reconnaissance missions, and to record the technology and processes that contributed to mission success. Writers of books, articles, and program histories covering the early reconnaissance capabilities of U-2 and Corona often focused on the mechanisms used to enable high altitude flight and the numerous problems that required solutions for the programs to achieve success. The fact that the aircraft and satellites carried cameras with film is only part of the story. Few articles mention what happened to the exposed camera film from these very sophisticated camera-carrying platforms.

The limited articles that attempted to follow the trail of the exposed camera film usually referenced Westover Air Force Base (AFB), located near Springfield, Massachusetts. Those references stemmed from Westover's Special Projects Processing Facility (SPPF), a well-equipped wide-web photographic laboratory operated by the United States Air Force (USAF). However, Eastman Kodak Company's Bridgehead operation served as the primary processing facility for the U-2, Corona, Gambit, and Hexagon systems. The more recently released references on Gambit and Hexagon shed more light on Kodak's role, but not to the degree of specificity outlined in this historical account.

Kodak sustained its commitment to these covert programs throughout the Cold War period, and Bridgehead became the center for high-altitude photographic imaging technologies–the conduit for providing innovative films, film processing technologies, and information transfer from other Kodak divisions to government programs. To facilitate application of Kodak expertise, the government provided several Kodak scientists and technicians working in those divisions with "need to know" security clearances. Examples of these non-Bridgehead areas included film manufacturing and testing, Kodak's Research Labs, Photo Technology Division, and Industrial Labs. Kodak's upper management ensured the effectiveness of this conduit by sharing pertinent information, including company proprietary information about film and photographic science technologies under the shroud of security.

Lincoln Plant, a government-owned and Kodak-operated facility on the west side of Rochester, served as the first special processing facility. Later, they relocated that capability to Kodak's Hawkeye Plant, located at the edge of the Genesee River, north of downtown Rochester. There, Bridgehead evolved to support the government's overhead reconnaissance systems. A sophisticated, state-of-the-art Photographic Operations Center, it derived its code name from its location adjacent to the Driving Park Bridge that spans the Genesee River Gorge (cover photo). The government maintained Westover's SPPF as an alternate processing facility and a backup to Kodak's Bridgehead operation. In the same manner that the U-2, Corona, Gambit, and Hexagon programs were highly classified as critical strategic operating systems, the government also classified the existence and operations carried on at Bridgehead.

Bridgehead had a unique role in classified overhead reconnaissance programs—it was at the crossroads of the nation's Intelligence Community (IC). Besides obviously working closely with its backup facility at the Westover SPPF, Bridgehead closely interfaced with Itek Corp. in Foxborough, MA, the manufacturer of the Corona camera, America's first satellite reconnaissance system; Perkin-Elmer Corp. in Danbury, CT, the manufacturer of the Hexagon camera, a satellite-based broad area search reconnaissance system; Air Force and Navy photographic field operations around the world that were supporting both strategic and tactical photo reconnaissance; the photographic interpretation community in the U.S., particularly the National Photographic Interpretation Center in Washington, DC; and virtually all of the federal government's intelligence and defense mapping agencies. Bridgehead also collaborated internally within Eastman Kodak elements, working with Eastman Kodak's proprietary aerial film research, development, and manufacturing technologies as well as its K-Program, a highly classified segment of the company in Rochester building the Gambit camera, a key component of a major satellite reconnaissance system.

The authors of this historical account record the story of Bridgehead, including events leading up to its formation, and the primary role it played as part of the U.S. Government's early aerial reconnaissance programs, which relied on Kodak's film and photo-science technologies. They are witnesses to exceptional intelligence that would settle questions—among others—of gaps in strategic bombers, numbers of intercontinental ballistic missiles, and compliance with arms limitations treaties. Accordingly, this is a history of an essential part of the effort to win the Cold War and defend the American people.

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Chief, Historical Documentation and Research
Center for the Study of National Reconnaissance

Chapter 1

KODAK'S ROLE IN THE NRO'S U-2 PROGRAM

In late 1954, the CIA contacted Dr. Albert Chapman, then President of Eastman Kodak Company, to request Kodak's direct involvement in the U-2 program in the areas of film and film processing. Because of the unusual nature of the request, including its classified status and its importance to national security, Dr. Chapman consulted with Kodak's Board of Directors. Realizing the significance of this project as it related to national security, the Board soon notified the CIA of their intent to participate and began to select its project team. Kodak selected Fordyce Tuttle, Business Manager of Kodak's Apparatus and Optical Division (A&OD), as the first person to obtain a classified security clearance and interface with the CIA, and CIA briefed him on the mission of the U-2 program. In support of the U-2 mission, the CIA elaborated on the role it envisioned for Kodak: supplying photographic film for the cameras, processing the exposed camera film, and duplicating film and creating enlargements of the imagery for photo interpretation.

Project team development continued as company managers further identified candidates with relevant skills and asked them to transfer to new work assignments, slated to span a two to three year timeframe. Some of the first employees assigned to the new project included Dr. Kenneth MacLeish from the Kodak Research Laboratories, Harry Yeoman from the Color Print and Processing Division, and Edgar L. Green from Kodak Park's Engineering Division. As plans progressed, Kodak's employees codenamed their role in the U-2 program after Fordyce Tuttle, and thus it received the name "Tuttle Project" (TP).

In addition to human resource decisions, the management team needed a secure location for offices of the new organization. By 1956, Kodak established the offices for the Tuttle Project in a penthouse atop Kodak's Camera Works, a division of A&OD located in downtown Rochester, NY–later, Kodak's Corporate Headquarters. This location required a means of allowing only project workers with proper security clearances access to the penthouse. Hence, Kodak required the project's assigned employees to exchange their Kodak passes for a one-inch-square pink clip-on access badge. Employees referred to this badge designation as the "TP Pass." In the ensuing months, the project expanded beyond the original two to three-year scope as the government added compartmented projects to the program. These additions periodically required security managers to modify the badges to include quarter-inch-wide vertical stripes of various colors–each color representing approved access to a particular project within the TP. The length of each stripe denoted the level of clearance: the top third of the badge length denoted minimum security clearance level and awareness of a classified project, allowing facility personnel in to secure areas to perform facility work; the top two-thirds of the badge length allowed full access to general and detailed project information as needed; and full length of badge indicated the prior two, plus awareness of the project's customer. TP Passes continued in use for over 40 years as a requirement for access to Special Programs—a group of departments in Kodak's Government Systems Division.

In the early 1960s, Ed Green, the Tuttle Project's Program Manager, requested the development of an emblem for use on tokens of appreciation for distribution to deserving TP Project employees.

Recalling the evolution of the TP Project, the TP Badge, and related security procedures, designers created an emblem of a colorful Indian teepee, which represented the beginnings of the program. Its yellow color designated the access color assigned to the first project stripe on access badges. The teepee's green door reflected the name of the first program manager and signified a then-common expression applied to project activities going on "behind the green door." The background stripes were symbolic of project accesses. For over 30 years, they used the emblem on pins, plaques, and other commendations given to employees and customer representatives for their services to the Project.

Figure 1: TP Pass. Pass scanned from a Bridgehead Recognition Award Plaque.

Although simplistic in its design, the teepee emblem perhaps symbolized great strides toward world peace and an understanding of known or potential enemies of the United States. For during those decades, reconnaissance systems rapidly advanced under a shroud of secrecy beginning with the U-2 program.

The U-2 Program:

President Eisenhower authorized the design and manufacture of the U-2 aircraft and the initiation of a high altitude photographic reconnaissance system, codenamed "Aquatone" in 1955. Engineers designed the U-2 to fly at altitudes in excess of 60,000 feet and incorporated an "A" camera (designed and built by the Hycon Corporation), configured in either of two systems:

- **The "A1" camera**—built with a tri-metrogon mapping configuration, a system of aerial photography that simultaneously took one vertical and two oblique photographs for use in topographical mapping.
- **The "A2" camera**—configured for photographic reconnaissance. The A2 incorporated 24-inch lenses, used 9 ½-in.-wide film, and had a 9 x 18 in. format for each of three cameras mounted in the U-2 aircraft in a fan configuration; one left, one vertical, and the other right.

In the 1958-59 timeframe, the "B" camera (also manufactured by Hycon) became available, incorporating a 36-in. focal length lens. This camera system used two 9 ½-in.-wide rolls of film that moved through the camera in opposite directions to expose imagery in an 18-in. square format. The system reduced torque and improved stability, but it missed objects at exact nadir because the image appeared in the gap between the two film rolls. The "B" camera also provided the capability of tilting the lens head from almost horizon on the left to almost horizon on the right through five different imaging positions: high oblique, medium oblique, vertical, medium oblique, and high oblique. The CIA used U-2 aircraft with these camera systems for all over-flights of the U.S.S.R. from 1956 until 1 May 1960.

Interestingly, this clandestine operation relied on a simple, but effective, means of packaging to transport the film from the retrieval area to the film processing plant. U.S. Army ammunition boxes, modified with a foam lining, effectively served as parcel packaging for the camera film rolls. Following a U-2 mission these so-called "B-boxes," made their way back to Rochester, NY for photographic processing at the government's Kodak-operated Lincoln Plant facility by way of a customer courier service (known as Friendly Airlines).

U-2 Camera Films

Kodak's participation in the U-2 program began in 1956. One of the first tasks was to establish a covert film supply system, which was completely independent from the conventional commercial film supply network. Managers at Kodak Park (the multi-plant facility where they manufactured film products) adopted the code word "Project F" as the film supply system for all films produced for the U-2 program. Project F films were slit and spooled from acetate-based black & white (B&W) aerial films. Original camera negative films used on U-2 flights were 9 ½-in.-wide rolls of Kodak Special Plus X Aerial Aerographic film coated on .0052-in. (5.2 mil) acetate base.

Figure 2: Lincoln Plant. Photo courtesy of the Don Alkins family, Rochester, NY. Photographer unknown.

Early Processing Operations

The first Photographic Operations Center had humble beginnings in the spring of 1956, in a facility owned by the Navy Department known as Lincoln Plant located on the west side of Rochester. The Central Intelligence Agency (CIA) directed initial operations, while Kodak's employees oversaw technical and production operations. In a concerted effort to meet project demands, Kodak's management team took several decisive steps to advance the capabilities of its facilities. They moved rapidly to provide a secure facility to accommodate equipment and staff. Within a short time span, they also reassigned supervisors, engineers, and technicians from their commercial production and processing departments to operate this facility. With great resourcefulness, and with the added pressure of time constraints, this team scrounged processing equipment, chemical mix operations, and photographic printing equipment from various parts of Kodak's manufacturing operations. The team installed them in the building known as Lincoln Plant's Unit 7, formerly known as the "Perfume Factory"—a name derived from the facility's former business of bottling and packaging perfumes. This plant gained a new mission as a temporary photographic processing laboratory to handle those U-2 payloads returned to Rochester for processing. It had a projected lifespan of only two or three years.

Utilizing a Primary Eltron processor and a Secondary Eltron machine, technicians processed exposed camera films in two stages, which involved interruption of the normal development cycle.

This process required interruption to obtain a "reading" on the unknown exposure levels of the imagery because the A-2 camera system did not have the ability to adjust film exposure based on illumination of the photographed scene. Constructed of stainless steel, the Eltron processors extended 25-ft. in length with a 150-foot-long thread path (including the wet and dry sections), which moved the film continuously through the sequential black & white processing steps. The Primary Eltron operated at a drive speed of 5-ft/min., while the Secondary Eltron operated at a drive speed of 7.5-ft/min. The Primary Eltron supplied a preset low level of primary development, after which the film passed through a "stop" solution to arrest development, and was then washed and dried without being "fixed." Technicians then visually evaluated the film under special safelight conditions to determine the level of density achieved and the nature of the imagery. They conducted this operation in near total darkness with only a very dim dark green safelight used for the visual inspection. If the imagery possessed sufficient density for the acquired targets, they put the film through the Secondary Eltron (bypassing secondary development) to receive only a fixing solution (and subsequent washing and drying). If they determined that the imagery required additional density (e.g., low luminance areas and partial shadows), they placed the film in the Secondary Eltron for additional development as well as the traditional stop, fixer, wash, and drying steps. Because this double processing technique was cumbersome and slow, it became obvious that the processing of original negative (ON) films needed significant improvements. However, Lincoln Plant lacked appropriate space for expansion.

Figure 3: Kodak's Hawkeye Plant. Photo courtesy R.D. Sherwood and J. Sherwood.

Transition to Hawkeye

To overcome the limitations of the Lincoln Plant photo lab installation and its inadequate operational space that prohibited expansion, the government and Kodak formulated guidelines for an expanded capability. They agreed that the expanded capability should be located in a Kodak facility where expertise and personnel were readily available. Moreover, the expansion plan needed to include the design and installation of state-of-the-art photographic processing and reproduction equipment. The expansion process also required that all activity remain top secret and in no way compromised the existence of a major photo laboratory that served the photoreconnaissance community. In addition to these guidelines, the National Reconnaissance Office (NRO) and CIA created a plan to meet defined needs on an aggressive schedule. Available space in some of the buildings at Kodak's Hawkeye Plant presented an opportunity to locate new lab facilities there–code-name "Bridgehead"—which denoted the secret location.

Despite the use of older buildings serving as a good cover for the covert operation, money provided by the government out-fitted the new lab with newly designed processing equipment. Installing the new equipment and moving from Lincoln Plant to Bridgehead (BH) required a staged approach. The staged approach required the printing of the ON imagery onto duplicate films at Lincoln Plant, transporting the exposed film to Hawkeye to use the high volume processing capabilities, and then transporting the processed duplication films back to Lincoln Plant for packaging and shipping. This logistically complicated arrangement, although temporary, enhanced the ability to supply a large quantity of desired high-quality imagery on a timely basis.

Subsequent steps used the same strategy—design and build new ON processing equipment and install and operate the new equipment at Bridgehead without compromising the basic and unorthodox equipment, which had hurriedly but successfully, been "kludged" to meet an urgent U-2 support requirement. After installing the complete cadre of original processing, duplicate printing, duplicate processing, inspection, and shipping equipment at Bridgehead, engineers and technicians modified the obsolete equipment left at Lincoln Plant to support exploration of the potential advantages of color in reconnaissance photography.

Chapter 2

THE CORONA, GAMBIT & HEXAGON PROGRAMS: KODAK'S ROLE IN THE PROGRESSION FROM U-2 TO SATELLITE IMAGERY

In the 1950s, the U.S. Intelligence Community (IC) endeavored to acquire good information about happenings behind the Iron Curtain. Meanwhile, the pressing intelligence demands of the Cold War promoted the development of various aerial and satellite reconnaissance systems. President Eisenhower proposed his 1955 "Open Skies" initiatve, allowing reciprocal access for reconnaissance over-flights to monitor military activities in various countries. Conversely, the USSR's Nikita Khrushchev opposed Open Skies. The U-2 program facilitated photoreconnaissance missions; however, the government anticipated a relatively short operational life for this program. In 1958, President Eisenhower set in motion a daring attempt to use unproven, but developing space technologies to counter the secrecy behind the Iron Curtain. In their study of uses of space, Project RAND, a federally-controlled research center based in California, researched the space approach to reconnaissance and concluded that "reconnaissance data of considerable value can be obtained" via use of reconnaissance satellites.

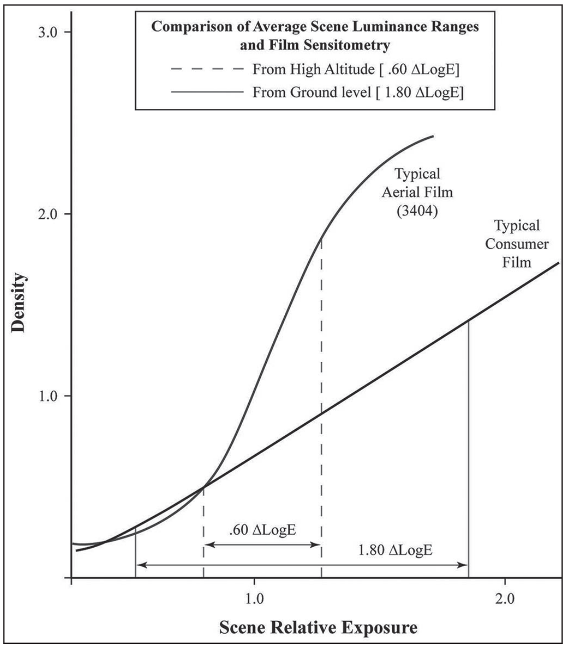

Figure 4: Comparison of Average Scene Luminance Ranges and Film Sensitometry.
Graphic by T. Havens and J. Havens.

During this intensive three-year development program, the government and associated contractors worked to resolve multiple security and program management challenges. Kodak closely engaged in aiding the effort by developing the films and ground handling technologies needed for the Corona system, one of the new programs competing for space-borne reconnaissance roles. These imaging systems used specialized films, chemical processes, and reproduction equipment, and Kodak developed the films and technologies. Although Kodak developed better processing and ground-handling equipment for the U-2 program, with the rapid advancement of satellite photoreconnaissance technology, these systems necessitated even higher resolution acquisition films to resolve the objects much further away when photographing them from space. Additionally, the need to penetrate the natural haze of the atmosphere required a high-contrast film producing a relatively narrow exposure range, which required critical exposure control and precision processing.

These haze effects reduced the "average scene exposure range" from a very high altitude to a fraction of typical scene exposure ranges at ground level. This circumstance necessitated high contrast precision exposure and processing to capture the maximum scene information. Lower contrast consumer films provided a margin for variation not available to the aerial imaging system. Kodak's workforce possessed the expertise with microfilm emulsions, and they worked toward extending that specialized knowledge to produce finer grain aerial films.

Kodak contributed further innovations to the emergent satellite program. It produced films on ESTAR base early in the Corona program to resolve breakage problems associated with acetate film base. The stronger ESTAR base allowed the development of thinner films, which provided an increase in film-load length for a given weight limitation. Concurrently, Bridgehead made improvements in film processes and ground handling equipment, which increased system performance and production capabilities. Kodak's efforts continued throughout the life of the Corona program, and combined with camera system performance improvements, ground resolution improved from 35 to 40 feet in the early missions to 6 to 10 feet in later missions. The Bridgehead facilities successfully processed over two million feet of camera film over the life of the Corona program.

Corona Black & White Camera Films

Kodak routinely supplied camera films for the U-2 program by 1958, the inaugural year of CIA's Project Corona. Accordingly, the film-supply system at Kodak Park followed the same procedures established for the U-2 Project. Kodak Special Plus X Aerial Film SO-1153, coated on an acetate base, was the first Corona camera film. Slit to 70mm width, the film wound around cores supplied by the camera manufacturer. They modified B-Boxes with new foam liners to carry the carefully wound film for shipment. The SO-1153 film worked well for all ground tests, but as testing progressed to simulate space environments, the acetate-based film failed. Solvents used in the manufacture of the acetate base out-gassed in the space environment, resulting in the base losing its structural integrity. It quickly became apparent that space photography required a new film base.

ESTAR, a relatively new material, held the promise of meeting the film base requirements for space-borne films. Earlier, E. I. du Pont deNemours and Company (DuPont) had developed a strong clear flexible sheet film from polyethylene terephthalate (PET), called Mylar. Kodak had purchased a licensing agreement from DuPont to permit Kodak to manufacture the PET with the provision that Kodak limit its use to films in photographic applications. Kodak called its new film base "ESTAR." Initially, scientists used ESTAR films for applications that required rigid dimensional stability. However, Kodak engineers quickly recognized the necessity for using ESTAR base for Corona's space application. They soon modified Kodak's ESTAR manufacturing equipment to provide long lengths of film base for use on Corona. In the spring of 1960, Itek Corporation (the Corona camera manufacturer) evaluated test lengths of Kodak Special Plus X Aerographic Film coated on ESTAR base (identified as SO-102). Itek determined that SO-102 worked well and used it in the first successful Corona mission containing film. This mission, named Discoverer XIV, flew on 18 August 1960, and carried a film load limited to ten pounds of 70mm-wide SO-102 (approximately 3000 feet).

While they originally produced ESTAR base with a thickness of .004 inches (4 mils), there was the potential for producing even thinner film bases. As manufacturing techniques improved, it became possible to reduce the ESTAR base thickness to .0025 inches (2.5 mils), identified as ESTAR Thin Base film. Because the thinner base permitted a larger film payload for the same weight, most of the Corona flights used this ESTAR Thin Base film. Twenty-inch diameter rolls of thin-based Corona camera films were only slightly longer than the 6000-ft. U-2 rolls. However, the rigors of rocketpowered launches imposed quite different and more stringent spooling requirements on the Corona film roll. For example, high vibration levels caused shifting of adjacent layers of film in the camera roll. Film manufacturing engineers eliminated the problem by winding the camera roll under precise tension and alignment control. These improvements also resulted in flatter face-walls on the finished roll, which allowed the attachment of flanges to both sides of the camera film load before packaging in the metal B-Boxes.

Kodak manufactured all films on relatively few very large machines, designed to handle coating widths of either 42 or 54 inches. Unfortunately, they did not design any of the machines to handle very thin film base. Because it was not feasible to construct a dedicated special facility for manufacturing Corona films, Kodak developed special techniques to transport the thin base during manufacture and its subsequent emulsion-coating operations. In addition, Kodak engineers and technicians built special equipment to accommodate the unique camera spools, ultrasonic splicing capabilities, and winding equipment to assemble the approximate 8000-ft. film lengths required for the Corona camera flight rolls. Both the photographic and physical characteristics of the camera film required very rigid standards. The Corona Project's flight rolls only used film that met all the required characteristics. The very complicated film path of the Corona camera required that the film had to be straight and without weave. In addition, the film support thickness had to be almost perfectly uniform to avoid the formation of "hard streaks" in the long tightly wound rolls.

Kodak Black & White Film Types Used in the Corona Program

This chart identifies the film types carried as the principal film load in the various KH systems. On occasion shorter lengths of color films or B&W infra-red films were spliced into the film roll for evaluation and/or as an aid in image exploitation.

DESIGNATION	KH-1	KH-2	KH-3	KH-4	KH-4A	KH-4B
TIME PERIOD	'59-'60	'60-'61	'59-'62	'62-63	'63-69	67-72
CAMERA MFGR.	FCIC*	FCIC*	Itek**	Itek**	Itek**	Itek**
CAMERA DESIGNATION	C	C'	C'''	?	J	J-3
LENS	f/5	f/5	f/3.5	f/3.5	f/3.5	f/3.5
MODE	Mono	Mono	Mono	Stereo	Stereo	Stereo
RV	1	1	1	1	2	2
FILM WIDTH	70mm	70mm	70mm	70mm	70mm	70mm
BASE TYPE	Acetate	Acetate	Acetate/Estar	Estar	Estar	Estar
BASE THICKNESS	5.2 mil	5.2 mil	5.2mil/2 ½ mil	2 ½ mil	2 ½ mil	2 ½ mil
FILM CODE	SO-1153	SO-1153	SO-132	SO-132	3414	3414

* Fairchild Camera and Instrument Corporation
**Itek Corporation

Figure 5: Kodak Black & White Film Types Used in the Corona Program.
Compiled by J. Moser from Eastman Kodak Co. records.

Technical advancements in camera design permitted changes in film design. As the Corona Project progressed, it incorporated faster lenses into its camera, which allowed use of slower, finer grain film. The combination of better lenses and finer grain/higher definition film resulted in acquiring much better photography, permitting greater enlargement and providing much more detail for photo interpreters. However, these finer grain films greatly increased cleanliness requirements, which required incorporation of more sophisticated equipment and heightened cleanliness standards in the manufacturing process.

Use of an even thinner ESTAR base held the potential for even longer film loads. In the late 1960s, Itek ran tests to determine if the Corona camera system could use Kodak's newly developed High Definition Aerial Film 1414—the same emulsion already in use but coated on .0015-in. (1.5 mil) ESTAR, known as ESTAR Ultra-Thin Base (UTB). However, the complicated film path and the curved platen in the Corona camera prevented UTB from tracking properly, and although Itek wanted to use this 1414 film in their KH-4B configuration, the risks outweighed the benefits. The UTB film never flew on a Corona flight.

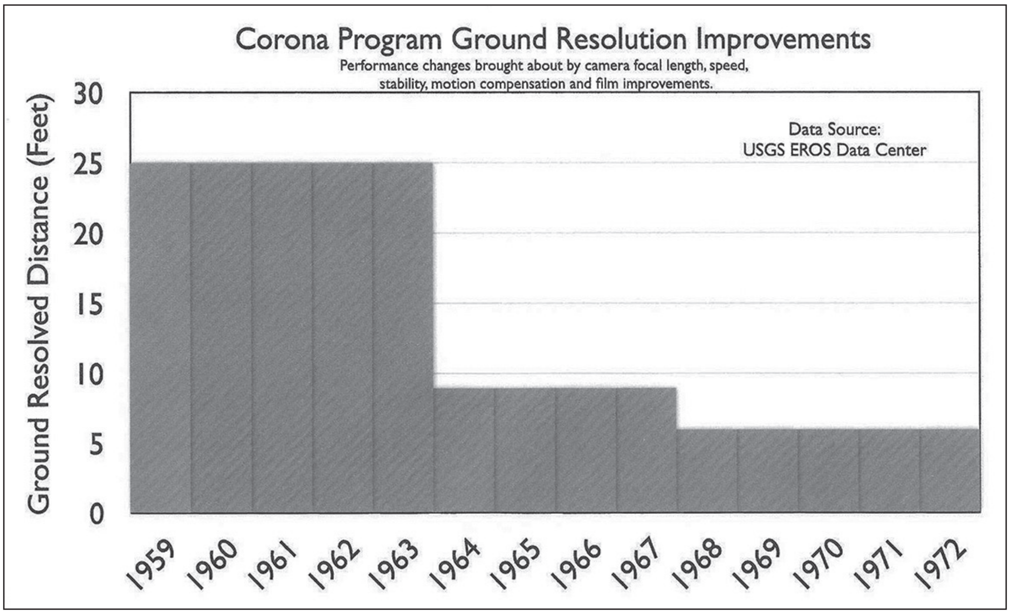

Figure 6: Corona Program Ground Resolution Improvements.
Data Source: USGS EROS Data Center; graphic by T. Havens and J. Havens.

For all of these initiatives, film manufacturing at Kodak was always a highly proprietary operation. Accordingly, Kodak funded all the development work, manufacture of new equipment, and modifications of existing equipment needed to produce the special films for the overhead reconnaissance programs. Many years later, these innovations received honorary recognition. In February 2005, the National Academy of Engineering selected Project Corona as the recipient of the Charles Stark Draper Prize. This prize honors an achievement that significantly affected society by improving the quality of life, providing the ability to live freely and comfortably, and permitting the access of information. Due to the secrecy of this project, the recipients received this award forty-five years after the first successful photography from space. The recipients—Mr. James W. Plummer, Lockheed; Mr. Minoru S. Aracki, Lockheed; Mr. Francis J. Madden, Itek; Dr. Edward A Miller, General Electric; and Mr. Don H. Schoessler, Kodak—accepted the award on behalf of their respective corporations.

(See Appendices for a listing of Kodak films available for aerial imaging applications in the last half of the 20th Century.)

Satellite Reconnaissance: Black & White Mission Processing at Bridgehead

At Bridgehead, the term "mission" meant all the activities involved in receiving a single Recovery Vehicle (RV) from a reconnaissance satellite, from downloading it to processing, duplicating and shipping its film payload. With Kodak's commitment to support government surveillance programs, Kodak's Special Programs unit began the development of a sophisticated B&W film processing and reproduction operation at Bridgehead. The unit's primary tasks, accomplished in round-the-clock (two twelve-hour) shifts, typically over a period of three to four weeks, included: preparing the ON film for processing; processing it; breaking it down into manageable lengths; adding man-readable information to each frame of imagery; printing and processing duplicate copies (mostly duplicate positives but some duplicate negatives as well); adding header and trailer identification information to the original and duplicated copies to facilitate user handling; and preparing the finished copies for shipment. The outcome of the tasks was the delivery of a finished product of the highest quality to the government customer in as short a time as possible.

Additional tasks included the generation of multiple copies of selected frames and creation of very high quality enlargements of selected targets (up to 153X) in order to meet specific customer requests. Except for specialized paper-based enlargements, technicians transferred imagery in ON films directly to high-resolution duplicate positive films (without magnification) for viewing in front of diffuse-light viewers often equipped with high magnification microscopes. Film-based duplicates (transparencies) were essential to achieve maximum resolution levels, tonal range, and highest possible image quality. Most duplicating films were ESTAR based except for some early duplication films coated on triacetate base.

In the same manner that manufacturers built, assembled, and tested space-borne hardware under very high standards of cleanliness, Bridgehead operations conducted operations in a clean-room environment. Operating personnel wore clean-room attire—lint-free hats, body suits, gloves, and shoe coverings—specialized clothing known as "bunny suits."

Recovering, Transporting and Processing B&W Corona Films

Typically, the Corona mission flowed smoothly from payload recovery and transport through the Bridgehead film processing and reproduction operation to the subsequent shipment of finished product. Specially equipped aircraft flown by the 6593rd Test Squadron out of Hickam Air Force Base, Hawaii "snatched" the Corona RV (containing the exposed ON film) in midair over the Pacific Ocean as it returned to earth under its parachute. After returning to base, personnel assigned to the mission placed the RV in a specially constructed shipping container and transferred it to a Military Air Transport Squadron C-130 military aircraft. They then flew to a western U.S. Air Force base for refueling before going on to Rochester, N.Y.

The operation required a secretive arrangement among Bridgehead personnel, the Air Force, and the civilian airport's manager in Rochester. Upon arrival at the airport, the aircraft always taxied to "Bravo Pad," located near one of the commercial runways but a significant distance from the airport's passenger terminal. Bridgehead personnel drove a leased, unmarked truck and entered the airport's security perimeter via a normally locked gate, using their own key for access. (Previously, the airport manager had undergone a security clearance investigation and received a classified briefing about the mission, which enabled operations to occur without interference by airport employees.) There, without attracting attention, Bridgehead personnel transferred the shipping container to the truck and transported it to Lincoln Plant and later on to Hawkeye. The aircraft loadmasters loaded any residual shipments of film or equipment from the truck and did not return until the first priority copies of the mission were ready for pickup. Once the shipping container arrived inside the Special Programs perimeter, Bridgehead personnel inspected it for integrity and general condition and prepared it for movement into the pre-splice operation.

Although nearly all missions proceeded smoothly, such sensitive photography required preparation for possible mission problems. Early in the satellite reconnaissance program, the government challenged Bridgehead engineers to develop a plan to handle RVs that "splashed down," as opposed to those recovered in the normal snatch recovery manner (under parachute). Designed to stay afloat only on a temporary basis, the RVs incorporated a specially designed plug that would completely dissolve, allowing the unit to fill with water and sink to ensure unfriendly nations could not gain vital information. While still afloat, however, it appeared inevitable that seawater would seep into the RV. The government tasked Bridgehead to prepare equipment and procedures capable of extracting the exposed negative from this potentially damaged and internally wet unit while minimizing loss of imagery.

To prepare for this possibility, Bridgehead personnel conducted trial runs of possible scenarios such as if it would be best to submerge the entire rolls in simulated sea water, leave as received, and slowly unwind assisting separation of convolutions where needed, or just wetting areas of the roll that had been splashed. In all cases, they assumed that in the area between wet and dry, the emulsion might act as glue, making it very difficult to unwind convolutions. To gain experience, they prepared "dummy" rolls and simulated "splashed down" conditions to varying degrees to determine best techniques for differing conditions. Technicians gained expertise in this assessment, but they also recognized that in a real situation, the best procedure could not be predetermined and would need further definition following a methodical evaluation and some careful trials. Fortunately, they never needed to apply their complicated training about theoretical "splashed down" conditions. Water recoveries occurred for single RVs from Corona missions 1012, 1020, and 1042. However, minimal leakage or damage occurred in all of these recoveries, and it was not enough to require any unusual procedures other than detailed initial inspection. Upon successful return of an RV, Bridgehead personnel followed a sequence of processing steps that most generally ran like clockwork, as described in the successive portions below.

Responses to Evolving Reconnaissance Systems

The U.S. reconnaissance community utilized the Corona acquisition system from 1960 to 1972. During this period, satellite program engineers also designed and put into operation other overhead systems to meet changing intelligence needs. On 17 September 2011, the U.S. Government officially declassified two of these systems, the Gambit and Hexagon programs, which required new equipment capabilities in Bridgehead operations. Hence, this chapter further sheds light on advancements in existing technologies in order to meet the demands of emergent satellite missions.

The separately compartmented K-Program within Eastman Kodak utilized both the Lincoln Plant and Hawkeye facilities (non-Bridgehead areas) to design, develop, and produce the Gambit camera, used for acquiring specific targets, while Perkin-Elmer Corporation in Danbury, CT produced the Hexagon camera as a broad-area search system. Kodak received the contract to design and build Gambit's camera in 1961. According to declassified NRO documents including, *The Gambit Story*, Gambit's camera possessed an f/4.0 lens with reflecting and refracting elements. It had a 77-inch (+/-0.5) focal length with a clear aperture of 19.5 inches. They further compared it to an astronomical telescope with a much larger half-field of 3.20 degrees. At an altitude of 90 miles, it produced a remarkable two to three foot ground resolution at nadir. The manufacturers designed both camera systems to transport ultra thin-based and ultra-ultra thin-based (UUTB) original negative films primarily to increase payload size without increasing weight. Gambit possessed a web width of 9.5-in., and Hexagon's was 6.6-in.

Film Technologies and Processes

Despite the security requirement within Special Programs that separated camera developers from film processors, each operation successfully functioned to achieve the common goal of supporting the Gambit mission. Moreover, the new camera system allowed for successfully integrating some existing technologies and processes into an expanding demand for photoreconnaissance imagery. For instance, the Bridgehead operation designed most of its equipment to handle web widths between 70mm and 9.5-in. in width. Because these UTB and UUTB films were extremely sensitive to minor transport irregularities, all of Bridgehead's equipment that handled ON films had to be fine-tuned, or in some cases redesigned, to transport these new film products. The Gambit system's camera carried improved exposing capabilities in frames as short as 3-in. in length and as long as several feet with the ability to change exposure settings on a frame-by-frame basis. This capability drove the need to be able to adjust ON development on a frame-by-frame basis.

Other advancements at the Bridgehead production facility optimized program success. For instance, they designed and developed dual gamma sensitometry as a significant improvement in viscous developer processing. In that regard, it improved the developed image quality of both Gambit and Hexagon films. Optical titling was another major development driven primarily by the increased size of payloads, the need to minimize the risk of damage to the ON record, and the need to eliminate a bottleneck in production operations. Moreover, careful control of the wavelengths of light used in exposing ON imagery onto duplicate positive copies during the printing process allowed Bridgehead production operations to provide the highest possible image quality transfer without compromising efficiency, reliability, and delivery timelines. Another requirement that dictated the need to develop new equipment was that of minimizing image distortion during the reproduction of imagery acquired on the ON record. A new customer requirement, Geographic Area Breakdown, drove the development of sophisticated editing and ultrasonic splicing equipment used to breakdown and reassemble processed rolls of Gambit original film into new rolls containing images of common geographic areas. Research and development (R&D) efforts accommodated the evolving requirements of these satellite systems while also upgrading processing and reproduction capabilities to meet program needs.

Pre-Splice

The first step in the film processing and reproduction cycle consisted of the pre-splice stage. Once inside the darkened pre-splice room, Bridgehead personnel opened the film recovery vehicle. They placed the tail end of the mission film roll (containing the most-recent exposures) on a Pre-Process Inspection Table where they spliced on an unprocessed densitometric step wedge for sensitometric control, an unprocessed sensitometric sample of the flight film, a length of uniformly exposed film for physical Quality Control (QC), and a long ESTAR trailer. The trailer film was long enough to more-than-fill the thread path of the ON processing machine and was already loaded onto the Film Spool Dolly. Then, as they slowly un-spooled the film from the RV (with back-tension supplied by a second operator) and onto the film dolly for transfer to the processor, the pre-splice operator carefully inspected both film edges for any irregularities that might cause subsequent handling problems. They carefully managed the transfer rate from the recovery vehicle to the dolly in order to prevent the build-up of electrostatic charge on the film and to allow for proper inspection of the film. If they encountered any problems—a rare happening—they stopped the unspooling and made repairs before the transfer to the dolly resumed. Once they reached the head end of the film roll (containing the first exposures), they attached another densitometric step wedge, a uniformly exposed filmstrip, and a shorter leader to the film, and moved the pre-spliced roll to the ON processor.

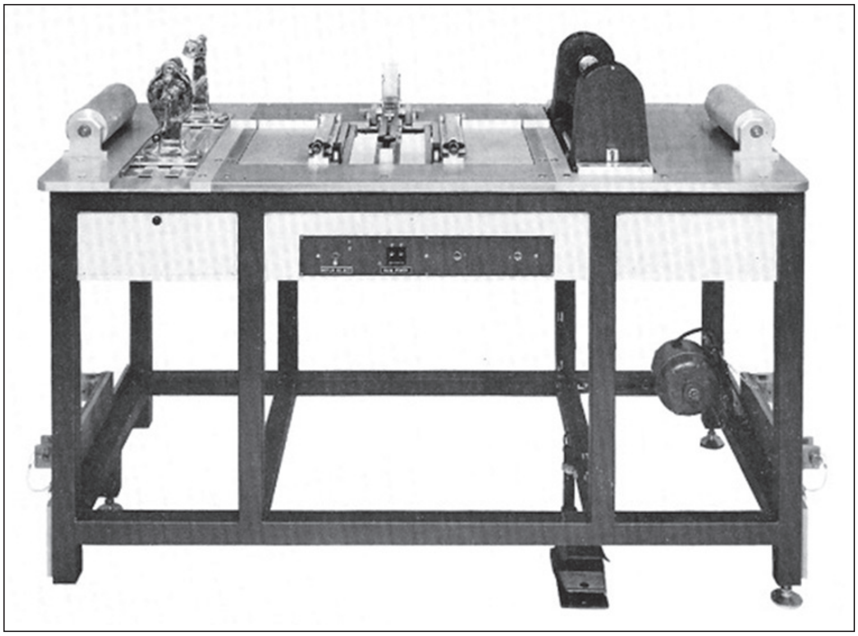

Figure 7: Pre-Process Inspection Table. Ground Handling Equipment for Reconnaissance/ Aerial Photography Fact Sheet, May 1972, produced by Bridgehead's Special Programs unit.

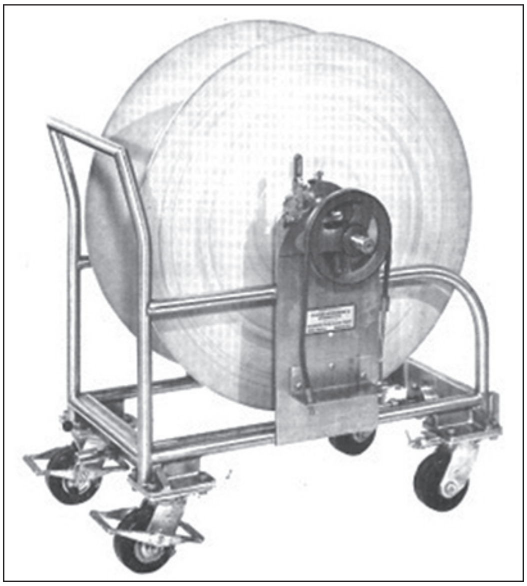

Figure 8: Film Spool Dolly. Ground Handling Equipment for Reconnaissance/ Aerial Photography Fact Sheet, March 1978, produced by Bridgehead's Special Programs unit.

From time to time, the load returned in an RV contained more than one type of film. If a mission contained experimental B&W, conventional color or color infra-red film, operators identified the types in pre-splice by use of a footage counter while feeling for the tell-tale film splice, as identified in the "roadmap" prepared during makeup of the camera film supply roll. When this occurred, they removed color films and took them to a separate color facility at Lincoln Plant for processing (see Color Production Operations at Lincoln Plant section).

Photographic Certification

Bridgehead technicians accomplished photographic certification primarily by visual evaluation for uniformity in processing and by densitometric measurement of photographic step wedges, which they then compared to Master Specification Aims previously established for the respective film/chemistry combination. They made these sensitometric step wedges by exposing the film to 21 logarithmically-graduated segments of exposure on a strip of film (similar to that used on each mission) on a specially calibrated stable printing device, designated as the Kodak Sensitometer, Type 1-B, Model V. Technicians calibrated this sensitometer to a secondary standard available at Kodak Park. They aged, froze, and stored the exposed strips until approximately an hour before use, an amount of time sufficient to equilibrate with room temperature. Once the exposed strips reached room temperature, the technicians spliced sensitometric strips into the header and trailer (which had been prepared earlier), which were then spliced into the mission acquisition film at the pre-splice operation and prior to committing the mission to the processor. They applied these same processes to the duplication film processors, except there they processed each roll with a sensitometric control step wedge made on the duplication films and then took densitometric measurements to aid in adjusting chemical replenishment rates.

In order to have an appreciation for the accuracy and precision of the Quality Control measurements, Bridgehead engineers and photo scientists conducted studies to examine the total system variability of all the component stages. These areas included the variability of the photographic film products, the component chemicals of the processing solutions, the composite chemical processing solutions, the processing machines, the sensitometric step wedges, the densitometers, curve plotting equipment and the QC operator techniques. They used this data to establish stringent, but achievable specification aims and control limits.

Original Negative Processing

By the time the first Corona mission arrived (1960), Special Programs personnel had upgraded the Eltrons to permit the processing of the original negative on a single machine instead of the separate Primary and Secondary machines. This processor, called the Speltron (for Special Eltron), incorporated both a deep-tank primary developer section and a spray secondary developer section. All original negatives received the primary development, and then a highly skilled technician evaluated the film "on the fly" before an infrared scanner to determine if the film required additional (secondary/tertiary) development, or just water, before passing through the fixer and wash sections. The processor automatically recirculated, filtered, temperature controlled, and replenished all processing solutions according to pre-established specifications set by operators.

As part of the plan to expand film-processing operations at Bridgehead, coupled with the growing success of the Corona photoreconnaissance project, engineers designed and built two Trenton ON film processors. They brought them online in 1963.

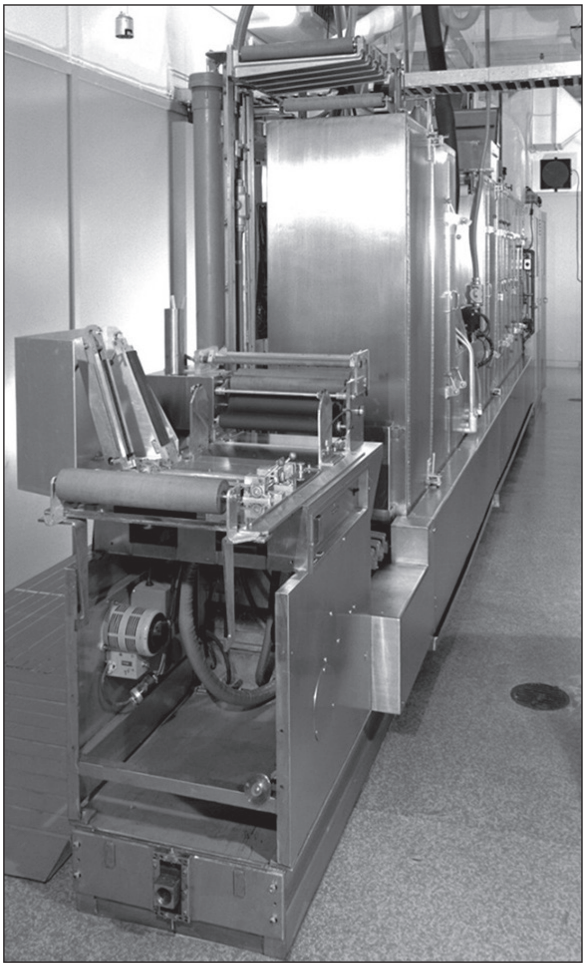

Figure 9: Trenton Film Processor. Photo from archives of Bridgehead's Special Programs unit.

These spray machines had a throughput speed of 20-ft/min., which allowed simultaneous processing of the forward and aft Corona camera films—one on each machine. The Trenton design provided three levels of development—primary, intermediate, and full on a "trend" basis—through the use of an infrared scanner and converter tube (a cathode ray tube [CRT] operating beyond the spectral sensitivity of the film), which allowed a skilled operator to see the image density characteristics after primary development. The operator then manually selected additional intermediate or full development for the film length based on the density levels observed on the frames of imagery passing through the scanner. Later, installation of electro-optical infrared film scanners permitted monitoring minimum density levels on the partially developed imagery at the interrupted process point. The scanners sampled eighty 0.1-square-inch silicon solar cells, spaced across the film imagery width and illuminated with an infrared source, at the rate of 5,000 samples per second, effectively giving 100% coverage of the exposed imagery. Adjustable signal-level trip points selected primary, intermediate, or full processing based on the minimum density threshold of the imagery. A further variation on this arrangement, called "Trenton Automation," used a technique of trend analysis over time to integrate and effectively average a number of readings before selecting a required development level.

Before a mission could be committed to a processor, Bridgehead technicians certified the machine to ensure that it was in control and ready to handle the ON film. They certified the Trentons using unprocessed sensitometric step wedges exposed on an established standard control film of the same type as the film from the recovery vehicle and a uniformly exposed length of the same film to certify processing uniformity and physical quality through the processor. Once films were processed, technicians used a densitometer (an optical device which measured the opacity or density of each gray scale step) to read the step wedge densities and graphed them for comparison with the aim specification. They evaluated the uniform density length on a light table to verify process uniformity and to certify the processor for physical quality. After technicians certified the processor for processing, they spliced the leader of the pre-spliced film roll onto the leader already in the processor's thread path, started the film transport system, and fed the ON into the processor. The production workers monitored the processor operation from the head end of the processor through the take up end in total darkness or under very low safelight conditions. In case any film breaks or malfunctions occurred, Bridgehead operators placed small tanks of stop bath and fixer in the processor room for use in salvaging film.

Black & White Frame-by-Frame Processing

As the satellite reconnaissance program advanced, the Bridgehead workforce developed specialized and improved Black & White processing techniques. Soon after operational systems started providing high definition, variable length frame-by-frame acquisitions, Bridgehead management recognized that they needed a frame-by-frame processing capability. To accomplish this task, research efforts defined a method of applying developer in a viscous formulation by combining it with a thickening agent made from a water-soluble polymer. In the processor, the film web received primary spray development (usually at 90° F) before entering a viscous developer cabinet, which maintained the ambient air at the process temperature, and maintained the humidity at a high relative value. While in this cabinet, the equipment applied a viscous formulation (also heated to the process temperature) to the emulsion side of the film on a frame-by-frame basis. The viscous developer coating was typically less than .06-in. thick and over-coated the width of the moving web to ensure complete film-width coverage. The application technique used precision coating hoppers, manually engaged for coating or retracted when not in use. Because the viscous developer coating had sufficient resistance to shear, it maintained a static layer of uniformly concentrated developer. It covered those previously coated frames regardless of subsequent physical orientation of the moving web.

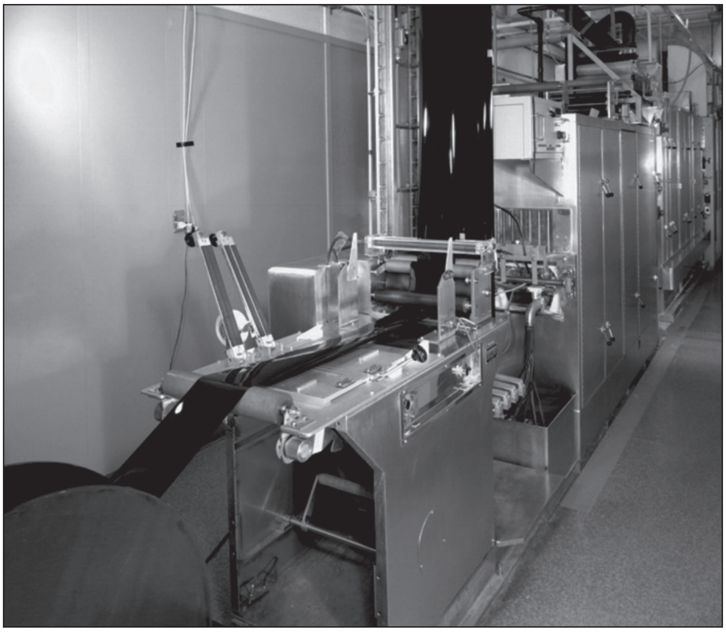

Figure 10: Yardleigh Original Negative Film Processor. Photo from archives of Bridgehead's Special Programs unit.

The two Yardleigh Processors were the first production processors to use viscous development. As in the Trenton Processor, the ON received initial (primary) development in a spray cabinet, and then the technician used the equipment to arrest development in a stop bath. Subsequently, if a frame required full development, the first coating hopper in the processor's environmentally controlled viscous developer cabinet would immediately coat it. If only intermediate development was required, it received a delayed coating by the second hopper located further along the processor's web path. That arrangement allowed both levels of viscous development to use common squeegee and stop stations to end full and intermediate development levels. This overall set-up allowed for a true frame-by-frame process level capability at any one of three levels of development.

The earliest applications of this capability in December 1966 required an operator to view the film after primary (spray) development via an infrared (IR) viewer and to make a judgmental decision based on the overall density of the partially developed image. If he judged the primary development level to be satisfactory, he did nothing, which prevented the engaging of the hoppers. If he judged that a full level of development was called for, he pushed the "Full" button to engage the first hopper for the duration of the frame under development. If he judged that an intermediate level of development was called for, he pushed the "Intermediate" button and engaged the second hopper for coating at the appropriate time. Technicians timed the coatings applied by the hoppers to begin and end at a frame line or space between frames. Nevertheless, the decision process was risky and vulnerable to human error. Inevitably, technology advancements allowed automation of the process-level decisions.

The ability to scan on a frame-by-frame basis in a processor necessitated two requirements. First, it necessitated a "road map tape" available at Bridgehead before arrival of the film record to be processed. This tape worked to define how the camera had generated exposed frames. Second, using safe light sources, the processor's scanner needed the capability to detect frame marks exposed in the camera system and developed to an adequate density level for detection following primary development. These requirements were easily satisfied and allowed the computer-controlled developer system to synchronize with the exposed imagery undergoing processing. They then scanned the primary developed imagery on a frame-by-frame basis, and depending on scanning data, each frame received either no additional development (primary), an intermediate level of development, or full additional development. Bridgehead personnel implemented this system in the next major upgrade of the Yardleigh Processors.

The scanners used in the Yardleighs were the same design as those used in the Trentons—eighty 0.1-in. square silicon solar cells spaced across the width of the film web and illuminated with an infrared source. They read the images at the rate of 5,000 samples per second, which effectively provided 100% coverage of the exposed imagery. The operators then evaluated the scanned data on a frame-by-frame basis using criteria established in research studies and used these criteria to control the intermediate and full development hoppers. A highly experienced operator always monitored the process decisions made by the scanner algorithms and the frame-mark-detection operations. As a precaution, this operator could override the system if necessary.

B&W Dual Gamma Sensitometry

New possibilities in the design of developers resulted from adopting viscous developer processing. In addition to the new latitude in designing a desirable sensitometric response (curve shape), the Bridgehead team also learned that the edge effects inherent in static layer development could be used to improve image micro-contrast.

This innovation maintained the broad exposure level necessary to accommodate the highly variable brightness conditions at exposure. The final selection of developer design provided a high macro-contrast of images that were in limited light situations and an extended low macro-contrast for brighter scenes. These brighter scenes were still of highly acceptable quality due to the high micro-contrast provided by static layer development. For many decades, film technology experts recognized the existence of "edge effects" in static layer development—a process by which the exposed image received additional developing agent energy from areas adjacent to the image giving it a "sharp edge."

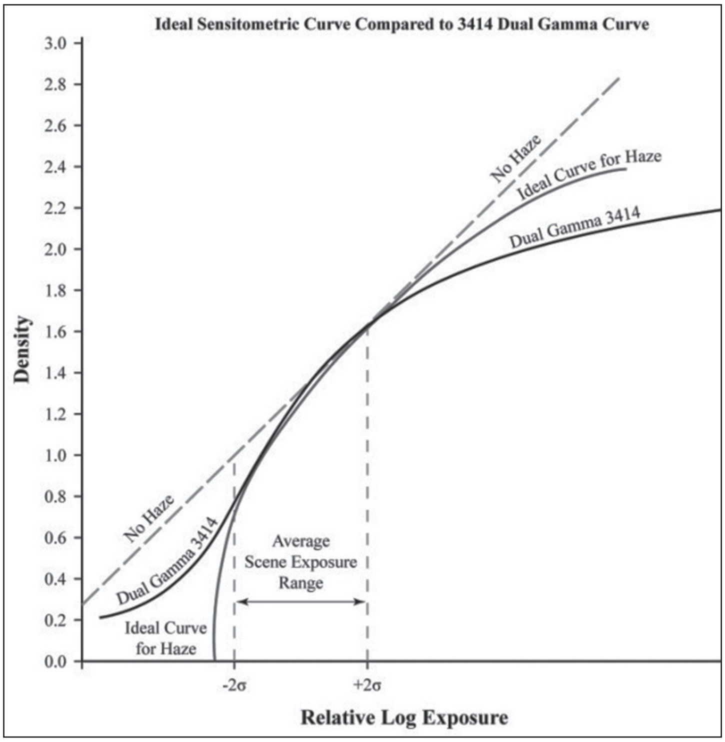

Figure 11: Ideal Sensitometric Curve Compared to 3414 Dual Gamma Curve. Graphic by T. Havens and J. Havens.

By March 1969, Bridgehead utilized newly designed equipment and chemistry, and the quality of the delivered product provided substantial improvement. Notably, these advancements led to higher quality films and the design of processing chemicals to enhance the quality of the acquired image. They also expedited the evolution of printing and processing hardware into a high-volume processing and reproduction system that ensured not only quality but also the achievement of output speed, efficiency, and reliability. The

Gambit missions in 1969 first used the dual gamma process, which proved its reliability for processing B&W acquisition films from all subsequent Gambit and Hexagon missions.

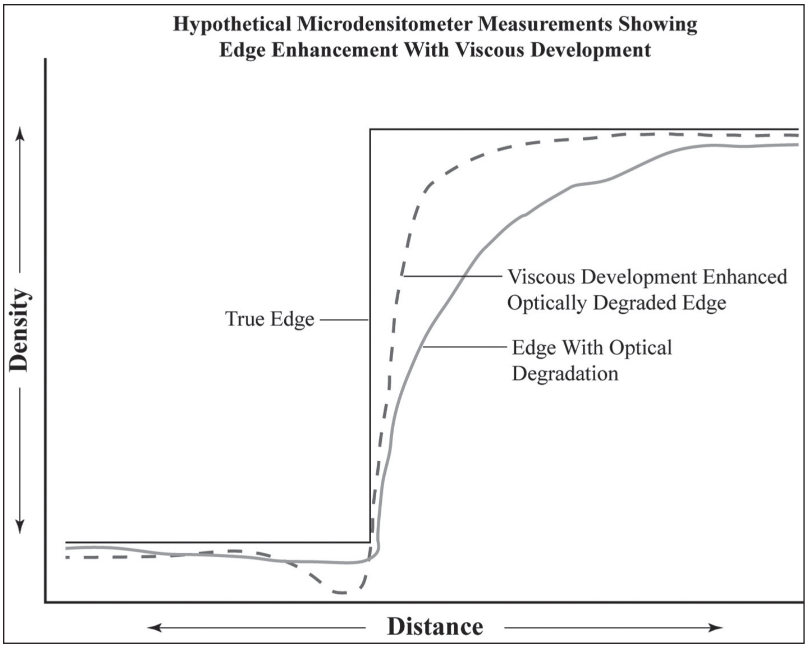

Figure 12: Hypothetical Microdensitometer Measurements Showing Edge Enhancement with Viscous Development. Graphic by T. Havens and J. Havens.

Optical Titling

One of the post processing operations was the manual titling and lacquering required for placing man-readable information on each frame of processed imagery. These titling operations were labor intensive and a constriction in the overall workflow (see a detailed description in the next chapter). Engineering management proposed the concept of writing this titling information onto the film in the processor early enough in the process to produce a readable and reproducible image. With rapidly improving computer/software technology, along with an increased understanding of available satellite acquisition data and specific location information about the frame marks exposed during acquisition in all satellite systems, Bridgehead engineers and technicians performed studies to explore the possibility of exposing required titling information during the development process. In order to accomplish this objective, several issues challenged the team members, which led to several questions:

- Could IR sensors, placed in the developer cabinet, possess the capabilities to read the location of the start of frame imagery precisely and relatively early in the development process?
- Once the operators and their equipment identified frame location, was there enough exposure/development time remaining to provide a suitable silver image assuming the exposing device would be located in a practical location in the processing machine?
- Could the operators and their equipment obtain acquisition data (including orbit revolution, frame number, security classification, etc.) over a secure transmission link on a timely basis so that the titling instruction tapes would be available at the time of processing?
- Could they demonstrate that they could place software in order to synchronize the optical titling hardware with the acquisition information (commonly called getting in-sync with the roadmap)?

- Could engineers and technicians develop equipment and procedures to correct any errors resulting in incorrect title information exposed on the negative?

The Bridgehead team easily resolved some of these challenges. Other challenges took substantial effort. However, the R&D-sponsored Contract Control Board (CCB) eagerly supported the effort and provided funding because the perceived payoff was highly significant. By the summer of 1970, Bridgehead workers overcame the equipment, software, and procedure challenges and eliminated one of the difficult stages of the production process for follow-on acquisition-system film records. In August 1970, a portion of Gambit mission 4328 utilized optical titling. By November 1970, Gambit mission 4329 utilized all optical titling to meet its titling needs, which led to optical titling for all primary B&W acquisition films on subsequent Gambit and Hexagon missions.

Chapter 3

PROCESSED ORIGINAL NEGATIVE HANDLING

Primary Inspection of Processed Original Negative Film

The era of black & white reconnaissance photo production involved a number of steps and skilled production workers. Once the ON processor's take-up roll accumulated enough original processed film, the steps included separation at "inter-op wraps"[1] into shorter lengths called "lab-cuts;" inspection of lab-cuts at a primary inspection table; and documentation of the ON's physical condition prior to the start of the duplication process.

The inspection documented any scratches, film artifacts, edge damage, and other abnormalities found on the film, and repairs were made as needed. Workers used this inspection as a basis of comparison in the final inspection of the original film before they packaged and shipped it to the customer. The customer received records of both inspections. During Primary Inspection, operators also spliced identification leaders and trailers onto the film. They then printed each lab-cut as one large roll to provide copies for initial exploitation (by visiting government personnel) and engineering analysis of camera system performance (by visiting government and contractor personnel).

Customer Representatives

From the early days of Kodak's support to the IC, Lincoln Plant/Bridgehead operations maintained a close working relationship with the National Photographic Interpretation Center (NPIC). Prior to the arrival and receipt of imagery—from aircraft or satellites—at the Rochester plant, photo-interpreters from NPIC were present to perform certain duties. In early programs, they reviewed the processed negatives, defined what titling to affix, decided what cloud-covered imagery to edit, and completed a quick review and assessment of very high priority targets. They then produced a subjective opinion of the quality of the acquisitions.

As programs matured, the NPIC role changed somewhat to align with program needs. For instance, the advent of optical titling, and in the case of Hexagon, the Post Flight Analysis (PFA) performed at Bridgehead immediately after the receipt of the RV, reduced the role for these representatives.

Nonetheless, throughout the many years of these programs, the visiting customer representatives continued to play an important role. Over the years, they worked to identify the need for additional copies beyond the base number of copies required and indicated special targets that required custom duplicates or enlargement briefing prints for the exploitation community. For this purpose, briefing materials consisted of paper or transparency enlargements up to 40X, produced on the Kodak 10-20-40 enlarger. Later in these programs, the Beacon Precision Enlarger (BPE) enabled production of high quality enlargements up to 153X from an input target area of .5 to 3.7 inches in diameter and an output image area of up to 40 inches X 40 inches.

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1 Inter-op (short for "between-operations") wraps were lengths of unexposed film which resulted from film being advanced within the camera as it started up to get into an operational mode or shut down after an operational mode.

Primary Breakdown

Upon successful printing, processing, and delivery of the lab-cuts to visiting government personnel, Bridgehead production workers took the lab-cuts to the Primary Breakdown clean room area to be broken down into shorter lengths of film, based upon the acquisition sequence and length limitations for a packaged duplicate roll of film. This operation took place on film-handling tables equipped with rewind spindles, a diffuse light source for viewing the negative imagery, film cutters, and tape splicing mechanisms. Workers removed leaders and trailers previously added for lab-cut printing and broke down the ON into 250-ft. lengths (including new leader and trailer) for duplication according to a customer-supplied manifest. They also added processed step wedges to each end of the ON strips for monitoring and controlling the duplication process. They then spliced previously prepared identification headers and trailers onto the head end and tail end sections of the ON so that their information would be transferred during the printing function. The identification headers contained security information, the mission number, camera (forward or aft) information, the orbital pass number, orbit mode (ascending or descending), and the part number. The mission necessitated part numbers because many camera imaging operations produced a greater length of exposed film on a pass than the length of duplicate film that could be held on a duplicate film spool. As a result, the pass had to be broken down into multiple parts. Per customer direction, workers edited out any long lengths of imagery that contained 100% cloud cover, labeling and titling them as such for inclusion with the shipment of the original films. Finally, they applied corresponding labels (generated from the manifest) to the spools of ON for internal tracking and control as they were passed to the titling operation.

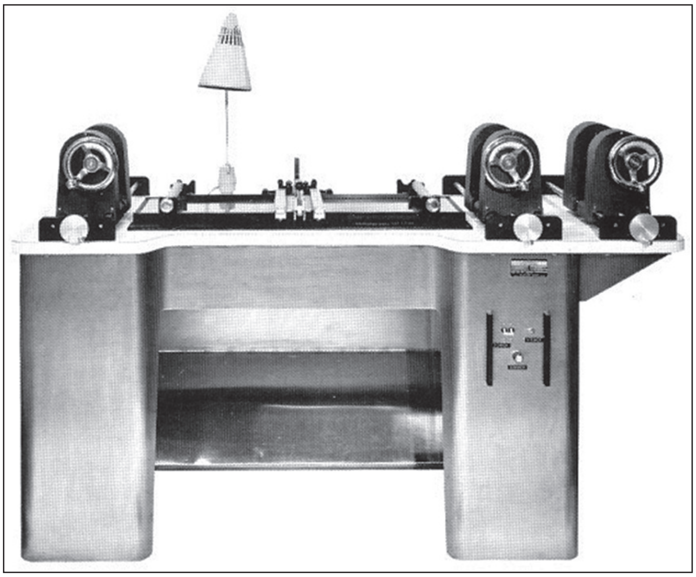


Figure 13: 30-Inch Editing Table. Ground Handling Equipment for Reconnaissance/Aerial Photography Fact Sheet, September 1978, produced by Bridgehead's Special Programs unit.

Titling and Lacquering

Once production workers broke down the film, they titled each frame of imagery with security information, mission number, camera (either forward or aft), pass, date, and specific frame number. They relied on specially developed "Dual-head Titlers," which used time, temperature, and pressure to transfer man-readable information from a printing head through a tape carrying a transfer pigment designed to adhere to film. Using this process, they added both a fixed-field (carried on a disposable embossed plate) and an indexing frame number to the ON along one edge of the film web adjacent to each frame. Bridgehead engineers worked closely with a tape manufacturer in Brownsville, Texas to adapt a standard, commercially available tape for titling. Although Brownsville Titling Tape carried transferable pigment that was soluble in alcohol to allow corrections without damaging film emulsions, product variability was a frequent problem. Furthermore, manually indexing each frame into position for titling caused a holdup in production operations and added an undesirable risk to the ON. Although machine operators expended significant effort to optimize the durability of the titled data while minimizing the extent of film embossing, finished titles were vulnerable to flaking and degradation through handling. To protect the titled data and ensure that titling pigment did not migrate to adjacent wraps in the film roll, they applied a thin continuous coat of clear lacquer over the titles along the edge of the film. Technicians accomplished this additional step by moving the titled film roll to an edge-lacquering machine (emulsion down) where it applied a continuous strip of lacquer to the underside of the horizontal web as it moved at constant speed in contact with a lacquering wheel. Driven by the web, the wheel picked up lacquer as it passed through a small reservoir beneath the wheel and carried it up to the film, coating the edge-titled data. The lacquer was sufficiently volatile and thinly applied to dry quickly into a flexible coating, which allowed rolling of the film shortly after the lacquering station. These steps readied the "lacquered roll" of ON film for printing and production handling.

Figure 14: Dual Head Titler. Photo from archives of Bridgehead's Special Programs unit.

This operation was a manual, labor-intensive, frame-by-frame titling operation that added man-readable information adjacent to each frame of ON imagery. The successful implementation of optical titling removed the manual titling operations as a constriction on throughput in the early part of mission production. The operation used manual titling for corrections and for image formats that required special handling.

Ultrasonic Splicing

Initially the operation cut the Corona camera 70mm flight rolls from master rolls approximately 5000 feet in length. As the payload restrictions eased, flight rolls increased in length from the initial 3000 feet ft. to 5000 feet, supplied as one continuous piece of film. As manufacturing technologies permitted decreasing the ESTAR film base thickness from 4 mils to 2.5 mils, the camera systems could carry longer lengths of camera film without exceeding payload weight limitations. These changes required the development of a splicing technique for joining two 70mm lengths of film. Taping two ends together that increased the web thickness at the splice did not work due to thickness constraints in the camera film path.

Kodak's Film Manufacturing Division developed a method of ultrasonically fusing two ends of the 70mm film together to form an ultrasonic film splice. After scraping the overlapped areas of all film coatings, they made this splice by overlapping the ends by a small amount. Technicians placed the overlapped film on an anvil, and as an ultrasonically driven tool passed slowly across the width of the film web, they applied sufficient pressure to cause the induced ultrasonic energy to heat and literally fuse the two film ends together. This welding action produced a strong splice, but it also splayed out a small tab of fused base material beyond both edges of the 70mm margin of the film web. To remove the unwanted tabs, they used a circular-shaped cutting tool to nip them off one-at-a-time along with a small amount of film within the margin of the film, which resulted in a small circular cutout where the splice met each edge of the film web. Sufficiently sophisticated, this ultrasonic splicing operation allowed technicians to accomplish the task in a darkroom environment. Laboratory testing of these film splices confirmed strength and reliability of the process. Tensile tests indicated that ultrasonic splices nearly equaled the strength of un-spliced film base. Kodak's Film Manufacturing Division used ultrasonic splicing to build up all rolls for the Gambit and Hexagon programs. When requested, they built up rolls with various types of film to meet customer requirements (e.g. B&W, Color, and Infrared).

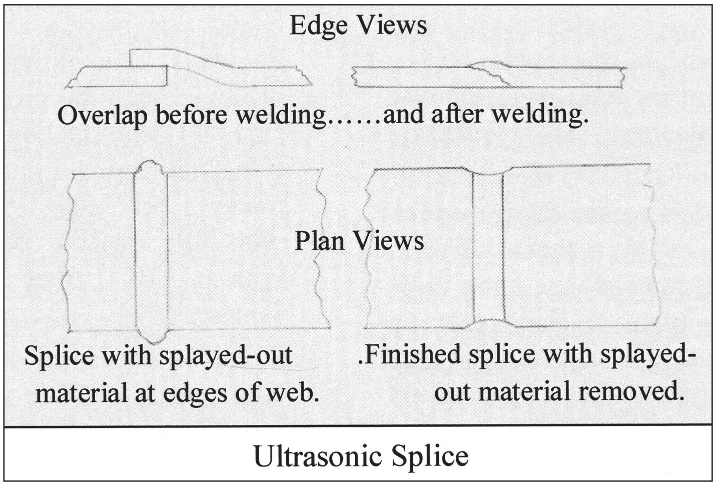


Figure 15: Ultrasonic Splice. Graphic by R.D. Sherwood.

Bridgehead used ultrasonic splicing on processed ON films from the Gambit and Hexagon programs prior to the production of duplicate copies. In those applications, the Bridgehead production operators separated the processed ON between frames and then reassembled the ON using ultrasonic splices to join imagery of the same geographic areas.

Cleaning

Upon completion of titling and lacquering, and prior to duplicating, technicians passed the ON through a cleaner/waxer. This apparatus removed foreign matter from both surfaces of the film strip and applied a thin coating of protective wax over the emulsion surface of the ON, which worked to suppress static buildup in the printing operation and to maintain duplicate print quality. This step used a Clinton Cleaner/Waxer, a wide-web machine that used a hydrocarbon-based solvent for cleaning. Subsequent cleaning operations throughout the duplication process used the Tacky Roll cleaner. This apparatus removed any dirt attached to the film as well as any microscopic film skivings that came from the camera film and duplication films as they ran through printer transport systems. Bridgehead engineers eventually replaced these cleaners with improved adhesive cleaners and web cleaners located on the printers.

Chapter 4

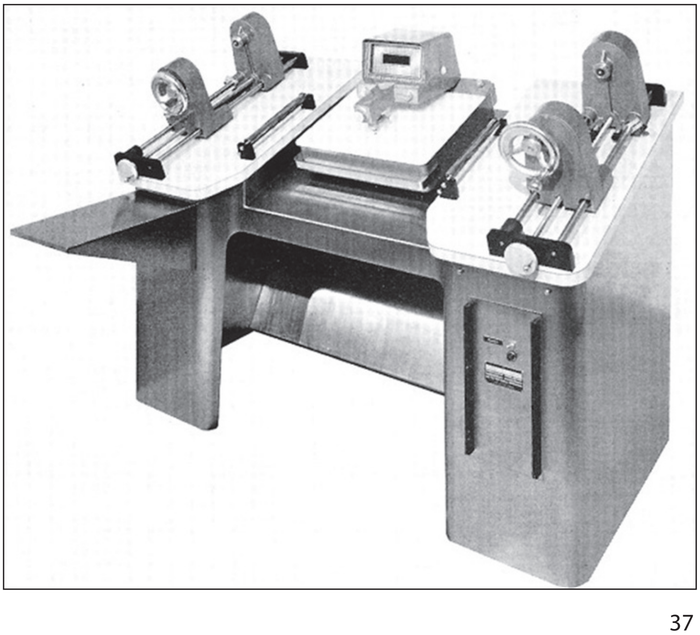
ORIGINAL NEGATIVE REPRODUCTION & DUPLICATE PROCESSING

Black & White Duplicating Films

Another key contribution of Bridgehead's workforce included innovations in film duplication. The photographically processed image exposed in the camera resulted in a negative image. The photo interpretation community extracted all critical intelligence information from duplicate copies photographically printed from the original camera negative. Duplicating films did not have to withstand the physical rigors of flight film, but they did have equally demanding photographic image and cleanliness requirements. Bridgehead technicians duplicated the first Kodak Plus X Aerocon II camera films onto Kodak Aerographic Duplicating Film 5427. Film manufacturing later converted this film to ESTAR base and changed the code to Kodak Aerographic Duplicating Film 2420. They printed higher definition camera films onto Kodak Fine Grain Aerial Duplicating Film 8430. Ultimately, this same film coated on ESTAR support was named Kodak Fine Grain Aerial Duplicating Film 2430. Materials science advanced to include regular commercial packaging, rather than B-Boxes, which carried and delivered the duplicating films. A pre-established price per roll set the price the government paid for the delivered film.

With the reproduction of Gambit and Hexagon original negatives and the increasing resolution of acquisition films over the life of the programs, Kodak developed new and more specialized duplication films to maximize the transfer of all information on the original negatives to the duplicate positives and duplicate negatives.

Figure 16: Densitometer Table. Ground Handling Equipment for Reconnaissance/ Aerial Photography Fact Sheet, September 1976, produced by Bridgehead's Special Program unit.



Predicting Printing Conditions

To ensure correct printing conditions, Quality Control operators visually reviewed the overall densities of the frames in a roll of processed ON. Using high quality densitometers with ½-mm apertures, they measured minimum and maximum image density in several ON frames to provide a statistically sound base for printing exposure calculations. Operators advanced through the roll until they noted a significant change in density. Then, they took additional sets of densitometric readings. They summarized the readings from each roll and used the midpoint, minimum, and maximum densities to make the prediction of printer density. The operators input predictions in rotary nomographs in the early days of the program and used this densitometric information to predict the First Copy printer intensity. In cases of an extreme range of densities within a roll, the prediction process led to recommendations that the roll be broken down into two or more parts or that additional "light" or "dark" copies be printed. A First Copy printing ticket with this information then accompanied the ON roll to the print room for creation of the First Copy pilot print. As time and technologies progressed, this step in the film processing business grew more sophisticated.

Printing

Bridgehead photo scientists designed film reproduction systems to meet the spatial and tonal reproduction requirements of each acquisition film. Each ON film-process combination required its own processing and reproduction systems to maximize spatial and tonal image quality in the duplicate positives, duplicate negatives, and enlargements produced. Production workers set the printers to the exposure conditions indicated on the First Copy or the Print Ticket, and printed multiple rolls of ON onto rolls of duplication film up to 1,000 feet in length. QC workers monitored printers similar to the methods used for chemical processing, by using various density patches to measure return densities, uniformity, and physical surface characteristics. To indicate the total system response, they printed processed sensitometric exposures from the specific acquisition film onto the duplicate film and compared then to the Master Specification Aims.

The earliest roll contact printers were tabletop units designed to print 70mm film at 25 ft./min. The printers pressed the ON filmstrip into intimate emulsion-to-emulsion contact with the unexposed duplicate filmstrip, and then passed them over a printing drum where a high-intensity light exposed the duplicate film. Production workers printed and processed pilot copies of the ON, which QC evaluated and adjusted the printer settings for optimum image quality transfer. Then, duplication of that part of the ON in the numbers defined by the customer followed this process.

Figure 17: Niagara Printer, Model III.
Image Management Fact Sheet revised 1987,
produced by Bridgehead's Special Programs unit.

At an early stage, Bridgehead management realized that available roll contact printers could not satisfactorily meet high production volumes. As a result, Bridgehead engineers and photo scientists developed large floor standing machines—Niagara, Redondo, and Kingston Printers—to handle up to 9.5-in. wide webs. These printers had many advanced capabilities. To achieve highest spatial resolution transfer from the camera film to the duplication film, the printers contained mercury vapor light sources heavy in the ultra-violet (UV) portion of the spectrum. Interchangeable light sources were among their unique features. Other improved capabilities included special transport features for optimum distortion control, viewers to allow operators to see the position of ON frames, looper accessories to allow continuous repetitive printing of a short length of ON, copy counters, and duplicate film cleaners.

Not sensitized in the red portion of the light spectrum, the B&W duplicating films allowed production workers to handle the duplicating films in environments using medium wattage red safelights designed for use with this class of films. This feature made operations faster and safer for the production crews in both the printing and processing areas. They used up to eight printers in the production operation with two to three printers occupying a common printer room suffused with a subdued red safelight.

Selective Wavelength Printing (SWP)

In the late 1960s, Kodak researchers and developers worked toward developing higher resolution, finer grain acquisition films for the Gambit system and for the planned Hexagon system. Imaging scientists recognized the need for higher resolution and finer grain duplicating films. Their goal was the highest possible image quality transfer (both spatial and tonal quality) from ON to duplicate positive without compromising production efficiency, reliability, and timeliness of multiple copies disseminated to the IC.

These photographic duplication films were similar to finer-grained, low-noise, high-resolution materials used for microfilming. However, these materials were inherently higher contrast as well as "slower" (less sensitive). Therefore, unless an image had an extremely short-range and low-density tonal scale (such as selective images acquired with extreme haze or cloud shadow), these high contrast materials met only half the requirement. They provided high-resolution transfer but "clipped" the tonal scale of all but the lowest contrast images.

Two major developments in contact printer lamp house design, along with the use of viscous processing described previously, made it possible to accommodate the inherently higher contrast, higher resolution duplicating films. They controlled film response to a lower contrast by only partially developing the reproduced image. Viscous development, which employed carefully formulated chemistry, provided the necessary precision for incomplete yet reliable development. Thus, they achieved somewhat lower contrast, but incomplete development also resulted in a significant reduction in the threshold sensitivity of these already inherently "slower" (lower sensitivity) films. Loss of photographic sensitivity of these duplicating films required a significant increase either in lamp house intensity or unacceptable reductions in production throughput rates. Hence, the first major development in lamp house design increased the light output intensity by a factor of four. A 400 watt (versus 100 watt) mercury arc lamp provided sufficient energy to maintain contact printing throughput rates, even when using less than complete development of the higher resolution films.

The second major development made use of the characteristics of the spectral output from the mercury arc lamps. By using custom interference filters, that shift peak density as the angle of incidence changes, it was possible to selectively modulate the intensity of the two strong wavelengths in mercury arc lamps (365 nanometer and shorter 334 nanometer) changing the ratio of intensity, and therefore, the effective contrast of the duplicate. This technique allowed additional contrast control by taking advantage of the spectral density of the original print master image and the spectral sensitivity of the duplicating films. The mission objectives achieved high contrast when printing with wavelengths at or near 365 nanometer. Significantly lower contrast occurred with shorter wavelengths near 334 nanometer, and they achieved intermediate contrast levels with the proper mix of the two wavelengths.

Combined advances of higher intensity lamp houses and selective wavelength contrast control enabled the production of higher definition images. They accomplished this objective without loss of efficiency and without reducing production throughput rates. Subsequent lamp house advances and refinements, such as dual lamp houses, Xenon lamps, better filters, and additional optics, offered even greater flexibility to maintain or enhance the reproduction quality through custom printing of the increasingly higher-definition imagery of later acquisitions.

November 1970 marked the time Bridgehead production operators achieved the first full reproduction copy onto Kodak SO-192 High Resolution Aerial Duplicating Film using SWP contrast control. In January 1974, the mission reached another milestone when the 400-watt Redondo Printer, with an ABCC (Actinic Butterfly Contrast Control) filter, successfully produced copies using SWP with full variable contrast control.

Distortion Control

Some recipients of B&W duplicate copies from Corona and later programs utilized the imagery for a generation of topographic maps. Due to the amplification of mapping errors generated by the scale and altitude of the photography, these customers had a primary concern that the imagery contained the lowest possible degree of distortion. Toward this goal, Kodak's Bridgehead Design and Engineering Department (D&E) developed and utilized special printers designated the "Kingston" and the "Linear Gate Printer" to minimize the degree of distortion produced during printing.

Conventional continuous contact printers typically wrapped the original and duplicate films around a drum (typically 12 inches in diameter) to establish contact during exposure. A pressure roller against the drum initiated contact between the two webs, which was then sustained by a combination of web tension, partial vacuum, and electrostatic and molecular attractions. The apparatus broke contact between the two webs subsequent to printing by using a roller to separate the negative film from duplicating film while it was still on the drum. The Kingston Printer succeeded in minimizing distortion. This printer incorporated a larger diameter print drum (28 inches) into its design, which reduced distortion due to the different degrees of curvature of the acquisition film while in contact with the duplicate film during exposure. Additionally, to minimize distortion from any twisting or pulling in the film path, the Kingston incorporated the use of castor rollers rather than fixed rollers into its design. Finally, the Kingston had specially designed variable torque motors on supply and take-up spindles to minimize pulling of the film as the radius of the film rolls changed during printing. Bridgehead used this printer to produce a limited number of duplicate copies for mapping customers.

Another development effort, the "Linear Gate" printer, further attempted to reduce distortion. This printer not only eliminated the distortion caused by exposing over a curved surface but also had an attractive design feature that allowed frequent slewing of the ON. This innovation allowed exposure of multiple copies of selected imagery in tandem for efficient use of duplicate film. Another benefit of this drum-free design was the ability to include energy-measurement devices that allowed the design of dynamic exposure intensity control. The design proved to be very practical; however, because of the product development timing and cost, the Bridgehead production system saw limited use on Gambit and Hexagon.

The need for distortion-controlled copies generated the development of distortion monitoring. To accomplish the requirement, the Bridgehead team drew from techniques developed in the Kodak Research Labs, which utilized a procedure that evaluated Moiré patterns produced by matching slightly out-of-phase dot patterns. This procedure called for printing a dot pattern screen (e.g., 1000 dots/inch) and placing the processed duplicate print in contact with a slightly different dot pattern screen (e.g., 999 dots/inch). Technicians evaluated the interference pattern (Moiré), entered it into a vector analysis program and compared the resultant average (Root Mean Squared or RMS) value against established limits on distortion for the duplicate copies. They conducted this test cyclically—every two hours of low distortion copy production—to determine quality and certification of the copies for shipment to mapping customers.

Duplicate Film Processing

In the early days of the Corona program, duplicate film processing occurred on three relatively slow processors at Lincoln Plant. These machines were designated the Model III, Drape, and Kongo. The Drape was a deep-tank machine. The Model III had a spray developer section and deep-tank finishing sections. The Kongo was an experimental all-spray machine used as a backup to the other machines. All three processors ran at a nominal 20 ft. per minute.

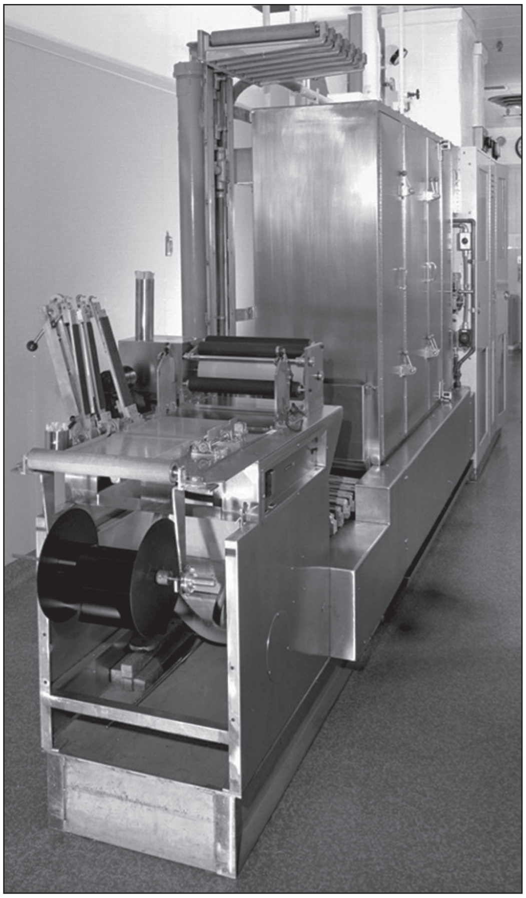


Figure18: Dalton Duplicate Film Processor. Photo from archives of Bridgehead's Special Programs unit.

When Bridgehead came on line (early 1960s), production workers processed duplicate films in spray Dalton Processors, 25 ft.-long machines designed to run at 100 ft./min. Two Dalton machines came on line in 1962 and were the first processors designed and built specifically for high speed duplicate film processing. Technicians prepared chemical processing solutions in a new mix room facility capable of supplying both duplicate and ON processors (Trentons), which came on line at Bridgehead approximately one year after the Daltons.

Technicians sealed exposed (printed) duplicating films in light-tight film cans and moved them to the Dalton Processor room for processing with print tickets accompanying each roll. In the processor room, machine operators systematically accomplished high-volume duplicate film processing on the Dalton Processors in a safelight environment. They spliced a sensitometric wedge and a uniformly exposed length of duplicating film onto the head of each roll prior to placing each roll on a supply spindle and mounting it on the feed stand of one of the processors. (A feed stand included supply spindle supports—holding a roll of film to be processed—and a splicer for attaching rolls of film together.) They stopped the feed when a film spool on the feed stand was almost empty, allowing the accumulator at the processor's feed end to continue supplying the processor. They spliced the head end of the next roll to the tail end of the roll already fed into the processor (this typically took about 20 seconds). Finally, they mounted the new roll and spindle on the supply spindle holder, and released the brake, where upon the accumulator returned to its full position.

Repeating this carefully timed procedure for each roll of unprocessed film enabled continuous operation of the duplicate film processors. At the take-off end of the processor, a second accumulator filled up when the operator stopped the film take-up to make a cut. The operator cut the film when it filled up a 1000-ft.-capacity take-up spool, making those cuts at the end of a printed part or at the sensitometric wedge. The Quality Control group certified and maintained these processors to a specific sensitometric aim. They used MacBeth densitometers with 3mm spots for densitometry of the processed sensitometric control strips previously exposed on a 1-B Sensitometer. The QC group evaluated the control strips with each master roll of dupe film processed throughout the duration of the mission processing cycle. They used this information to adjust developer replenishment rates. With the introduction of viscous development, it was not necessary to process these 1-B sensitometric control strips as often. The operations also used large-spot MacBeth densitometers for this purpose. After matching the print tickets with the processed roll, they sent both items to Duplicate Inspection.

Duplicate Film Inspection

QC technicians evaluated each roll of processed duplicate film for image quality and physical quality. At Duplicate Film Inspection, production workers removed any sensitometric wedges and uniformly exposed filmstrips, and sent them to QC for evaluation. Production workers then broke down the film into shorter rolls.

The Duplicate Film Inspection operation included two phases: a "First Copy" evaluation and a visual inspection. In First Copy evaluation, a QC technician examined the first copy printed of each segment of the ON for density range and contrast to verify the print prediction made at the densitometry stage. If the QC technician approved of the density range and tonal mapping, the approved First Copy allowed operators to print all additional copies using these First Copy printing conditions. If the images on the roll did not meet densitometric criteria, QC calculated a new set of printing conditions for the subsequent printing of a new pilot First Copy. They repeated this pilot print and inspection process until QC approved one or more sets of printing conditions for that specific roll. In some circumstances, the density range of the ON throughout the roll was so great that they produced and sent special "light" and "dark" copies with the nominally exposed roll. The image quality evaluation also included a quantitative evaluation using the imagery and sensitometric control patches to verify that the duplicates were within the control points established for that reproduction system. QC also evaluated the image under high magnification to verify there were no mechanical problems in the printing and processing functions, which potentially affected spatial image transfer.

Duplicate Film Inspection also ensured the integrity of the physical quality, without compromise. QC technicians looked for proper tracking, processing artifacts, scratches, and any other physical damage to the duplicate film roll that could affect exploitation or any other imaging uses of the film. They also tested duplicate films to verify proper "fixing" and washing to ensure archival keeping. After establishing final printing conditions, operators started the high-volume production of multiple copies of each approved roll—a roll being a specific pass and part number as determined at breakdown. Priority shipment requirements dictated the number of copies produced at a time, with production of first priority shipments naturally preceding lower priority shipments.

Finally, production workers in the Duplicate Inspection area broke down the long processed rolls of duplicate positives or negatives. Inspectors provided a final physical inspection and a final densitometric control measurement of each broken-down roll. Then, they applied labels containing the roll identification information and copy number to the film spool and enclosed the wound spool in a plastic bag, inserted it into a metal can, and applied another label to the outside of the can and the lid. They forwarded the completed roll to the Production Shipping Office (PSO) for manifesting and packaging. In the mid-1960s, advancements in materials engineering included replacement of plastic bags and metal cans with heavy-duty plastic cans produced in Kodak Park.

Briefing Board Production

During mission production operations, customer photo interpreters took up residence in the Bridgehead production area in order to examine lab-cuts for earliest identification of needed enlargements of selected targets. The photo interpretation community chiefly utilized contact (1:1) transparencies. However, they also utilized enlargements—usually printed in sizes of 11x14, 16x20, 20x30, or 30x40 inches—for briefing purposes. In some cases, they used enlarged transparencies but relied most frequently on 11x14 inch paper prints. The enlargements were from three to 153 times magnification depending on the nature of the target.

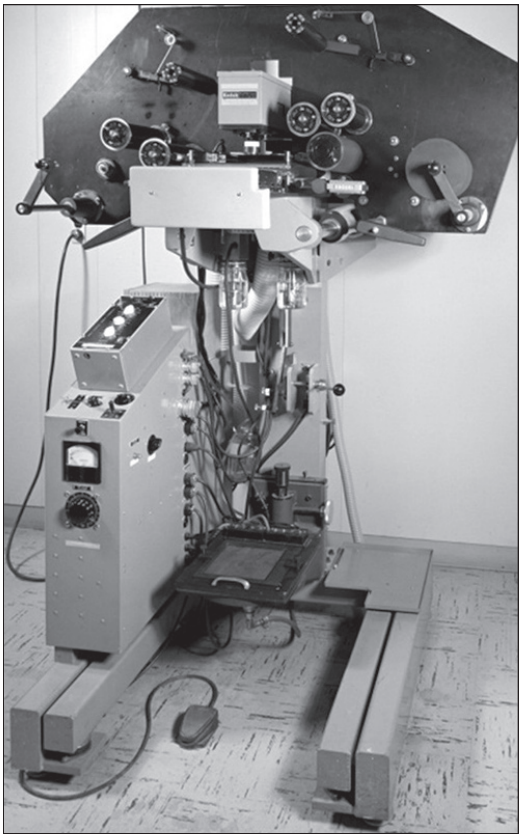


Figure 19: 10-20-40X Enlarger. Photo from archives of Bridgehead's Special Program's unit.

Enlargement Printing

Bridgehead engineers and technicians designed and built Briefing Board Enlargers, for the production of high quality enlargements. They specifically designed these enlargers to provide careful handling of original film rolls from 35mm to 9.5 inch widths. In the beginning of the Corona program, engineers designed, built, and utilized the Kodak 10-20-40X Enlarger for these three magnifications.

By the mid-1960s, the Corona program utilized the breadboard Beacon Precision Enlarger (BPE). This early proof-of-performance unit had several lenses with very high quality state-of-the-art optics. It printed from input target areas of approximately 0.5 x 0.5 to 3.7 x 3.7 inches, producing enlargements of from three to 153X. The BPE, similar to the 10-20-40X Enlarger, incorporated the use of a liquid-gate film platen for the original film. The liquid gate consisted of two glass platens which sandwiched the target original film and a non-wetting liquid (tetrachloroethylene) that closely matched the index of refraction of the original film. They used this liquid to fill-in fine scratches, prevent any optical anomalies at the glass platen/film boundaries, and fill in any other anomalies in the surface of the film, which prevented the objectionable enlargement of anomalies during printing. Special Programs engineers adapted liquid gate technology from techniques developed by the Kodak Research Labs for use in commercial motion picture duplication printers. A vacuum easel board held the duplicate film/paper sheets in a very stable and flat position during exposure. Later in the program, engineers modified the easel to hold a 9.5 in.-width roll film adaptor to produce enlarged color transparencies.

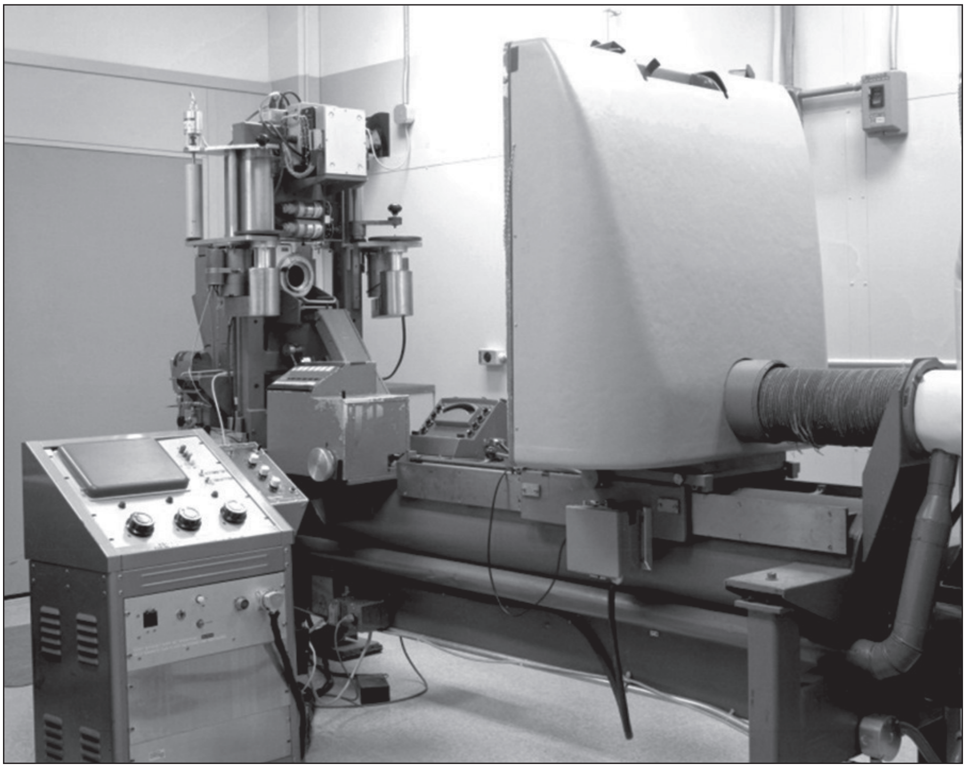


Figure 20: Beacon Precision Enlarger.
Photo from archives of Bridgehead's Special Program's unit.

Enlargement Processing

Bridgehead technicians processed enlargements in an off-line operation, except for roll transparency prints, which they processed on conventional processors. They processed briefing board sheets in commercial processing equipment such as the Kodak Roller Transport Processor, the Automat Black & White and Color Processor, the Kreonite roller transport Color Processor, and the Startech Processor, modified for B&W paper prints. Personnel inspected and certified the finished Briefing Boards in the Photo Enlargement Area and forwarded them to the PSO for inclusion in the regular customer shipments.

Final Inspection of the Original Film

After fulfilling all the duplication requirements, Bridgehead QC technicians re-inspected the original camera film for any physical artifacts and compared results to the primary inspection previously received after processing. Once they completed inspection, they wound the ON onto 250-ft. spools oriented with heads out. Very methodically, they labeled each spool, inserted it into a plastic bag, placed it in a metal can with a metal lid, and after sealing it with tape, they labeled both the can and the lid and delivered it to the Production Shipping Office for packaging. QC summarized and shipped the supplied inspection results to the customer. Moreover, they also evaluated their methodologies in-house to determine how to improve the production system.

Post-Flight Analysis

During the Corona years, a team consisting of key players collaborated to evaluate the performance of the camera system, film, and all other components of a completed mission. This Post Flight Analysis (PFA) team consisted of representatives from the program office, the camera contractor, NPIC, and film suppliers and processors from Bridgehead. One or two people from Bridgehead represented Kodak as supplier of the ON film roll and the processing and reproduction at Bridgehead. They completed that evaluation either at Itek (the Corona camera manufacturer) or at a government facility. Bridgehead employees made minimal contributions toward the evaluation of Gambit missions. In anticipation of Hexagon on-orbit life and becoming the IC's main search system, planning went ahead to allow for evaluation of the performance of this active satellite system on an expedited time schedule. In addition to evaluations of the hardware and film that might suggest changes in system instructions, the mission often identified a need for early interpretation of high priority targets. To meet these requirements, Bridgehead facilities engineers set up an area within the Bridgehead security perimeter for a PFA team to make its evaluations.

The PFA Team gathered according to a schedule that paralleled the receipt of a recovered film RV. Bridgehead then provided this team with an initial duplicate positive of the "as taken" film record. Occasionally, NPIC asked for the separation of a portion of the "last photographed" images from the recovered roll, processed first, and a single duplicate positive prepared as soon as possible because of the highly desirable coverage contained in those images. NPIC personnel then performed an initial photo interpretation of these high-interest areas. The Bridgehead member on the PFA team served also as the liaison for communication between the team and the Bridgehead organization. In addition to providing a complete as-photographed copy for the PFA Team, the interpretive community frequently requested Bridgehead workers to provide micro densitometry and enlargements of specific areas and other items of interest. The PFA Team worked around the clock until they completed their evaluations—a task that always required several days of coordinated effort.

Chapter 5

COLOR PRODUCTION OPERATIONS AT LINCOLN PLANT

During the early 1960s, and throughout the era of black & white film production, the U.S. Intelligence Community expressed an interest in experimenting with multi-spectral signatures via color film products. As a result, the CIA requested that Kodak research and design color films suitable for use in Corona. Earlier experiments with commercial color films, such as Ektachrome and Kodacolor films in ground test cameras, indicated that they would not be suitable due to their low image resolution. They tested Kodachrome film since it had adequate resolution but abandoned the possibility because of its complex processing requirements. Thus, the CIA asked Kodak to pursue the development of color film products with improved resolving power. Kodak chose to develop a color positive film of the Ektachrome type. The possibility existed to reduce the granularity and thus improve resolving power at the trade-off of film speed similar to that accomplished with B&W aerial film products.

Throughout the decade of the 1960s, several color film advancements took place. In 1964, Kodak introduced the first color acquisition film: Kodak Aerial Color Film SO-121, a high definition Ektachrome Aero product on 2.5 mil ESTAR base. This film had a speed, expressed in Aerial Exposure Index (AEI), of six and a resolving power of 160 lines/mm. Over the course of approximately five years, Kodak improved upon both film speed and resolution. In 1969, they introduced a high definition improved version of SO-121 as SO-242 with an AEI of two and resolving power of 200 lines/mm. Customer photographic interpreters experimented with matching these color films with B&W images, producing stereo pairs of imagery in order to obtain a mix of the higher resolution B&W image with the multi-spectral identity enhancement of the color image.

Color Pre-splice

During pre-splice operations, workers metered and separated the different types of black & white and color films, splicing them onto separate take-up rolls or dollies. This increased efficiency by enabling managers to schedule the resources needed for processing in the appropriate machines with the proper processing chemistry. After they separated the color film portion of any payload from the B&W portion at Pre-Splice, they placed it in lightproof containers and sent it to Kodak's Lincoln Plant facility where other workers accomplished the steps of processing and duplicating of the film.

Color Acquisition Film Processing

Color acquisition film processing followed a certain methodology to achieve its results. Prior to receipt of the color acquisition film, a QC team determined the processing specification for the particular color film. This step included arranging the chemistry and the mechanical configuration of the processing machine for both the acquisition film and the duplication film. Color film processes required slightly more seasoning (the processing of film to stabilize the chemistry) than B&W film processes. Color film processes also required higher chemical concentration replenishment rates due to the greater oxidation potential of color chemicals as compared to the B&W chemicals. During this operational phase, technicians in this department also determined the initial printer settings in order to minimize lead-time once the time-critical mission arrived.

Upon the acquisition of the films, technicians conducted the film processing in a deep-tank sinusoidal-path machine called the Grafton, an apparatus assembled from spare components unearthed at Kodak Park—an innovation similar to the assembly of early B&W film processors. Within this apparatus, they used Ektachrome motion picture chemistry ME-4, modified to obtain a variable contrast throughout the tonal scale along with enhanced edge sharpness. The complexity of the multilayered color film eliminated many of the process control methodologies available for B&W processing. Technicians also employed a chemical pre-hardener stage in the processing sequence to condition the relatively soft color emulsion, thus enabling the film to survive the numerous rollers in the processing machine.

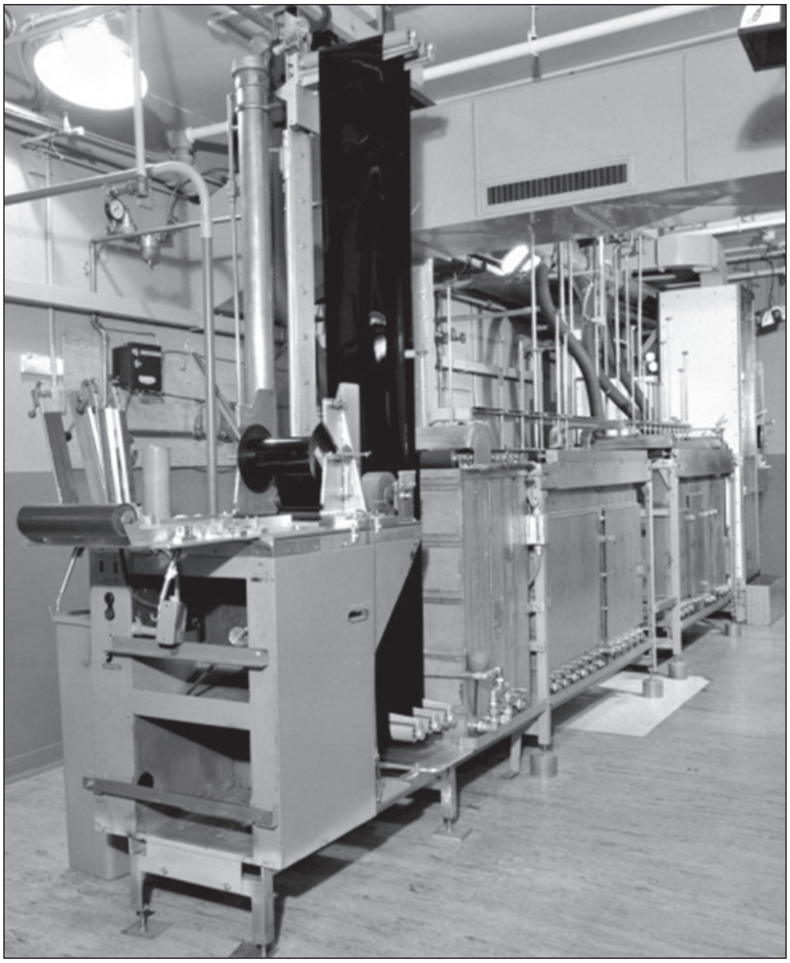


Figure 21: Grafton Color Film Processor. Photo from archives of Bridgehead's Special Programs unit.

As noted in the previous chapter, the Bridgehead facility and its workforce included its customer base within its facilities. Immediately after the processing of the original positive (OP), a team of several customers from the photo interpretation community inspected it for targets of interest. In the Gambit and Hexagon program, this customer base included contractor representatives. These customer representatives worked to identify the need for additional copies beyond the base number of copies required, which indicated special targets that required custom duplicates and enlargement briefing prints for the exploitation community. For this purpose, briefing boards consisted of paper or transparency enlargements, up to 40X, produced on the Kodak 10-20-40X-Enlarger. Later in the program, a breadboard Beacon Precision Enlarger (BPE) enabled production of high quality enlargements, up to 153X, from an input target area of 0.5 to 3.7-in. in diameter and an output area of up to 40 x 40-in.

Color Dry Operations and Duplication

The steps in the production cycle for color film were similar to those followed for black & white films. These steps included a Primary Inspection procedure that carefully inspected the color OP for any physical defects and "camera frame mark data." In the Primary Breakdown procedure, the Bridgehead workforce prepared titling information, which consisted of the proper frame number, frame marks, and orbital revolution number, and later transferred the information to the OP via pigment transfer tape on the Kodak Dual Head Titler. They spliced leader and trailer segments of clear film onto the OP and placed it into labeled containers. They separated Hexagon and Gambit rolls according to geographic area. The customer provided direction as to the duplication requirements, indicating the geographic area and number of copies requested by various users. They conducted a Secondary Breakdown procedure and densitometrically analyzed each can of OP. At that point, they added a "patch" segment of film to each can for Quality Control purposes. Finally, they cleaned the OP rolls prior to printing.

Color Printing

Bridgehead operators accomplished the printing on specially designed roll contact printers. They first used the Niagara Printer, a printer with its single mercury lamp, similar to a B&W printer, but with a color modification kit. The kit consisted of a tri-color drawer, which adjusted the color balance and intensity of the Red, Green, and Blue (RGB) filter strips by laying neutral density filters over the respective red, green, and blue color filter segments. Later in the program, Bridgehead engineers introduced a printer designed specifically for color known as the Rainbow Printer. This machine possessed three lamps—each projecting through a red, green, or blue filter—with individual power supplies that allowed variations according to the need to adjust for proper color balance and exposure.

Other advancements included achieving color positive duplicates using Ektachrome Color Duplicating Film, SO-360—a reversal film that produced a positive duplicate in one generation. They processed the SO-360 in the Grafton processor and used modified Ektachrome-type chemistry, similar to that used for the acquisition film. The technicians took densitometric measurements of the OP to establish initial printer settings for each roll, and they created a pilot duplicate print to determine the final color balance and density for each roll of OP.

Toward the end of the Corona program, and throughout the Gambit and Hexagon programs, the Bridgehead team conducted testing using a color duplicating film consisting of the acquisition emulsion on a 4-mil base. The inherently high contrast of an acquisition emulsion necessitated the need for a means to reduce the total system contrast of this product. They incorporated the technique of pre-flashing the film prior to printing, which reduced the contrast to that required for duplication. Pre-flashing, a procedure developed in Kodak's commercial printing labs, consisted of subjecting the color dupe film to uniform, balanced light exposure over the entire roll of duplicate film stock prior to printing. This technique resulted in a duplicate film with the greater resolution characteristic of an acquisition film but with an acceptable total system contrast and tonal range. It also resulted in duplicate copies superior to those produced with the conventional color duplication films.

Chapter 6

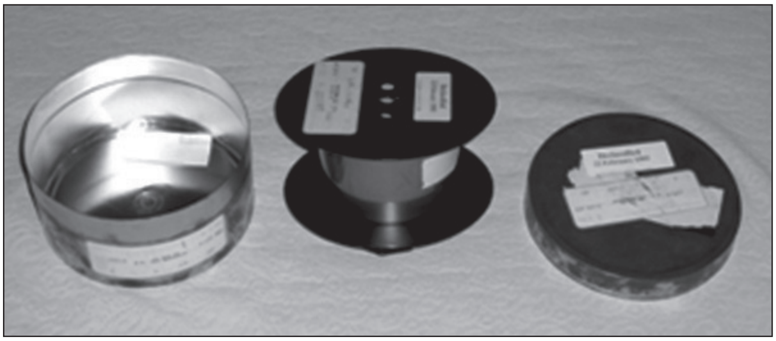
MISSION RELATED FUNCTIONS, EQUIPMENT ENGINEERING & CONTRACTUAL STRUCTURES

Shipping Office

In the realm of classified information and the handling of documents, every role player in the operation's chain was vital to ensuring national security. In order to prevent the compromise of sensitive information and its falling into the wrong hands, the Bridgehead team took no task or issue lightly. The Production Shipping Office stringently followed a set of procedures to ensure not only the efficiency of their role in product handling and delivery, but also, and most critically, the security of the classified cargo. They served to coordinate shipping requirements as specified by the customer to Production Operations and prepared the finished products for shipment.

Prior to mission arrival, Corona operatives sent a secure message to Bridgehead detailing which customers would be receiving specific products and quantities by geographic area. They generated a mission requirements letter describing these requirements, the number of copies, the copy numbers and the priority for completion. Considering the very large number of copies generated and the absence of computerized production control systems, the PSO undertook a major task to ensure the correctness of all shipments.

Figure 22: Typical 259-ft. MS 26565 Aerial Film Spool with storage can and cover. Photo courtesy D. Schoessler.



The finished product consisted of 250-ft. lengths of processed film wound on five-inch diameter MS 26565 Aerial Film Spools comprised of sturdy metal cores and flanges. The PSO workers followed a time tested and proven systematic approach to handle this cargo. They packaged each roll in a durable metal storage can that securely held the spool. In turn, they sealed each can with an industrial-strength adhesive tape, placed it in a close-fitting corrugated cardboard box and secured it with tape. Finally, they packed these boxes in heavy-duty corrugated cardboard cartons—six 9 ½-in. rolls to a carton or twenty-four 70mm rolls to a carton. The workers methodically taped the cartons shut, labeled them for the addressee, and wrapped a protective band around each one. They then assembled the cartons by priority. PSO utilized a color-coded address system, devised for identifying customers receiving film shipments. The PSO procurement specialists obtained Avery Easy Peel Labels, in every color available, and designated each customer by a unique color or unique color combination. The workers attached these labels (without inscription) to each film carton, and the labels served as the only indicators of a carton's delivery address—only personnel who had access to the color code designator could identify the recipients of these shipments.

As the shipment priority neared completion, Bridgehead representatives notified the customer, and the USAF dispatched a military aircraft to the Rochester International Airport to pick up the delivery. Bridgehead workers loaded the cartons of processed film on the same nondescript truck that had earlier picked up the RV, and took them to the Rochester airport. There, they transferred the cartons to the aircraft at Bravo Pad, and USAF crews flew them to Andrews AFB for distribution to customers. The National Photographic Interpretation Center in Washington, DC received the first priority shipment. Lower priority shipments that did not make the first-priority flight shipped on a later military aircraft sent specifically for that purpose. Typical shipments, resulting from processing and reproducing a single Corona mission, totaled a few tons.

Figure 23: Bridgehead Shipping Room.
Photo from archives of Bridgehead's Special Programs unit.

Bridgehead returned empty Corona Recovery Vehicles to their shipping containers, trucked them to the Rochester Airport, and sent them via military aircraft back to General Electric Company in Valley Forge, PA. Corona operatives also assigned Bridgehead a color code and marked all the "B Boxes" awaiting packing with camera film loads with the Bridgehead color code. Before reusing these containers for return shipments, they removed the Bridgehead label and applied the new one. The applied labels adhered extremely well to the metal boxes; thus someone had the difficult task of removing them with an electric drill and rotary wire brush!

The Shipping Office procedures and protocols were similar for the Gambit and Hexagon missions. With the Hexagon missions, the volume of films prepared, packaged, and shipped was significantly higher due to the larger film loads per Recovery Vehicle.

Production Control Group

The evolution and modernization of equipment and techniques affected various support departments in Bridgehead's operations over time. The Production Control Group (PCG) operations symbolized the arrival of technological advancements similar to many businesses on the threshold of the computer era. Workers adapted to computer technologies as replacements for more labor-intensive paperwork systems became available. The PCG operated Production Control and provided the work order preparation, in-process tracking, and order-fulfillment documentation necessary to meet customer timelines. The group used a hardcopy order system to specify the number and type of duplicate copies to make from each roll of original negative. Upon approval of the printer settings for a roll, they prepared and sent individual "print ticket" work-orders for each additional copy to the print room. PCG tracked the status of each print ticket manually on a special status board in the Duplicate Inspection work area. As they completed each roll, they signed off on the print ticket and updated the status board. Toward the end of the program, computer-readable punch cards replaced print tickets, and the department automated the monitoring and label printing steps.

Quality Control

As an effective business that guaranteed a valuable, quality product to its customers, the Bridgehead operation included a team assigned to monitor process variables and the meeting of quality standards. Quality Control established and maintained all standards for all film classification, processing equipment, reproduction equipment, instrumentation, and chemical processing solutions used in production. Responsibilities included certifying and monitoring all processors and reproduction equipment, inspections of original films, densitometric data collection, print exposure predictions, "first copy" certifications, and end-to-end sensitometric control of the production streams. Each production stream had components certified to common sensitometric aims, which allowed the printing of rolls on any printer and processed on any processor designated for that specific tone reproduction system. This procedure allowed for very efficient use of resources.

Micro-Densitometry

Bridgehead technicians used micro-densitometry as another tool to study and manage the image quality of the system. The microdensitometer utilized an extremely small spot size, typically a one micron slit aperture. This aperture size made possible the accurate reading of edge profiles and resolution targets for evaluation of as-taken imagery, as-processed imagery, and as-printed imagery, allowing evaluation and analysis of image quality at critical steps in the development of new processes and operationally in the acquisition and ground reproduction cycle.

The technicians accomplished micro-densitometry off-line using a scanning microdensitometer. With this equipment, it allowed orientation of imagery to the scan for the independent measurement of either longitudinal or lateral resolution. The technique allowed evaluation of resolutions up to 1,000 lines per millimeter, making it possible to evaluate proposed changes or improvements to the acquisition and ground processing operations. High resolution was essential, not only to evaluate the quality of duplicate copies, but especially for obtaining the quality of duplicate enlargements. When the enlargement capability for creating briefing boards went from 10X to 150X, extremely high image quality was essential to guarantee acceptable results.

Production Staffing

The Bridgehead production operations encompassed all aspects of handling, processing, duplicating, and shipping film products to the customer. It included core Production Operations, Quality Control, Maintenance, Chemical Control, Environmental Control, and the Production Shipping Office. Additionally, Security and Administrative Services supported these groups.

In the early days of the U-2 program, the core production operation was comprised of approximately 50 highly trained operators, technicians, and engineers. In the 1960s, as the Corona program came on-line and the scope of production support became better defined, staffing grew to 100-130 personnel. Their responsibilities included equipment operations, maintenance, integration of new technologies and improved processes, and preparations for the next Corona mission arrival.

When a mission arrived at Bridgehead, all production personnel worked twelve-hour days with operations on two shifts to provide 24-hours/day production operations for the duration of the mission. This routine lasted between two to four weeks depending on the frequency of missions. During peak production periods, another 30-40 personnel, who normally held other jobs within the Special Programs Bridgehead organization and specially trained in one or more areas of production, supplemented the core group to meet production timelines. By 1975, the total complement of all Bridgehead operations and support reached its highest level of 535 personnel.

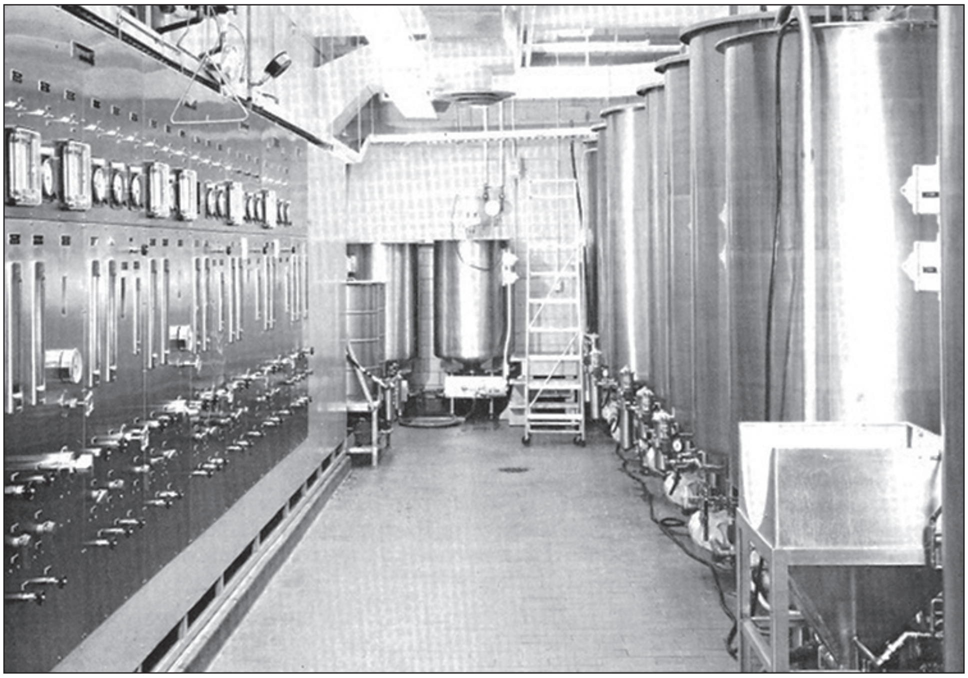
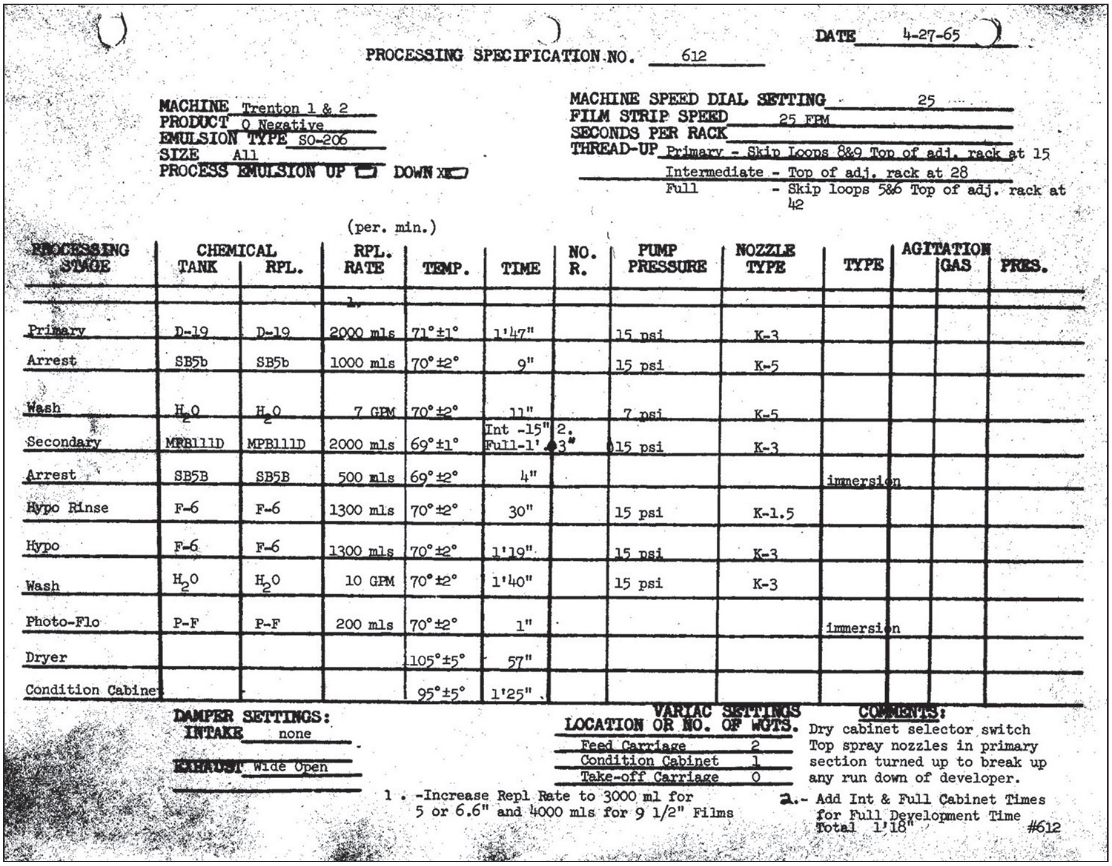


Figure 24: Bridgehead B&W Chemical Mix and Storage Room
with Distribution and Replenishment Panels at Left.
Ground Handling Equipment for Reconnaissance/
Aerial Photography Fact Sheet, July 1977,
produced by Bridgehead's Special Programs unit.

Processing Chemicals: Mixing and Certification

Workers with a range of abilities, talents, and educational backgrounds comprised the stable workforce at Bridgehead, including chemists and others trained in chemical sciences. The Bridgehead projects used chemical solutions for processing and finishing the original films and for duplicating films based upon Kodak formulations. Technicians prepared the solutions from raw chemical components in a large mix room specially designed to handle preparation, storage, and supply of these chemicals to the processors. Several days before receipt of each mission RV, technicians mixed chemical solutions such as developers and fixers, as well as auxiliary chemical solutions in the case of color chemistry, in their respective high-volume tanks and certified them.



PROCESSING SPECIFICATION NO. 612

DATE 4-27-65

MACHINE Trenton 1 & 2
PRODUCT O Negative
EMULSION TYPE SO-206
SIZE All
PROCESS EMULSION UP ☐ DOWN X☐

MACHINE SPEED DIAL SETTING 25
FILM STRIP SPEED 25 FPM
SECONDS PER RACK
THREAD-UP Primary - Skip Loops 8&9 Top of adj. rack at 15
Intermediate - Top of adj. rack at 28
Full - Skip loops 5&6 Top of adj. rack at 42

PROCESSING STAGE	CHEMICAL TANK	CHEMICAL RPL.	RPL. RATE (per. min.)	TEMP.	TIME	NO. R.	PUMP PRESSURE	NOZZLE TYPE	AGITATION TYPE	AGITATION GAS	AGITATION PRES.
			1.								
Primary	D-19	D-19	2000 mls	71°±1°	1'47"		15 psi	K-3			
Arrest	SB5b	SB5b	1000 mls	70°±2°	9"		15 psi	K-5			
Wash	H_2O	H_2O	7 GPM	70°±2°	11"		7 psi	K-5			
Secondary	MPB111D	MPB111D	2000 mls	69°±1°	Int -15" Full-1'3"	2.	15 psi	K-3			
Arrest	SB5B	SB5B	500 mls	69°±2°	4"				immersion		
Hypo Rinse	F-6	F-6	1300 mls	70°±2°	30"		15 psi	K-1.5			
Hypo	F-6	F-6	1300 mls	70°±2°	1'19"		15 psi	K-3			
Wash	H_2O	H_2O	10 GPM	70°±2°	1'40"		15 psi	K-3			
Photo-Flo	P-F	P-F	200 mls	70°±2°	1"				immersion		
Dryer				105°±5°	57"						
Condition Cabinet				95°±5°	1'25"						

DAMPER SETTINGS:
INTAKE none
EXHAUST Wide Open

VARIAC SETTINGS

LOCATION	OR NO. OF WGTS.
Feed Carriage	2
Condition Cabinet	1
Take-off Carriage	0

COMMENTS:
Dry cabinet selector switch
Top spray nozzles in primary section turned up to break up any run down of developer.

1. -Increase Repl Rate to 3000 ml for 5 or 6.6" and 4000 mls for 9 1/2" Films

2.- Add Int & Full Cabinet Times for Full Development Time
Total 1'18"

#612

Figure 25: Processing Specification Sheet for SO-206 on the Trenton Processors.
From archives of Bridgehead's Special Programs unit.

Testing consisted of processing a few hundred feet of film, similar to that used for the mission, along with three sensitometric strips on both the head and tail portion of the test run. They read the sensitometric strips on a densitometer, plotted the readings to produce a sensitometric curve; the Hurter and Driffield (H&D) curve (plot of density vs. exposure or D-Log E Curve) and compared it to the master curve on a specification sheet. Each film type and chemistry combination had a previously designated Processing Specification Sheet developed by QC personnel, which they based on extensive testing and evaluations months in advance of the mission receipt. They repeated this photographic testing until the test strips matched the respective specifications within established tolerances. The personnel repeated this certification the day before mission arrival and again before they committed the mission acquisition film for actual processing.

In addition to the sensitometric certification, several hundred feet of uniformly exposed film were processed and analyzed to verify processing uniformity. Moreover, they processed several hundred feet of uniformly exposed (flashed) film in order to determine that they achieved chemical equilibrium with the respective chemical replenishment rates utilized for the specific product/process combination—a procedure known as "chemical seasoning." After the QC technicians sensitometrically certified the film processor, and it was chemically seasoned, it was capable of processing thousands of feet of film with a high degree of sensitometric stability. The need for seasoning the processor was not required with later B&W viscous development. Technicians tested the individual chemical components of the processing solutions by chemical analyses of each critical component and compared results to the designated Chemical Mix Formulation Sheet, in order to certify the mix.

Duplicate Film Classification, Identification Strip Preparation, and other Pre-Mission Preparations

The mission always required advance preparation for the inevitable upswing when a successful satellite mission reached completion. Two examples of ongoing work included identification strip preparation and the duplicate film department responsibilities. Bridgehead workers prepared "idents" (short for identification strips) before receipt of a mission using information supplied by the customer. They exposed fixed-field information on filmstrips, processed in advance, and retained for attachment to individual sections of the ON, such that the total length of each roll did not exceed 250-ft. They manually added information unique to each film roll to the idents. Eventually, as the era of computers dawned, Special Programs engineers designed and built an "Ident Printer" that automated much of this task.

An outsider could also witness the continued flurry of activity in the duplicate film department. The Bridgehead team built up inventories of duplication films in the intervals between missions. They sampled and evaluated films for sensitometric characteristics and grouped them into similar classes for sensitivity, and then stored them in a stable 40 degree F. controlled environment. These steps allowed production to minimize variation in the reproduction processes.

Maintenance

Special Programs created a dedicated group of approximately twenty individuals who took responsibility for maintaining the unique film processing equipment used in operations at both Hawkeye and Lincoln Plant. These personnel possessed the advantage of working closely with Design and Engineering personnel who, in addition to having designed much of the equipment, had overseen its fabrication, installation, and checkout.

The Maintenance Group specialized in areas such as chemical mixing, tempering, recirculation, and solution delivery systems, including viscous developer handling systems. During the round-the-clock mission operations, maintenance personnel provided continuous support. In addition to equipment maintenance, Kodak's workforce included the Facilities & Maintenance Organization, which handled building maintenance and facility-type installations using individuals cleared to enter secure Bridgehead areas.

Figure 26: Bridgehead Maintenance Shop.
Photo from archives of Bridgehead's Special Programs unit.

Utilities and Waste By-products

Electrical Power—Early in the plan for the Hawkeye Plant, Kodak obtained an agreement with the local electrical power supplier (Rochester Gas and Electric Corp.) to provide a direct feed of preferred power from a local generating plant. Because of the high level of importance to the Bridgehead mission, they dedicated the preferred power feed for operating ON processors and their supporting equipment.

Water—Because of the sheer size of the photographic processing facility, Bridgehead used substantial amounts of water for preparing chemical processing solutions, cleanup of wet areas, and temperature control of processing solutions in processors. Water needed for temperature control came from a tempered, closed-loop water supply in the Hawkeye facility where equipment continuously re-circulated and reused the controlling water. By design, this process promoted water conservation and greatly reduced processing effluent and a potential security issue.

Exhaust Systems–A number of pieces of equipment used at Bridgehead required exhaust systems to handle excess heat, chemical vapors, and chemical dust. Technicians installed and operated all exhaust systems in accordance with evolving EPA standards while avoiding any security issues.

Wastewater Treatment Plant: Effluent Handling and Certification

From the early days of the processing and reproduction activity, right through the active period of Corona and beyond, Bridgehead managers always paid attention to the effluent the plant generated. The attention it received grew as the program expanded. They consistently evaluated three aspects, and a primary concern was security. This received utmost attention with the possibility that local routine testing by government agencies might identify the existence of a large photo-processing lab. Secondly, they routinely addressed the valuable discharges of silver, a common practice for any state-of-the-art photo lab. They applied unsophisticated methods (ion exchange) for recovering a good percentage of the silver headed for the waste stream. Lastly, Kodak invested heavily in reducing the pollutants in its waste stream, and the program actively stayed informed of available improvements. This investment was in response to a growing national awareness about damage to the environment caused by the manufacturing and service industries.

In the 1950s and early 1960s, when nationwide attention to pollution in public streams was in its infancy, Kodak undertook no major photo lab initiative at Lincoln Plant to address effluent treatment. Volumes at the photo lab had not experienced a substantial increase at that time. Unlike a relatively large electroplating laboratory at Lincoln supporting an unclassified project that was tested for the cyanide waste it was producing, the photo lab volumes did not attract attention.

It was not until the primary processing activity experienced a major increase and moved to Hawkeye that the effluent stream received substantially more attention—primarily because of the security issue. Bridgehead staff solved the problem through simple, but effective, technology. They collected the "bad actors" from the waste stream in holding tanks and transported them to Kodak Park in a program-leased tank truck. There, they deposited them in existing large treatment systems, thus making the volumes from Hawkeye insignificant in Kodak Park's total effluent treatment system.

Effluent Management

One example of Kodak's industrial and environmental contributions addressed the issue of silver in the waste stream. The recovery of metallic silver from processing solutions (fixer) had a dual purpose. Foremost, Bridgehead needed to keep silver, an undesirable component of the effluent, from becoming a security flag indicating photographic processing. Secondly, the government realized cost savings from the sale of the recovered silver through secure channels.

Kodak, in its commercial processing laboratories, had long established efficient electrolytic systems that utilized a series of alternating anode and cathode plates. This system, attached to a DC power supply, resembled the interior of a large automobile battery. Named "Hickman Cells" (named after the design engineer), it operated by continuously circulating the collected fixer solution throughout the cells or plates. Technicians recovered silver from solution by placing it on a cathode, and a controlled direct current passed between two electrodes suspended in the silver-bearing solution. This electrolytic system possessed the advantage of depositing the metal on the cathode in the form of nearly pure silver. Technicians periodically removed the cathode and chipped off the silver. This procedure resulted in lower refining costs and reduced shipping bulk. It produced no contamination to the fixer because of the filtering process, thereby permitting its reuse and a total reduction of chemicals.

From this basic technology, Bridgehead designed electrolytic silver recovery systems, adapting commercially available equipment (such as cylindrical "Silver Towers") that enabled the configuration to treat the fixer from the larger black & white and color processing systems.

On the smaller processors, such as the Roller Transport machines used for Briefing Boards and other testing support, they recovered silver from the effluent by use of metallic replacement cartridges. These systems integrated the use of the Kodak commercial Silver Recovery Units, which incorporated a plastic lined steel drum filled with steel wool connected to the processors via plastic hose. The mechanism recovered the metal when the silver-laden solution flowed through the cartridge and made contact with the steel wool. The iron went into solution as an ion, and the system released metallic silver as a solid to collect in the bottom of the cartridge or on the steel wool. When it no longer effectively removed the silver, the technicians exchanged the cartridges for new units.

Figure 27: Analytical Chemical Lab which monitored photo lab effluent content.
Photo from archives of Bridgehead's Special Programs unit.

In the mid to late 1960s, as the management team modified the role of Lincoln Plant to address color processing and reproduction, they gave increased priority to effluent management in that facility. As noted previously, and of particular concern, they addressed the presence of cyanide compounds by installing regeneration systems for bleach chemicals to keep contaminants leaving the facility to values approaching zero. Bridgehead undertook a major effort to develop effluent treatment systems for use in other government locations. In addition to the remarkable innovations Bridgehead workers contributed to space technology, they also contributed toward the betterment of planet Earth and its increasingly industrialized economy.

A second contribution that Kodak made to industrial operations and environmental stewardship included bleach regeneration. The color film (Ektachrome Type) processing chemicals used a bleach solution containing potassium ferricyanide. Since effluent codes restricted cyanide compounds, Bridgehead removed all measurable traces of these compounds in any effluent that might be inadvertently discharged from both the Lincoln Plant and the Bridgehead facility. In this case, they chemically reconstituted the bleach solution, which allowed its reuse multiple times. Bridgehead chemists accomplished this task by frequent analysis of bleach components (pH, specific gravity, ferricyanide, and ferrocyanide). When they reached established levels, they diverted the bleach solution for chemical treatment.

The chemists accomplished regeneration by adding a strong oxidizing agent (persulfate), which converted the ferrocyanide back to ferricyanide, rendering the bleach usable. They conducted this regeneration procedure approximately twelve times before the increased specific gravity of the bleach delayed bleaching time. This limitation led to longer bleaching time in the processor than could be accommodated. During that era, Kodak applied a precipitation technique to remove the ferrocyanide and then securely transported the sludge to a hazardous waste facility. In this manner, Bridgehead processes reduced the chemical effluent, recovered the silver, and kept the bleach from the effluent, thus lowering the security risk for photographic processing operations.

The Bug Farm: Rotating Biological Contactors

One of the more exceptional methods to address the waste stream issues seemed like something out of a science fiction novel. The "Bug Farm" was a research study that addressed the control of toxicity and signature of the liquid effluent of government photo labs. The Waste Treatment Facility personnel at the Eastman Kodak Company succeeded in activating a biological colony that lived and survived on liquid color film photographic waste. This colony of microbes fed on this photographic effluent converting it to sludge and water. For several years, Kodak operated a 20,000 gallon activated sludge facility using the liquid waste from its color photographic operations, clearly demonstrating the feasibility of this technology. Unfortunately, the size and configuration of this system was unacceptable for customer applications. The resultant issue became, "could this technology be incorporated into another compact configuration and still be successful?"

To resolve the issue, Bridgehead assembled a small (100 sq. ft.) four-stage Rotating Biological Contactor (RBC) from 12-in. phonographic records. They seeded the record surfaces with sludge obtained from Kodak's activated sludge unit, and they fed the RBC unit photographic liquid waste from the Bridgehead processing facility. Within less than a week, slime accumulated on each stage, clearly demonstrating the feasibility of this technology for treating photographic waste and rendering it to sludge and water. To obtain engineering, sizing, and efficiency data, they built larger 1000 sq. ft. four-stage units. They operated and monitored these larger units to insure the reliability and effectiveness of RBC units. The process assured successful customer applications; the RBC-treated wastewater from Photographic Processing Operations rendered the liquid effluent entering the sewer as innocuous as plain water. They collected remaining sludge separately for incineration. Kodak marketed commercial Rotating Biological Contactors to other interested parties—sized and installed at some customer facilities using the data and "seeds" from these experiments. This technology enhanced the "cover" for classified photographic processing facilities.

Design & Engineering (D&E) Group: Development of Specialized Film-handling Equipment

To sustain production requirements for photo-finished film products, Bridgehead required a complement of highly specialized wet and dry equipment to realize several key capabilities: safely processing and handling irreplaceable ON film records; producing highest possible output quality on a sustained basis; accommodating evolving film and processing technology changes and improvement;

meeting critical man-machine interfaces, often in darkroom environments; incorporating new and emerging electro-optical-mechanical and data handling technologies for optimum performance and maximum reliability; and minimum downtime for cleaning and maintenance.

To create the kind of equipment outlined above, Kodak formed a Design and Engineering Group (D&E) within the Special Programs organization. At its peak, engineers, designers, technicians, writers, and other support personnel comprised the D&E Group. Located initially at Lincoln Plant and later at Hawkeye, D&E worked closely with Bridgehead production and support personnel to propose new equipment and equipment upgrades for production operations, while also developing and testing breadboard equipment aimed at evaluating new design concepts. For equipment documentation, they worked to create and maintain equipment operations manuals and generate engineering drawings of required equipment for manufacturers. To meet budgetary needs, they worked to estimate costs of engineering, manufacturing, installation, and testing of proposed production equipment and managed the manufacture and procurement of repeat equipment orders. For newly acquired equipment, they supported first-article manufacture, installation, test, and evaluation. They also generally trouble-shooted equipment problems when required. D&E also developed specialized photographic equipment for other government agencies when requested. Because the operation manufactured equipment only under special order, they combined orders whenever possible for minimum unit cost and passed savings on to customers.

The government never classified the specialized equipment that D&E developed for use in Bridgehead operations. Although designed in a classified facility, in a setting that allowed easy confirmation of designs and development as meeting operational needs, they manufactured the equipment in open shops from unclassified drawings. The government authorities only classified its final installation location. Bridgehead's Technical Assistance (TA) Group maintained an unclassified equipment catalog and made copies available to potential users throughout the covert reconnaissance community. This marketing tool frequently resulted in building multiple follow-on copies of equipment for multiple customers.

When having equipment manufactured, Special Programs placed contracts within Kodak and with outside companies that had the necessary fabrication expertise and the ability to manage large and small subcontracts. Under more than one subcontract, a facility in Madison, Wisconsin built and assembled Fultron Film Processors and associated chemical mix and storage tanks, which took advantage of stainless steel fabrication techniques developed while meeting the needs of the dairy industry. On another occasion, a subcontractor worked with Kodak Park's manufacturing shops in Rochester, NY to produce Victor Film Processors and associated chemical tanks. A Rochester, NY company that specialized in producing products for the aircraft industry manufactured several printers and printer components. Kodak's Special Programs also used the services of local shops, with proven quality manufacturing records, to manufacture other equipment items.

Contractual Structures and Funding Sources for Bridgehead Operations

In the late 1950s, successes and failures in competing systems under development led the reconnaissance community to conclude that Corona would become the major system for providing overhead reconnaissance well into the future. Program managers merged initial processing and reproduction support for Corona into the Lincoln Plant—its capability proven during its support to U-2 acquisitions. However, Corona's early success spotlighted the shortcomings of the Lincoln Plant photo lab capability. As previously discussed, Kodak constructed some of the existing negative processing and duplication equipment using discarded tanks, rollers, drive motors, etc., from Kodak

Park to support the U-2 program. Additionally, those in charge of acquisition needed improved data and information about all variables affecting the quality of the acquired images. The photo-interpretation community voiced concerns about the quality of delivered duplicates because of the loss of information during the image transfer from the original negative to the duplicate positives. Finally, the escalating cold war tensions substantially expanded requirements for the number of duplicate copies produced.

As discussed previously in this narrative, Kodak significantly invested in its film improvements and associated manufacturing equipment as a distinguished world leader in film technologies. However, with the burgeoning demand for space reconnaissance technologies, the program required increased capital from the community that managed all operational phases. Thus, during the 1961-62 timeframe, E. L. Green, Kodak's General Manager of the Photographic Operations Center, and representatives from the NRO and the CIA recognized that the success of Corona demanded improved film, film processing, and image reproduction technology. Consequently, the project needed a funding source to empower the expertise of Kodak's workforce to conduct R&D with these purposes of developing and testing new ground handling equipment concepts, developing improved photographic processes for special films, supporting the evaluation of evolving film products, and gathering empirical data to develop image acquisition models. The NRO provided a level of funding to underwrite this work under a contract designated EB-1492. A Contract Control Board (CCB) approved and monitored the R&D efforts. On a quarterly basis, the CCB met with Bridgehead management to assess progress and approve or disapprove proposed new initiatives. Three representatives comprised the Board, one each from the NRO, the CIA, and the Air Force, with the Air Force representative acting as Chairman. This mechanism effectively stayed in place for over two decades.

The Bridgehead workforce successfully demonstrated new concepts for production equipment using breadboards and then modified lab equipment and other customized apparatus. They moved these pieces of hardware quickly into the production operation—with enough safeguards to ensure safe handling of the film, process reliability, operator interface safety, and other facets of operation. They utilized these apparatus until the D&E team designed, manufactured, tested, installed, and brought on-line permanent production equipment. The NRO administered these functions under a hardware contract designated EG-400.

The EB-1492 and EG-400 contracts served as basic agreements to which they added new tasks when approved and agreed upon by the government customers (including supporting documentation and detailed estimates). An annually renegotiated Operations Contract, based primarily on the projected level of mission activity, funded Bridgehead production operations. Because of its annual nature, the contracts carried a variety of designations. The NRO also served as the funding source for the operations contract.

Other government agencies engaged in classified aspects of aerial photography occasionally secured NRO approval to have work performed and equipment provided as additional tasks to these three contracts. On other occasions, Bridgehead contracted directly with various government agencies to perform specific tasks where they had the needed expertise. They frequently won these contracts on a competitive basis.

Chapter 7

OTHER FACETS OF BRIDGEHEAD OPERATIONS

Cue Ball

Due to the Intelligence Community's strict security rules, employees working in a common organization were often very unaware of each other's activities and did not always require a need-to-know about each other's operations. Operation "Cue Ball" exemplified this particular security arrangement.

As aforementioned, the government's Lincoln Plant, approximately three miles west of Bridgehead, served as a site for the development of one of the world's finest optical cameras for the Gambit Program. Naturally, the performance of that camera system required evaluation using Kodak's compatible flight films. Those films needed to undergo processing using a standard, repeatable process like the one actual flight films would encounter in the future. It made perfect sense for the government to instruct the Gambit Program to use a readily available processing capability at Bridgehead to meet this need. However, due to rigid security standards, employees involved in coordinating film processing lacked the need-to-know of where the test films underwent exposure or where processing took place. Only a small percentage of employees in the Gambit and Bridgehead organizations were "cross-cleared"—meaning they had a "need-to-know" about both the Gambit camera operation and Bridgehead's role as a film processor. This covert operation retained its cover through a chain of events that entailed simple communications, a code word, and lock boxes.

When the Gambit camera function required processing of test films, a department worker made a phone call to a local courier and announced that, "A Cue Ball was required." The courier picked up a film package from a designated Gambit-secure box and delivered it to a Bridgehead-secure box. Under a shroud of secrecy that covered where the film came from, Bridgehead operators processed it and returned it to the mysterious Bridgehead-secure box. Using the same route in reverse, the courier returned it to the Gambit-secure box at Lincoln Plant. For the cross-cleared employees, it all made perfect sense. For the others who knew only half of the story and worked solely in one department or the other, it remained a mystery.

Interface Role to Allow Application of the Capabilities of Bridgehead in Government Field Labs

The overseas operational location of the U-2 program did not always facilitate returning the exposed negative film to Rochester. As a result, the IC occasionally tasked selected CIA or Department of Defense photo labs (primarily Air Force and Navy), and in some cases friendly foreign country photo labs, with performing either an initial level of film processing or handling a full complement of processing and reproduction functions. However, IC agencies realized that not all of the field or foreign country photo labs were capable or prepared to handle the processing and reproduction tasks without assistance. Because the newly formed Kodak group, headquartered in the Perfume Factory at Lincoln Plant in Rochester, possessed the personnel and expertise for performing these tasks, the

IC requested their on-site assistance to specific locations on either a routine or a crisis basis. Kodak provided technical assistance and continued a collaborative working relationship with national IC agencies. Assistance took the form of consultations, sharing of technical information, assistance with solving photo lab production issues, installation and checkout of equipment, training, and temporary production staffing. Work in these field facilities exposed the Kodak group to the operation and use of other manufacturers' materials, chemistry, and equipment, and they learned to integrate these objects into the overall facility operation.

To coordinate assistance to field operations, they officially formed the Technical Assistance Group (TA), comprised of approximately six engineers, technicians, and an administrator. They were a component of Kodak's Special Programs unit. Their responsibilities included responding to requests for photographic information from field facilities; coordinating selection of personnel for travel to field facilities and assisting with making travel arrangement; establishing a contact link with employees on assignment; and most importantly, ensuring the documentation of observations and problems related to field operations, informing appropriate in-house groups for consideration and follow-up.

Several examples of TA's help provided during the U-2 program's operational years included activities that expanded across both the eastern and western hemispheres. In Taiwan, starting in the 1950s and continuing for many years thereafter, Kodak engineers and technicians assisted with equipment installation, training, film processing, duplication, Quality Control procedures, and staffing assignments. In 1962, at the height of the Cuban Missile Crisis, the IC urgently needed evaluation of imagery from U-2 flights in Washington from film processed locally rather than in Florida. At customer request, Kodak personnel moved film processors, printers, chemicals, and other support equipment from wherever they could find them to the Naval Reconnaissance and Technical Support Station in Suitland, Maryland. They had the facility staffed and operating within 48 hours, and the operation lasted until the crisis passed. Another operation where Kodak provided the help of TA had a tragic ending. Three Kodak employees—Ted Simons, Dick Moyer, and Wayne Koehler—perished in a helicopter accident when leaving their location at the U.S. Naval Base in Subic Bay, the Philippines. Regardless, this type of assistance continued throughout the operational period of the U-2 program and beyond. Kodak customized this assistance to meet the needs at each installation.

Technical assistance activities intensified during the early 1960s with the advent of the Corona program. At that time, the NRO required that secure processing facilities at SPPF (Westover AFB), 548th Photo Lab in Hawaii, Strategic Air Command (SAC) at Offutt in Omaha, Defense Intelligence Agency (DIA) Fern Street, and others be equipped and readied for processing and reproduction work should they be needed for distribution of duplicate copies of film imagery. This mission goal involved Bridgehead operations with the development and manufacture of photo processing, printing, viewing, and other support equipment under government contract. As this equipment became available for field use, the aforementioned facilities needed assistance with on-site installations, checkout, and training.

Additionally, other worldwide Air Force photographic facilities that had access to classified imagery needed assistance with reproduction and enlarging to meet local command requirements. Some of these Air Force Bases included Beal (California), Anderson (Guam), Wiesbaden (Germany), and Clark (Philippines). These bases welcomed the assistance in support of either local reconnaissance missions or special projects involving the U-2 aircraft. To assess the photographic-related assistance needs at these facilities, the TA group at Bridgehead coordinated and received approval from the NRO and Air Force to make routine visits to either provide on-site assistance or return with requests that required follow-up action. The traveling group normally consisted of engineers from the QC and D&E departments, along with a Maintenance and Installation Technician and one member from the

TA group. They debriefed the customer on return about any issues of importance, addressed issues identified during a facility visit, and answered directly to that facility.

In general, Bridgehead's customers funded the development of state-of-the-art photographic reconnaissance ground handling equipment and purchased selected items for installation at these strategic facilities. The TA group also functioned to maintain a catalog that described all of this special equipment. They maintained updated copies of this catalog in all government and military facilities involved in reconnaissance photography, thus spinning off developed technology to the IC at large. Because of the customization of this non-commercially available equipment, Bridgehead collaborated with potential buyers in an attempt to combine orders and minimize unit costs.

Kodak's TA program relied on proven customer service concepts. They based the program on the idea of good communication between all parties involved in a project and the willingness to discuss and resolve issues to the mutual benefit of all concerned. When it came to the relationship between a customer and a contractor, the concept worked with the support from the higher levels of management on both levels. That support endured throughout the above programs and mutually benefitted all parties.

Supporting Operations for Bridgehead: Westover Air Force Base

Early in the programs, the U.S. Government recognized the Corona and Gambit systems as the future primary sources of high altitude photo acquisitions and designated Kodak as the primary processing and reproduction center for retrieved payloads. However, they also recognized the possible vulnerability to the IC without a back-up processing and reproduction capability. To address this shortcoming, they designated the Special Projects Processing Facility (SPPF) at Westover Air Force Base near Springfield, MA as the back-up facility, and took actions to make that facility viable. They possessed no intent to mirror the entire capability of Bridgehead, but rather to have in place the ability to download an RV, process the B&W original negatives, prepare initial duplicate positives, and readily satisfy the high priority requirements of the using community. As the equipment came on-line, they planned and accomplished practice events. To make these simulated efforts as real as possible, Bridgehead prepared exposed "dummy" payloads and provided some initial training to workers at the Westover facility. Following these practice events, Bridgehead supported all follow-on efforts requested by SPPF where they needed hardware modifications or additional training. This collaborative effort provided greater assurance of a seamless mission, which in turn, alleviated CIA and NPIC concerns by having a viable backup capability in place.

Chapter 8

RESEARCH & ANALYSIS CONTRIBUTIONS

Another operational layer to the Bridgehead workforce included fulfilling roles to collect, research, test, and analyze data about films and the interface between camera performance and film capabilities. The "Red Dot" project exemplified another component of this remarkable era as it engaged Bridgehead researchers in field tests of camera equipment. From the East Coast to the West Coast, Bridgehead workers also provided labor to the "Red Dot" project. This project provided scientific modeling and analysis of the atmosphere to assist entities in charge of camera setting and image acquisition decisions. On another front, initiated in the late 1960s, the Film Evaluation And Test Laboratory (FEAT Lab) served as a testing service for the entire intelligence surveillance community to provide basic film and processing data. This laboratory served as a resource to evaluate the viability of aerial films for use in government photographic programs.

Moreover, Bridgehead scientists collaborated with Cornell University and its remote sensing program by researching, developing, and providing film technologies for geographical, environmental, and civil engineering applications. They further supported the security of the United States in an economic sense. One of their special projects aided in curtailing counterfeit currency operations through the research study of exemplars.

Red Dot Project[2]

Project Red Dot worked as an ongoing program to model the atmosphere to assist those responsible for camera settings and acquisition decisions. The Red Dot project functioned as a small part of a government-contracted cold war effort to gather photographic intelligence in denied areas in the days of the Cold War. The NRO and the USAF sponsored the Bridgehead Program, and in turn, the Red Dot project, to assist in the overall program of collecting and interpreting photographic intelligence from U-2 and space platforms. The Red Dot effort to optimize image quality played a small part in the overall success of these intelligence missions.

In the beginning of the reconnaissance programs of the early 1960s, the IC recognized that beyond the formidable engineering challenges associated with successfully building, launching, and recovering extreme high altitude aircraft and space-borne camera imagery, a number of additional challenges surrounding photo quality directly affected the usefulness of the product. With low polar orbits that characterized these types of space missions, photographic exposure and tone scale variations were extraordinarily large and mostly uncontrollable. Every 90 minutes, the spacecraft entered and exited the earth's solar limb. In between these times, the camera encountered illumination and atmospheric conditions that ranged from bright illuminated scenes under the clearest possible conditions to poor visibility conditions with dark and low contrast. These extremes taxed any photographic system, ground-based or otherwise, with only one chance to get it right.

2 Entire "Red Dot" section authored by Larry Christensen (Retired Kodak Engineer)

In the case of the U-2, Corona, and the follow-on Gambit and Hexagon systems, "getting it right," meant understanding and correcting imaging through changing atmospheres, from daybreak to high noon. In part, the technologies accomplished this feat in the processing and duplication phases of film imaging; but "really get it right" meant they needed to correctly setup cameras in the first place. Early on in this task, major engineering issues included simply selecting proper atmospheric "haze"[3] filtration and setting camera exposure time. Red Dot contributed toward resolving this task.

Bridgehead managers assigned a small team of Bridgehead engineers and technicians, in concert with the team leader for the prime camera contractor, ITEK, the task of figuring out the details of setting up the optimum camera/film system for exposure and haze filtration. The goal was to optimize the delivered image contrast and resolution while minimizing ground-based "on-the-fly" processing compensation for under or over exposure of the camera negatives. The further into the yellow-to-red part of the spectrum the team made the filtration for haze penetration, the more film speed was lost. Loss in film speed possessed the undesirable effect of under-exposure, or worse, image motion—a classical engineering tradeoff. Enough knowledge existed about how the atmosphere altered the scene brightness and contrast to realize that the program needed better mathematical computer models to plan and execute successful remote space missions. The earliest Red Dot testing effort set out to gather ground and aerial data on these two basic issues essentially using reconnaissance film as a light measuring instrument.

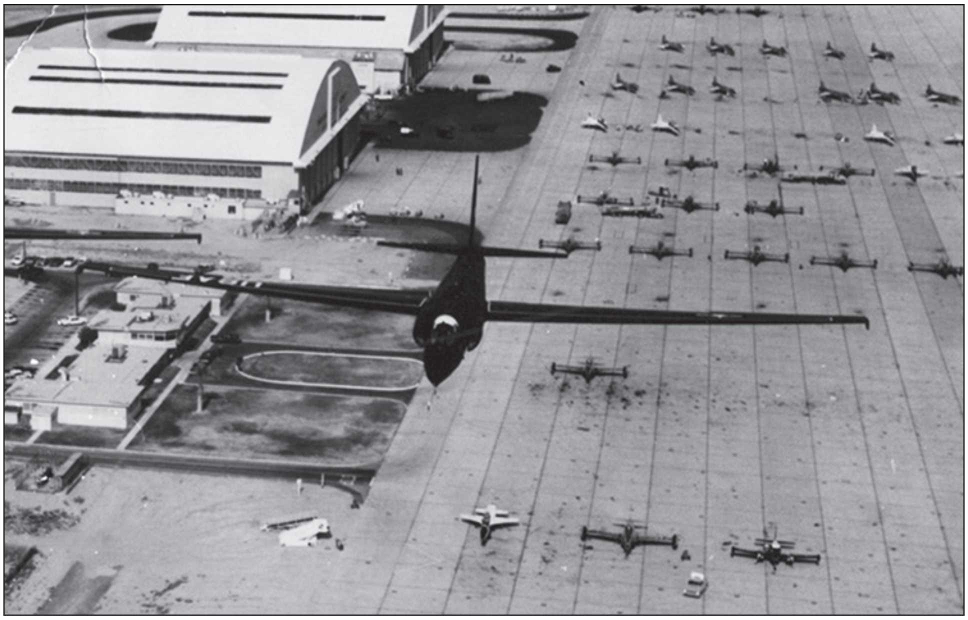


Figure 28: U-2 Aircraft Over Edwards AFB.
From the archives of Bridgehead's Red Dot Project.

The Red Dot group got its name from something as ordinary as red paper "stick-ons" for film cans and shipping containers. Everyone at Bridgehead instantly recognized the paper red dot as imagery belonging to the Red Dot group. The camera and film system served as a scientific data collection instrument. Extreme control over the film environment was necessary to maintain accurate calibration

3 The atmosphere is an optical medium that both attenuates the ground brightness and contrast of scenes and adds non-image light referred to as haze.

of the image plane brightness. Test films destined for ground and flight cameras, as well as witness samples, required freezing almost from the date of manufacture to the moment of processing in order that the "radiometer" (the camera film) remained unchanged in its D-LogE[4] characteristics.

Since the tests involved high altitude, the Air Force conducted flights in the California Mojave Desert, which necessitated packing of film shipments in dry ice (frozen carbon dioxide). The containers needed to possess an innocuous appearance to commercial shippers but recognizable to Bridgehead personnel as containing carefully calibrated film material. The Bridgehead team chose a simple red dot sticker to identify the containers to Bridgehead personnel and those responsible for the shipment handling. This plan seemed to work as intended, but one could only imagine aircraft and ground shipping personnel wondering about the boxes leaking a white fog reminiscent of a rock concert stage! Fortunately, this was long before the 9/11 terrorist attacks.

The most fundamental parameter in the camera/atmosphere imaging process was solar altitude.[5] In an engineering world dominated by twelve-inch slide rules, and before the invention of the digital calculator, one of Red Dot's more gifted members invented a very clever circular slide-rule for estimating solar altitude as a function of date and time of day. This device performed as a workhorse for the personnel as they planned flight tests and analyzed data.

Red Dot project computing power in those days consisted of two IBM 360 mainframes and a complement of mechanical calculators. Two experienced computer technicians programmed computers and ran the data analysis and model software. User engineers wrote most programs—life was a lot simpler then. The nixie-tube Wang, Kodak's first digital calculator, weighed about 20 pounds—portable in name only. The Bridgehead office celebrated the arrival of the first HP-35 hand-held calculator, purchased by one of our engineers. Today there is far more computing power in a cell phone than we had in total.

Known as "North Base" among informed participants, a remote installation on the grounds of Edwards Air Force Base, CA served as the center for the domestic U-2 program. The Air Force and the NRO directed the Red Dot team to conduct its earliest research tests using, at that time, the absolute state-of-the-art in high altitude vehicles and cameras. At an operational altitude of 14 miles, the line of sight to the ground looked through almost an entire one-atmosphere (the sky is nearly black above a U-2 pilot's head). The data derived from the U-2 flights was essentially identical to data possibly obtained from a space vehicle. The NRO and the Air Force provided remarkable resources to run the experiments. This engineering challenge occurred in an unusually stimulating place and time.

U-2 pilots took their role very seriously, even for research and training flights in their own backyard. Testing involved flight plans configured in a racetrack pattern (rather boring flying) with passes over the target range timed to changes in the sun's elevation above the horizon. Takeoff occurred at pre-dawn, and missions lasted four to six hours, short by U-2 standards. Many of the early tests used the "Delta configuration," a 24-inch focal length rotating optical bar, almost identical to the space-borne Corona system. However, because of stability and image scale concerns, the "Baker configuration" became the favorite onboard camera. The "Baker" employed two webs of 9½-inch reconnaissance film separated by a quarter-inch guide bar positioned at the image centerline. The adept pilots perfectly lined up their targets so that often the target array found itself directly in the film-less gap. This skill served well for flight qualification but did not benefit the research.

4 Density–Log Exposure curve. A sensitometric characteristic of the film/process system derived from the exposure to a calibrated multi-level gray scale.

5 Elevation of the sun above the local horizon.

Informally code-named the "Ground Truth-R-Us," the Red Dot program typically fielded a three or four member team, which positioned itself with the photographic and light measuring equipment on the flight path—in some unusual places—in the middle of the Mojave Desert. The team arrived to set up the gear before sunrise (with the temperature sometimes as low as 30˚F) at a target range consisting of a one-acre gray patch and other large resolution panels. While the U-2 flew its pattern overhead, the team monitored the ground level brightness of the target array. By noontime, the sun loomed high overhead and the temperature rose to about 90 ˚ F—making it difficult to dress appropriately. During the over-flight, the team was in constant motion reading instruments and taking simultaneous ground photography. Sweaty, dirty, and somewhat sunburned, they returned to North Base, retrieved the overhead imagery, and prepared the films and data for shipment back to Rochester. The team often processed the black & white film at the North Base photo lab. The pool at the Antelope Valley Inn (the favorite home-away-from-home) always looked good on those mission days.

Project flights always played a secondary role to higher priority training missions, and the weather, which needed to be clear, often did not cooperate. On those occasional stand-down days, the team often explored Mojave Desert attractions, the old western movie sets. Because of its proximity to Los Angeles, the desert surrounding Lancaster, California (the Red Dot team's home base) was a favorite location for many of the "shoot-em-up" westerns of the 1930s through the 1960s. Given some directions by the locals, the team could find its way to remote desert filming locations that retained their original character, which nearly replicated a western ghost town.

On mission days, the team could not attend the U-2 flight takeoff. Other times when other test flights progressed, they enjoyed the sight of a U-2 on takeoff from North Base—an amazing sight to see. With its huge glider-like wingspan and oversized engine, it took only a few hundred feet to become airborne and could practically climb vertically having almost as much thrust as weight. Covered in flat-black radar-absorbent paint, the U-2, with its unique climbing ability, disappeared from sight within seconds. Take-off watching and mission delays notwithstanding, the team eventually completed the test program and retrieved the valuable imagery for analysis at Bridgehead.

Mead Corporation of Dayton, Ohio managed all the ground target deployments for U-2 and satellite imaging under the moniker "Control Range Network," or commonly known as CORN targets. Deployment of huge ground-truth tri-bar resolution targets and gray scales required many hands, often in high wind conditions and over rough ground. Red Dot included contributions to the design and fabrication of several unique targets deployed by Mead, which included the slightly oversized "Mona Lisa." Mona was the very first log periodic target—about the size of half a football field, and about as heavy in this comparison with the sod included. A crew of Bridgehead personnel rented an empty building in Webster, N.Y. and spent the next several weeks painting the gray bar pattern on the canvas. Among hot dog and hamburger lunches, they completed and delivered the huge canvas to Mead. It was soon deployed for flight tests by some very determined and strong CORN personnel. This effort served as the very first attempt to directly measure total system optical performance in terms of Modulation Transfer Function (MTF)[6]. Although a bit unwieldy, it succeeded in this purpose.

Another foray into the experimental realm included the six-panel color targets used to calibrate color overhead photography. Bridgehead personnel gained expertise in the field of color interpretation and consequently developed a series of color panels of special reflective properties to augment the standard CORN gray scale. The panels allowed them to develop yet another mathematical model called "INSIGHT" that permitted estimation of true ground color from color satellite imagery.

6 The Modulation Transfer Function is a basic measure of optical performance in frequency space.

Returning ground and flight films to Bridgehead in Rochester, NY—the facility location that housed computers that allowed for computer modeling applications—using the same Red Dot shipping procedures, the team began the processing for the test imagery and witness samples. By carefully measuring the density of the gray panels and relating the film exposure to the apparent brightness of the panels, it was possible to model the effect of the atmosphere on the brightness and contrast of the ground scene as a function of the sun's elevation. These fundamental imaging data became the underpinning for not only the Corona system exposure programming, but also the later second and third generation (Gambit and Hexagon) longer focal-length space-borne systems that followed.

The team derived one particular processing innovation, in part, from those early flight tests. When viewed as a system, the camera, film, and processing could be manipulated to compensate for the degrading effects of the atmosphere directly in the ON film. Known as the "dual-gamma" process, the characteristic D-Log E curve could be shaped to compensate for low contrast, low illumination versus high contrast, and high illumination portions of the imaged scene. The objective was to position the scene exactly on the correct portion of the curve, i.e. the correct exposure regardless of solar altitude or viewing conditions. Later generations of space vehicles enabled corrections to exposure for second or higher film RV returns, which they accomplished with accuracy. The operation matched small, incremental on-orbit changes to the image plane slit-widths to the model predicted exposure level as the solar altitude changed below. As newer generations of high resolution black & white and color films became available, the spectral nature of scene illumination and atmospheric haze became a concern once again. Camera operations could no longer establish exposure control based on a one-size-fits-all concept. Hence, the team began to experiment with multi-spectral instrumentation and models. The first foray into this world employed a rather crude set of ground-level irradiance and atmospheric attenuation measuring equipment that allowed sampling different wavelengths of light through the visible and near infrared. Since the team members no longer relied on overhead imaging to obtain their data, they could set up anywhere, anytime, and they did. As the budget allocated more space payload resources to engineering purposes, the team coordinated activities with domestic vehicle orbital passes to compare predicted and actual results.

These early spectral or color models provided the ability to predict imaging conditions for systems that operated in various portions of the blue, green, red, or infrared spectra. The team also experimented with software that used the scene-atmosphere model to estimate reflectance of the ground surface, a technique used to estimate economic conditions in the former U.S.S.R. by estimating crop health and yields.

As newer electronic systems evolved, the need for better scene-atmosphere models became more urgent. Bridgehead designed and built, with the assistance of EG&G-Tucson as a subcontractor, a specialized instrumentation trailer in the mid-1970s. The mobile laboratory made spectral measurements of all aspects of the atmospheric effects on remote imaging from a ground-based mobile station. The project result led to greater precision and atmospheric model completeness not previously achieved. The team not only collected blue to near-infrared data on path transmittance, sky radiance, and various surface irradiances, but they also simultaneously collected weather conditions data, and occasionally even detailed information on the atmospheric particulate matter (i.e., dust) above through a cooperative agreement with the U.S. Army Atmospheric Sciences Laboratory and the University of Arizona. The most sophisticated and most critical instrument to the project, the "transmissometer," measured the atmospheric path transmittance. The second most valuable instrument was the "sky radiometer" which measured downward scattered light from the atmosphere. In addition, two "irradiometers" measured ground-level spectral solar and sky irradiation in various surface orientations. The weather tower provided conventional near surface weather data capable of correlation with the radiometric measurements over a range of atmospheric conditions.

To obtain data from the clearest to the worst possible optical conditions required driving the lab around the United States from St. Cloud, Minnesota in the dead of winter to Apalachicola, Florida in the dog days of summer. When possible, the team coordinated with U-2 over-flights using color film to provide general surround reflectance data and with the U.S. Army Atmospheric Sciences Laboratory for particulate measurements.

It took three years to complete the project, and it involved many talented people in the design and construction of the mobile lab. The research resulted in a robust atmospheric model utilized for electronic imaging systems as well as photographic cameras under a wide range of optical conditions. The "on-the-fly" and "dual-gamma" post-collection photographic methods that worked very well for early satellite photography gave way to more sophisticated digital electronic corrections done in real time in newer generation systems.

Figure 29: Mobile Radiometric Laboratory. From the archives of Bridgehead's Red Dot Project.

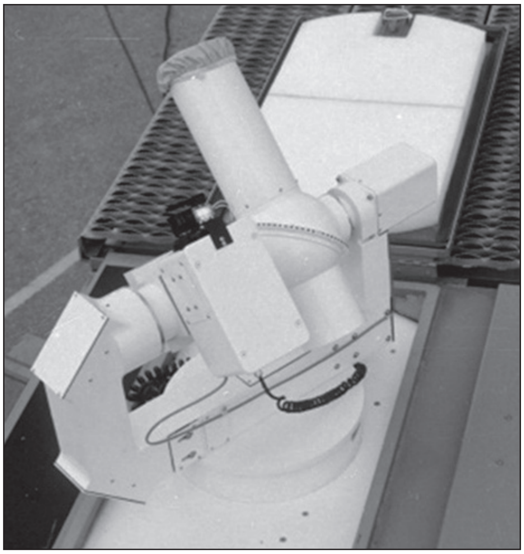


Figure 30: Sky Radiometer. From the archives of Bridgehead's Red Dot Project

The SCAT3 computer model, built from these in-situ experiments, served for many years and might still represent the most comprehensive attempt to describe the entire visible and near IR radiometric imaging process. For the first and only time in Red Dot history, Eastman Kodak received attribution in the final project report known as AWS/TN-79/001 "Spectral Radiometric Measurement and Analysis Program," published outside Bridgehead's classified channels for the Air Force Air Weather Service, Scott AFB in 1979. However, the breadth and depth of Red Dot did not end there; it also served as an innovator in comparative imaging.

Red Dot played another role as the first-line tester of new or improved films for reconnaissance systems and as the source for comparative imaging. Before committing U-2 and, more particularly, satellite resources to an experimental film, researchers assessed the performance and suitability of the film compared to the operational state-of-the-art films. The team usually conducted the tests in

Rochester, NY for convenience, but they relocated to other venues when appropriate. The specially designed four-Leica camera rig, with matched optics and calibrated exposure control, functioned as the earliest test equipment for this purpose. The four-camera design allowed simultaneous photography with different films under identical optical conditions. Built on a shoestring budget, the rig performed superbly for many years. Local flight-testing involved a Cessna aircraft flown at low altitude by a pilot from Hylan Aviation of Henrietta, NY. Two of our more intrepid members of the Red Dot group pointed the Leica rig out of a large hole cut in the bay of the plane. They were responsible for most of this photography.

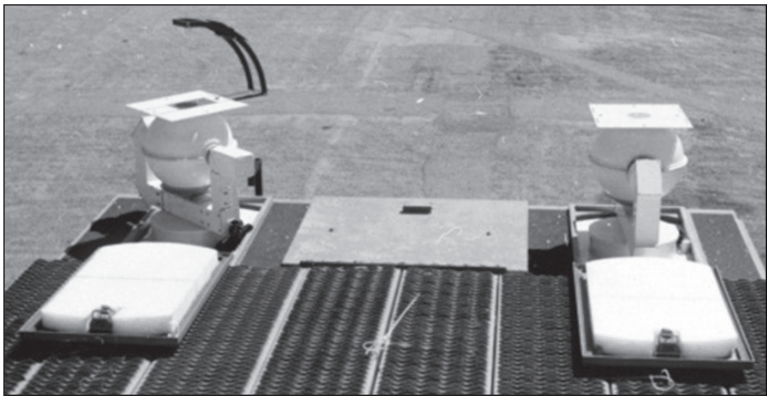


Figure 31: Two Irradiometers.
From the archives of Bridgehead's
Red Dot Project

The photos on the next two pages are typical of the comparative photography generated this way. This particular flight occurred directly over the Kodak hanger at the Rochester International Airport adjacent to the civil aviation runway. Visible at dead center (circled) in the first photo on page 74 at left are the team's tri-bar resolution and gray scale targets, which the team maintained and deployed.

The second photo on page 75 is the Kodak Park Division at its busiest time in history. These photos used an early version of the Kodak Aerial Color Film SO-242, a high-resolution color reversal film evaluated in the Leica rig preparatory to mission load.

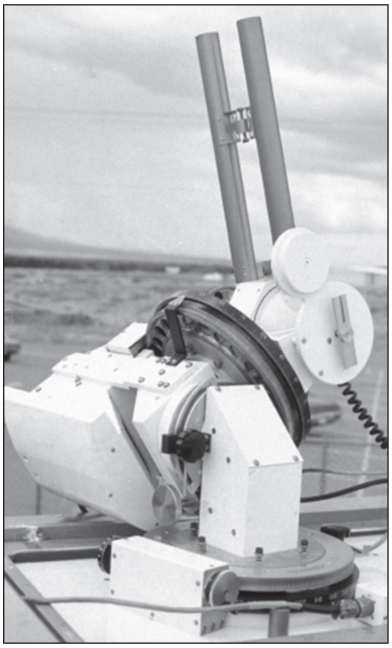


Figure 32: Transmissometer.
From the archives of Bridgehead's
Red Dot Project.

Kodak High Definition Aerial Film Type 3414, a very high-resolution black & white film, served as the workhorse for the space systems. Film Type 3414 was a state-of-the-art film designed specifically for reconnaissance purposes, and it performed exceedingly well. The film was capable of over 300 line pairs per millimeter (equivalent to a line about 1.5 microns[7] wide) at relatively fast photographic speed. This film set the standard for the highest possible resolution imagery and exceeded the theoretical performance of the most capable space camera optics. Researchers first evaluated the film during Operation Red Dot by experimenting with it in all sorts of low altitude and high altitude flights.

The Red Dot team was always trying to achieve the last few percentage points of performance out of the space imaging systems. With the development of multi-RV film returns in

7 One micron is one-thousandth of a millimeter. The thinnest human hair is 17 microns.

later Corona, Gambit, and Hexagon space system designs, the ability to compensate for any residual unexpected drift in film speed, exposure, or processing became possible, at least for the second or higher RV returns. The Red Dot team collaborated with the image quality analysis team, led by the NRO and a cadre of photo interpretation experts who labored over the first available mission imagery. Of primary concern was image plane focus, and the CORN tri-bar resolution targets provided these critical data. As soon as the collaboration resolved focus issues, exposure became one of the next topics of discussion.

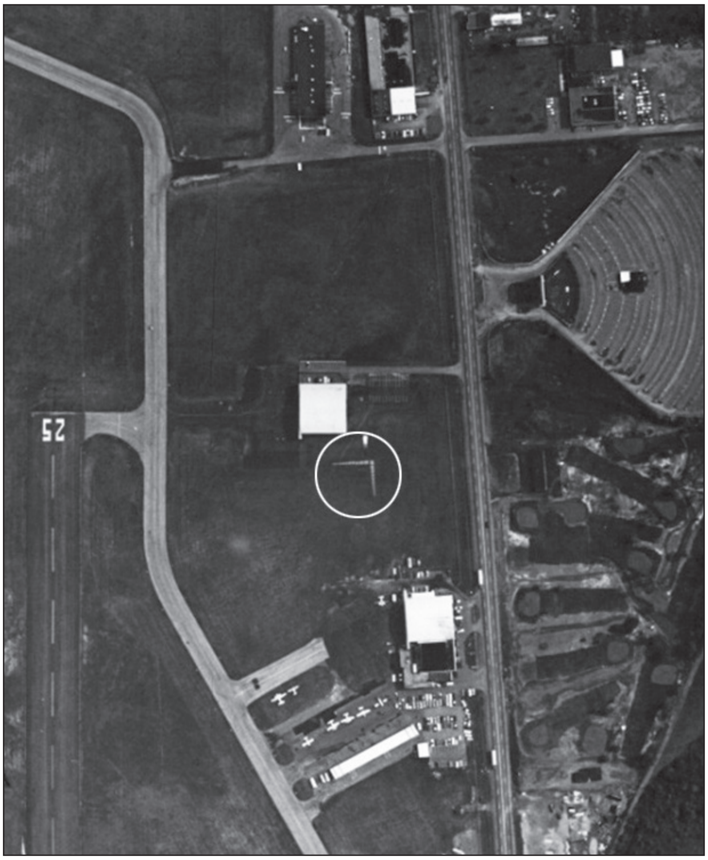


Figure 33: Deployed Tri-Bar Resolution and Gray Scale Targets. From the archives of Bridgehead's Red Dot Project.

The ability to accurately measure microscopic densities on the original film made all the gray scale and color CORN targets useful. The Red Dot labs possessed one of the few microdensitometers installed within Kodak facilities at the time. This technology scanned small portions of mission imagery, usually of urban areas, in a raster pattern collecting thousands of density readings and, in turn, exposure and brightness samples. The team compared the mean and extremes in density to the aim position on the D-Log E curve to determine the need for making second or higher bucket adjustments to the exposure algorithms. Usually, it required minimal exposure—a third stop here, a half stop[8] there—but the team was optimizing performance. Bridgehead technicians and several others spent hundreds of hours calibrating and scanning photographic imagery on the then state-of-the-art microdensitometer, a workhorse for all kinds of imaging studies.

After the analysis of hundreds, if not thousands, of similar scans for apparent ground scene brightness, technicians observed patterns about the logarithmic-normal distribution nature of scene brightness. As this methodology expanded for color, some interesting generalities emerged that proved useful in color tonal scale correction in all types of digital camera systems. To describe scenes by a function normally distributed in logarithmic space[9], real-time correction to an image was possible by using the parameters of the function approximating the classical bell-shaped curve. This concept, used successfully in commercial amateur digital photography, led to several Kodak patents. Transformed into

8 One photographic stop is a factor of two in exposure.

9 A doubling of brightness corresponded to an even increment of Log base 10 or 0.3.

frequency space[10], these types of scans also proved useful in the study of image processing techniques for enhancing image sharpness. Moreover, carefully calibrated light sources and high-resolution optical bench labs were also fundamental resources for the efforts, and Red Dot maintained an optical calibration lab second only to the Kodak Research Laboratory, an excellent scientific facility. Red Dot possessed the resources to resolve any possible radiometric or photographic issue anywhere in the vehicle design, development, or operational program.

Figure 34: Overhead Photo of Eastman Kodak's Kodak Park Facility. From the archives of Bridgehead's Red Dot Project.

The Red Dot project always closely allied with the needs of the photo interpretation community in their highly scrutinized pursuit of intelligence. The team did their best to make the task, if not easier, at least a little less risky. The country's Intelligence Community would always need photographic or electronic imagery of the highest possible quality, and the Red Dot team was pleased that they contributed to the overall success in this short period of history.

Film Evaluation and Test Lab (FEAT)

Initiated in the late 1960s, the FEAT Lab served as a testing service for the entire national reconnaissance community to provide basic film and processing data. It served as a government community resource to evaluate the viability of aerial films for use in government photographic programs.

"FEAT Sheets" summarized the geometric, sensitometric, and performance characteristics of each of the tested films, which were subsequently published for the customer community. "FEAT Sheets,"

10 Frequency space power spectra are the equivalent image detail as a function of spatial frequency rather than normal x-y space. Think holograms.

which became community standards, provided the film's official designation, a description of the film, its measured geometric and sensitometric characteristics, and its performance characteristics relevant to the film's ultimate use in the program.

Published geometric characteristics	Reported sensitometric characteristics	Performance parameters (measured from film processed at the recommended process)
Film width	Photographic speed	Granularity
Total film thickness	Spectral sensitivity	Visual resolution
Individual film layer thickness	Density-Log E curve at the film's recommended process. Granularity	Modulation Transfer Function (MTF)
Grain size		

The FEAT Lab measured the latter characteristics at program-relevant contrast levels.

On-site, high quality, vibration-free cameras that printed precision targets on the tested film products supported FEAT Lab film evaluations. After appropriate processing, observers certified in the art of resolution reading interpreted visual test targets. Certification insured that these observers read resolutions accurately and consistently. They interpreted machine-read targets with either macro or microdensitometers and then converted the data to the published form.

In the early days of the FEAT Lab, another group within Special Programs provided micro-densitometry of the FEAT Lab test targets. Later, the micro-densitometry function became a Film Evaluation and Test Service (FEATS) Lab service that supported other groups within the community. The FEATS Lab also provided an instrument calibration service that served not only its own instrumentation but also that of the entire Special Programs organization.

Chapter 9

A DAY IN THE LIFE…. MEMORABLE EVENTS & THE LIGHTER SIDE

As previously evidenced by this historical account, the Bridgehead employees significantly contributed to the successes of the U-2, Corona, Gambit, and Hexagon Programs and other special projects. This account summarized contributions of an operation that included film technology innovations through dedicated teamwork from the active years of the U-2 program (ca. 1950s), the Corona program (1960–1972), the Gambit program (1963-1984), and the Hexagon program (1971-1986). In addition to the day-to-day routines that advanced the satellite programs, the authors of this account remembered world events that challenged the Bridgehead team to contribute to missions other than their primary commitments. In other instances, they recalled external circumstances that challenged the Bridgehead mission objectives. Yet other memorable events included the appearance of distinguished visitors and certain managers that tenured at the plant. These events demonstrated Bridgehead's contributions to other world happenings and connections to key leaders and decision-makers of Cold War policies, as well as potential catastrophes that could have affected the satellite mission.

At other times, despite the serious nature of their work, they remembered the workplace as not always a somber place but a place energized by a wide range of personalities and unique perspectives. Thus, this chapter sheds light on some of the people behind the scenes as they shared their distinctive accounts of events. In their work world, which demanded top secrecy, they shared a lighter side: the humor and minutiae about a secret workforce. These details eloquently endured and further complimented the mission as a meaningful endeavor.

Cuban Missile Crisis: VIP Visits Bridgehead, a Secret Mission, and Surprising Outcome

In the early 1960s, Bridgehead workers dutifully contributed to the resolution of the Cuban Missile Crisis. During that tumultuous time, Bridgehead expeditiously responded to the call to action. The workforce moved contact printers, Versamat Processors, and other equipment rapidly to the staging area, and they accomplished this move within 48 hours. Approximately 20 operators reported to the Naval Reserve Training Station in Suitland, MD, and installed and enabled operational equipment in support of curbing this emergent Soviet threat.

Dr. Joseph V. Charyk, Under Secretary of the Air Force and the first Director of the National Reconnaissance Office, visited the Eastman Kodak Company during the Cuban Missile Crisis. He arrived by a private jet aircraft for a conference with Kodak Vice President Art Simmons and Ed Greene, General Manager of Special Programs. Under a shroud of secrecy, managers limited the audience for the meeting and did not retain documentation about the meeting. However, the authors remembered two action items that resulted from the event.

The first action item involved Versamat Photographic Processing machines. Managers diverted several Versamat machines from their normal shipments, immediately crated them for air shipment and moved them to the Kodak Elmgrove Plant shipping dock for special pick-up. The "Special Programs" unmarked truck, with a closed cargo hold, picked up the machines and delivered them to the Rochester, NY airport where a military cargo plane waited. The demands of the Cuban Missile Crisis urgently needed these Versamats in support of activities.

The second action item involved rolls of 5-inch wide Ektachrome film. Workers loaded several rolls of 500 ft. Ektachrome film on camera spools used by the Navy's "Heavy Photographic Squadron" or VAP. After the workforce readied the film for delivery, the managers tasked Mr. Ted Simons, a QC Engineer in the Special Programs organization, to courier these Ektachrome Rolls to the customer. They instructed Simons to bring a suitcase for a one or two night stay and the film rolls to the airport at a specific date and time. Upon arrival at the airport, a private military jet flew Simons directly to Ft. Lauderdale, FL. The Navy's VAP 62 missions, flown out of the Naval Air Station located at Ft. Lauderdale, utilized the film to meet mission objectives. Simons indicated that when he arrived at the Naval Air Station, there were security concerns. A higher authority at the station confronted him, "What is this young civilian engineer doing at this Navy base when we are deeply involved with the Cuban Missile Crisis?" Neither Bridgehead managers nor the military provided him with any "military orders." He only carried identification and some background information, which alluded to Dr. Charyk's visit. After consultation with the Pentagon, they welcomed Simons and used his film package on a low-level over-flight of Cuba. He remained at Ft. Lauderdale until they flew the mission and then returned to Rochester with the exposed roll of Ektachrome Color Film for processing.

After the secrecy and gravity of the operation, workers successfully developed the film and received a rather light-hearted surprise as an outcome. The VAP 62 organization did an outstanding job of photographing Cuba at an extremely low altitude in perfect vivid color. Undoubtedly, they recorded numerous military targets. However, one frame of photography sparked the interest of the people at the Film Processing Lab. This frame recorded a bucolic Cuban farm scene. The chickens and the geese scattered in all directions, perhaps alarmed by the airplane. An old wooden outhouse stood near the middle of the frame, with the door wide open. A startled Cuban farmer, with a perplexed expression on his face and his mouth hanging open, was photographed while he was busy "going about his business."

Lights Out

On a more serious and more regional note during the mid-1960s, a failure in the electric grid led to the Northeast Blackout, which impacted tens of millions of people. For Bridgehead employees, the event created an atmosphere of high anxiety because the Trenton Processor was actively processing an original negative when the power shutdown occurred. Although quality assurance technicians tested equipment for periodic power disruptions, this real-time event truly challenged the backup power capability, emergency shutdown procedures, and inevitably, Bridgehead's ability to fulfill its mission as the primary provider of satellite images for the Intelligence Community. Much to the relief of all Bridgehead team members, procedures went smoothly and equipment performed according to design.

Dropped Shipment

En-route from New York to Maryland, a delivery aircraft incident in 1961 nearly led to a loss of valuable reconnaissance imagery. Film shipments routinely occurred as part of every mission, with at least two, and as many as four, shipments for each mission via military aircraft. On one occasion, the military aircraft leaving Rochester for Andrews Air Force Base developed engine trouble and steadily lost altitude on its southbound flight. The pilot decided that they needed to lighten the load as the only way to reach safety at Andrews AFB. As a result, the crew jettisoned a number of film cartons over a remote area of Pennsylvania. The aircraft command post immediately notified the Pennsylvania State Police and the Pennsylvania National Guard, and they cordoned-off all roads around the drop area—a more challenging feat during the era before the common use of Global Positioning Systems—and undertook a broad search for the dropped cargo. With gratitude to the quick response of police and Guard personnel, they located and accounted for every carton of the highly classified film, thus averting a major security breach. In gratitude to the Bridgehead Packaging and Shipping Department and their fastidious attention to the art of packaging, most of the packages survived the ordeal, enabling the IC to utilize most of the dropped film—only bent spool flanges needed replacement. The incident gave new meaning to the term "Dropped Shipment!"

Square Pegs in Round Holes

Reflecting on internal events and unique talents at the production facility in the mid to late 1960s, a memorably creative and philosophical Special Programs Manager, Edgar L. Green, authored and distributed a series of informational notes titled *Square Pegs in Round Holes*. The first issue occurred in May 1966, and he wrote the 46th and last note in April 1969. The notes primarily focused on personnel issues and the handling of people. They served to reach as many people as possible by providing encouragement, solving problems, avoiding pitfalls, improving morale, and acting as a vehicle for the Program Manager to communicate his ideas. Mr. Green issued the notes whenever he saw the need, rather than on a routine basis. He issued several notes in a given week, and then several months might have elapsed before the next issue appeared. He numbered and dated each note, which pertained only to one topic per issue. These selected excerpts capture the spirit of these notes:

- …We had one man quit because his wife couldn't find a job here. If we had known about it, I could almost guarantee we could have found a job for a trapeze artist, which she wasn't–just a skilled technician.
- Encouragement of constructive criticism by individuals and their participation in problem solving is not a sign of weakness.
- Without a sales force of any kind and without advertisement other than our simple "fact sheets," we have grown rather rapidly. All we have to sell is quality.
- Don't sit there and sulk—SOLVE THE PROBLEM.
- Morale is no burden—it's much easier to have than to do without. Morale is continuing to write *Square Pegs in Round Holes* notes even though you suspect no one is paying any attention to them.
- The only complete mistake is the mistake from which we learn nothing.
- So, at least listen to the other fellow's ideas and reserve judgment until the facts have been examined.
- The experience of others is the cheapest thing you can buy.
- A peg that fits the hole has some chance of surviving, but one that never did fit will fail in some manner. In this respect, the hole (job) is almost always stronger than the peg (man)…

A Secret Visitor

One day in 1976, the entire program was on its best behavior when the Director of Central Intelligence, George H. W. Bush, was quietly "whisked" in and out of the Hawkeye Plant (using the back door and the freight elevator) to receive a technical briefing on Bridgehead's progress in support of an important government program. Neither the media nor the public ever knew of his presence in Rochester on that day.

On the Lighter Side

The demands of mission support along with a common belief that the program worked to make a significant contribution to the future of the nation, caused the entire workforce to feel like family. During mission support times, nearly everyone worked on one of two twelve-hour shifts with very little time for family and outside activity. This unique work environment cultivated trusting and long-lasting relationships between employees with very few "secrets." It also provided a perfect platform for jokesters and pranksters. Some of the stories that surfaced from this setting included the following characters and scenarios:

Characters and Role Players

- Marvin Butterworth, a fictitious character who mysteriously showed up on work schedules, assignment directives, congratulatory letters, etc., until one day the Program Manager, Edgar L. Green, asked his secretary, **"***Who the hell is this Marvin Butterworth?* I don't remember hiring him!"
- Cuyler Chatfield made a career of "putting people on," with the surprising attribute that he succeeded with the same people two and three times. One of his favorite pranks included selling government surplus jeeps. He actually succeeded in having his victims "sign up" for delivery. El Beck, head of Bridgehead's Technical Assistance (TA) Group, became a favorite target of this prank.
- Don Fose, a talented comedian and cartoonist, created a "newsletter" that reported on strange happenings involving his fellow employees. He accomplished this creative endeavor while monitoring a Dalton processing machine that ran flawlessly. A classic example of his work reported on a fictitious relay race that put teams of various cultural backgrounds on opposing teams with laugh-aloud results. Because of the strong camaraderie of team members, everyone enjoyed the humorous stories!

Saturday Duty

During the era prior to workforce diversity and strict affirmative action laws, Bridgehead assigned male workers to certain special duties. Contractual requirements committed Bridgehead to remove labels from returned film cans, covers, spools, and boxes when time permitted. Workers used loud, noisy grinders to eliminate any identification markings remaining on the returned items. These "sanitizations" usually occurred on Saturdays during non-mission time in the basement of Lincoln Plant. Workers used masks (surplus gas or paper), gloves (too bulky with which to handle the cans, lids, and spools), and fans (Lincoln Plant air conditioning) for the comfort and safety of the operators. This operation usually required a hot shower before rejoining the human race and a plausible explanation to an operator's wife / girlfriend as to how he got so filthy at work.

The Flintstone

During the very early 1960s, Bridgehead supported the Argon program, a system designed specifically for mapping purposes with a camera provided by Fairchild that yielded a 5x5-in. format. Several of the cameras shared space with the Corona system in its early days of operation. At that time, and in addition to processing the ON, a higher authority tasked Bridgehead with providing hardware to produce positive copies of the acquired images on emulsion-coated, commercially available, glass plates believed to help minimize distortion in the copies. The emergent Design and Engineering Group, directed by Stan Duffield, hurriedly designed and fabricated a simplistic system of submerging, lifting, and moving the plates through the development process stages. The program manager, E. L. Green, understood that engineers designed and built many new technologies that needed identifiers. He tasked Harold Sacrider, supervisor of the production group, to name the equipment. He and his production operators described the design of the glass-plate processor as possessing both "brute force and awkwardness." They aptly named it the Flintstone. The connection with the TV series depicting actors of the Stone Age provided many laughs in the lunchroom. Conversely, Mr. Duffield did not find the name humorous.

Mission Accomplished

In 1962, Dick Stowe and Don Schoessler attended a Corona Payload Interface Meeting in Massachusetts in collaboration with Itek Corporation. After the meeting, Itek engineers asked these two Bridgehead employees to act as couriers and hand-carry a quantity of defective and unprocessed films back to Rochester for inspection and processing. The couriers, holding the appropriate security clearances, packed the classified (but unmarked) cylindrical containers and documents in a briefcase and headed back to Rochester via Boston's Logan Airport.

Much to their consternation, the trip turned out to be other than routine. On that day, a bomb threat disrupted air travel at Logan and delayed their flight. To complicate matters, airport authorities had tasked the Boston Police Department with inspection of all carry-on suitcases. Together, the two travelers anxiously, but quietly, brainstormed how to handle their situation—carrying classified material in a canister that might suspiciously look like a bomb. Remaining composed and thinking quickly, they averted a potentially calamitous situation—having the classified film confiscated. Privately with a police officer, they calmly explained their predicament and presented multiple forms of identification, without divulging any deeper truths about their mission. The officer, in turn, explained the situation to the aircraft's pilot who personally assessed the two couriers. He then made special arrangements to place their briefcase in an aft storage compartment while accommodating them in seats where they could monitor the compartment while seated. Although other passengers nervously scrutinized the two couriers, the flight arrived in Rochester without incident. Much to their relief, the two couriers accomplished their mission.

Chapter 10

BEYOND NATIONAL PHOTORECONNAISSANCE: STUDIES & SUPPORT IN THE LATE 20TH CENTURY

Electro-Photographic Duplication

A portion of the Bridgehead R&D program investigated potential improvements in the image chain and alternative imaging systems. As discussed previously in this account, the Bridgehead facility addressed wastewater effluent and treatment systems, which included precious metals and the potential compromise of secret operations. Thus, they also launched an investigation to determine if electro-photographic duplication had quality and cost advantages over conventional silver halide systems. They gave this traditional study increased emphasis in the mid-1970s when Congress passed a law that required government programs to reduce or eliminate the use of "precious materials," which included silver, the major component of the existing photographic system. Bridgehead consulted with other companies, investigated other technologies, and worked with the Kodak Research Laboratories for candidate systems to augment or replace the existing silver halide-based duplication and laser recording systems. Several possible options included Diazo duplication, Coulter films, and iodoform, none of which met all the performance requirements for the government program.

Kodak Research Labs identified a system using single-use liquid-toned electro-photographic materials designed for microfilm applications, deemed potentially able to meet the performance requirements of the program. They initiated a two-phased program to investigate this system—one financed by Kodak to develop films and materials to meet the government's specific needs, and a second one to develop hardware in a total and practical system. A Bridgehead scientist worked with Kodak Research personnel to evaluate the potential of the electro-photographic system and methods to optimize that system for government program requirements. Besides being a non-silver system, several other attributes existed for both major production facilities and remote field photographic applications. The design alleviated the concerns about optimizing success without compromising security and the concerns about environmental stewardship and prudent management of resources. This duplication process relied on relatively simple steps: charge, expose, tone, and dry. It used no water, which presented a major advantage for field operations that lacked clean water sources. As an environmental bonus, it nearly eliminated effluent because technicians replenished depleted toner for further development. Moreover, it allowed the burning of unsuitable materials because of the chemical composition similar to kerosene or jet fuel.

The program evolved in several stages, including government-sponsored applications for specific programs. It began with a demonstration, which highlighted potential image quality performance by Kodak. This led to four major developments: hardware and material to demonstrate potential to meet the requirements to replace an existing silver halide duplication system, with evaluation by Kodak and government operations personnel; prototype hardware for evaluation by government personnel to operate in their facility; a laser recorder system designed to make an all electro-photographic system; and a proposal for the design of a new electro-photographic facility including hardware and operations. These studies met all system requirements for both recording and duplication, leaving only a cost analysis to examine if the new technology made good sense economically, which led to several important conclusions. It was found that materials costs were comparable to the existing silver halide system, so there was no material cost benefit. The operation needed new hardware and operational requirements with potential unforeseen risks to the existing critical production program. Bridgehead needed to continue with the silver halide system but consider electro-photography for other potential applications.

Other relevant items that emerged from this research included new films with unique features. Kodak developed two films, SO-426 with blue/UV spectral sensitivity for duplication, and SO-102 designed to match the spectral and intensity output of the Argon laser recorder. Additionally, they developed toners that met the hue and performance recommendations provided by potential users.

The Cornell University–Eastman Kodak Co. Consortium

Kodak collaborated with a leading university on an investigation to determine feasibility of specially designed acquisition films to identify seepage from landfills. For more than 40 years, the School of Civil & Environmental Engineering at Cornell University promoted and developed a remote sensing program. This program gave aerial photography, and various other forms of scanning and sensing, a synoptic view of our Earth for engineering and environmental applications and analyses.

For a longer period, Eastman Kodak Co. developed photographic films for all types of uses, including aerial photography from as far back as Word War I. Over the years, the value of photogrammetry and photo-interpretation analytical tools increased sharply as optics quality, film image resolution, and color capabilities continually improved. The government restricted many of these classified developments because of their applications for use in military reconnaissance. However, they methodically declassified such restrictions for use in non-military applications in the private and government sectors.

Private, corporate, government, and academic sectors collaborated to support each other in common research endeavors. The Kodak and Cornell entities developed affiliations with the National Aeronautics and Space Administration (NASA), Environmental Protection Agency (EPA), and other agencies and organizations where photographic technology and imaging science served as important tools in numerous scientific investigations. One cooperative effort occurred from 1974 to 1976. The chairperson of remote sensing at Cornell obtained grants from NASA and the EPA to investigate seepage from landfills. The investigation involved taking aerial photographs of several landfills in central New York State and included ground teams to correlate what the photographic images revealed. Senior scientists from Cornell led the ground survey team. Under the direction of a research associate and project coordinator at Cornell, they flew five photo missions during various seasons to accomplish the remote sensing aspect of the project. Another research assistant used the photographs to locate and identify seepage and to direct the ground crews to those sites for confirmation and analysis.

Eastman Kodak Co. furnished two types of film for this project: Kodak Aerochrome MS film 2448 (ESTAR base), which provided natural color photographs, and Kodak Aerochrome infrared film 2443 (ESTAR base), which provided a false-color image. The "false color" provided an image in which healthy vegetation appeared red, while the unhealthy vegetation appeared as a blue-green color (cyan). The researchers then evaluated the photographs to determine if any seepage from the landfill affected the health of surrounding vegetation and the distance of seepage migration. They also examined photographs to determine the possibility of identifying a specific type of leachate—wastes seeping from the landfill—from any characteristic color signature on the image. Additionally, they used a thermal scanner to record temperature radiation, which they correlated with the various photographic images and the ground measurements. NASA supported the photographic part of the mission by processing and printing copies of the exposed film.

The use of aerial photography proved to be of great value to many investigators over time and ultimately led to many practical applications. Remote sensing vastly improved since the mid-1970s and produced new scanners and sensors that captured broader ranges of the electro-magnetic spectrum. With these developments, researchers found more ways to use remotely gathered images and data. Some common examples are reflected in the table below:

CIVIL ENGINEERING APPLICATIONS

- Inspection of dams, bridges, highways, airports
- Highway citing
- Flood plain geography, review of waterways (navigation problems)
- Drainage improvements

ENVIRONMENTAL APPLICATIONS

- Forest evaluation, lumbering, disease
- Analysis of wetlands, freshwater problems, agricultural runoff to lakes and ponds
- Insect infestations, plant and animal diseases
- Wildlife management

GEOLOGIC APPLICATIONS

- Topographic mapping
- Identifying mine sites
- Location of natural resources: natural gas fields, coal, oil, minerals

Cornell University, Eastman Kodak Co. (with Bridgehead expertise), and several U. S. Government agencies (e.g., NASA and EPA) collaborated in sharing technical information for specific projects. Similar collaborative efforts throughout the country yielded great results in remote sensing.

Study to Evaluate Exemplars

Bridgehead spearheaded a study to evaluate the threat of color copying for counterfeiting and possible countermeasures. This task engaged Eastman Kodak in a study to evaluate exemplars, provided by the Bureau of Engraving and Printing (BEP), of advanced currency design consisting of a variety of colors with different multicolor tint patterns and a variety of line frequencies.

This report culminated Eastman Kodak's participation in a two-year Exemplar Evaluation Study, sponsored by the Board of Governors of the Federal Reserve System. The Bureau of Engraving and Printing provided 69 advanced U.S. currency design exemplars to Eastman Kodak for the primary purpose of evaluating the reproducibility of the following advanced counterfeit deterrents: color/

multicolor tints, line and dot patterns for inducing Moiré, and a variety of Optical Variable Devices (OVDs). These technologies encompassed tools available to both the amateur and the professional counterfeiter.

Reprographic techniques consisted of a high technology Hell Chromagraph Color Scanner, Model DC 300 B/L, and conventional graphic arts Robertson Tri-Color Process Camera. Kodak employed a Kodak Experimental Color Copier and a commercially available Canon NP Color Copier to assess the degree of difficulty in reproducing these advanced currency deterrents. Contrary to popular belief, they did not find that the incorporation of color/ multicolor tints, by itself, were a significant deterrent. Today's advanced reprographic systems can easily reproduce color originals with a copy quality that has a high probability of passing as a counterfeit. The lack of ink sample spectral purity, the availability of improved photographic and lithographic materials, and improved processes yielded a reasonable facsimile copy.

Accordingly, this study failed to identify colors that were difficult to reproduce. The reprographic techniques employed in this study (excluding the Canon NP Color Copier) posed a significant threat for counterfeiting color originals. However, color/multicolor should still be part of the new currency design because it adds technical difficulty in making forgeries and will interact with other counterfeit deterrent design features to produce Moiré patterns.

Additionally, they undertook a comprehensive study to evaluate geometric line and dot patterns that will result, with the reproduction of color originals using halftone-screen-separation techniques, in a conspicuous change in copy appearance, i.e., Moiré patterns. They defined technical parameters that provided a high probability of inducing prominent Moiré patterns. These parameters, however, might be incompatible with current design constraints that do not permit altering the motif of advanced currency models. It became the task of the designer to balance these technical parameters with the aesthetic features to achieve maximum utility. They also discussed methods that can defeat Moiré and their trade-offs in resulting copy quality.

The application of Optical Variable Devices, in the form of affixed Department of the Treasury and Federal Reserve seals, provided the highest-level advanced currency deterrent identified from this study. The OVD seals found to offer the greatest protection against counterfeiting included the multiple diffraction grating (without overprinting), silver holographic hologram, and watermark (modified). Secondary level deterrent OVD seals included the reflective inks, thin film interference filters, thin thread, and simulated window security devices. They found these latter OVD's adequately reproduced and were readily available as commercial substitutes. The study provided recommendations that potentially improved several of these OVD seals' optical properties. Deterrence levels provided by incorporating color/multicolor tints, line and dot patterns, and OVDs effectively accomplished a system's approach to substantially increase the technical complexity required for preparing counterfeit copies. It also probably stymied the amateur counterfeiter and potentially delayed and frustrated the advanced counterfeiter or those familiar with graphic arts materials and processes.

Chapter 11

EPILOGUE

Bridgehead operations continued until the late 1990s when maturing digital imaging technologies supplanted the need for extensive silver halide imaging reproduction systems. Similarly, Kodak's focus moved away from its traditional film and silver halide imaging technologies. In 2001, as part of its restructuring strategy, Kodak sold its special government business operations to ITT Corporation, headquartered in White Plains, NY, forming ITT Space Systems, LLC, a wholly-owned subsidiary with other operations in Fort Wayne, IN and Clifton, NJ. Government business operations at Kodak's Hawkeye Plant remained essentially undisturbed while Lincoln Plant operations moved to other facilities to clear the way for the government to divest itself of that facility. At the turn of the 21st century, as funding permitted, contractors worked on deconstruction of Bridgehead and Lincoln Plant's film processing capabilities. By 2009, they quietly eliminated all vestiges of the Photographic Operations Center at Bridgehead–the end of a remarkable era.

The final exit of the Hawkeye plant was completed on 23 October 2012, when the last business operations of Exelis (successor to ITT Corporation, which had purchased Kodak's Government Systems business eight years earlier) moved to other facilities in the Rochester area. That milestone concluded 101 years of continuous operations related to consumer, commercial, and government photographic programs at Hawkeye. Kodak remains the owner of the facility, but with no prospective tenants lined up for occupancy, the future of the Hawkeye plant is in doubt.

Appendix A

BRIDGEHEAD CHRONOLOGY

YEAR	MILESTONE
1955	Dr. Chapman coordinates Eastman Kodak (EK) management support
1956	Photographic processing lab established at Lincoln Plant (LP)
1960	First Corona film load returned to LP in suitcases
1962	Dr. Charyk visit; Support to Cuban Missile Crisis
1963	"Bridgehead" adopted as code word for LP and Hawkeye (HE) operations
1963	First Gambit 1 Recovery Vehicle (RV) received
1966	First Gambit 3 RV received
1968	First color film on Gambit 3
1968	First color film on Corona
1969	First two-RV Gambit 3 mission
1969	First Dual Gamma processing
1970	First Optical Titling of the Original Negative (ON) (Gambit)
1971	First Hexagon RV received
1972	First color film on Hexagon
1974	Ultrasonic splicing in G area breakdown tables used to restructure ON frames by geographic area
1974	Actinic Butterfly Contrast Control (ABCC) printing on Hexagon
1975	First Mapping camera RV on Hexagon
1975	Low Distortion Kingston printer used with low distortion certification software
1976	George H. W. Bush (Director CIA) visits Bridgehead
1984	Last Film Mission – Hexagon RV received
2012	Final exit of the Hawkeye plant when the last business operations of Exelis (successor to ITT Corp.) moved to other facilities in the Rochester area; concluded 101 years of continuous operations related to consumer, commercial, and government photographic programs at Hawkeye.

Appendix B

KODAK PHOTORECONNAISSANCE FILMS - 1954 TO 1973

KODAK AERIAL FILMS FOR ADVANCED SYSTEMS

SPEC ORDER	NAME	Year	AFI[1]	RP[2]	BASE	CHARACTERISTIC
SO-1121	Super-XX Aero	'54	80	100	recon	1st new generation higher definition aerial film
SO-1129	Super-XX Aero	'54	80	100	topo	1st new generation higher definition aerial film
SO-1166	Super-XX Aero	'57	80	100	recon	SO-1121 w/ext red sens
SO-1159	Super-XX Aero	'57	80	100	topo	SO-1121 w/ext red sens
SO-1153	Super-XX Aero	'55	80	100	L Pan NC	SO-1121 on TB w/pelloid
SO-1188	Super-XX Aero	'58	80	100	L Pan NC	Unclassified version of SO-1153
SO-102	Plus-X Aerial (ESTAR Thin Base)	'60	80	100	2.5 mil ESTAR	SO-1153 on thin base ESTAR
SO-135	Plus-X Aerial (ESTAR Base)	'60	80	100	4 mil ESTAR	
SO-1182	Fine Grain Aerial	'57	6-10	300	gray acetate	Variation of microfile film, ext red-first version
SO-1213	Fine Grain Aerial	'57	6-10	300	gray acetate	Modified SO-1182
SO-1221	Fine Grain Aerial	'57	6-10	300	L Pan NC	Modified SO-1182
SO-213	Fine Grain Aerial	'62	6-10	300	gray acetate	current designation of SO-1213
SO-226	Fine Grain Aerial	'62	6-10	300	4 mil ESTAR	SO-1221 (SO-221) emulsion
SO-206	Fine Grain Aerial	'62	6-10	300	2.5 mil ESTAR	SO-1221 (SO-221) emulsion
SO-121	Panatomic-X Aerial (Gray Base)	'60	20	160	gray acetate	
SO-130	Panatomic-X Aerial (ESTAR Thin Base)	'60	20	160	2.5 mil ESTAR	
SO-136	Panatomic-X Aerial (ESTAR Base)	'60	20	160	4 mil ESTAR	
SO-243	High Definition Aerial Film (Gray Base)	'58	1.6	500	gray acetate	
SO-132	High Def-Low Speed (ESTAR Thin Base)	'60	1.6	500	2.5 mil ESTAR	SO-243 emulsion

1 Aerial Film Index. 2 Resolving Power. * Revised Order Numbers.

SPEC ORDER	NAME	Year	AFI[1]	RP[2]	BASE	CHARACTERISTIC
SO-362	High Def-Low Speed (ESTAR Thin Base)	'65	1.6	500	2.5 mil ESTAR	Faster speed 3404
SO-230	High Definition AHU Arial	'66	1.6	500	2.5 mil ESTAR	Replaced SO-362
SO-205	High Definition AHU Arial	'66	1.6	500	1.5 mil ESTAR	
SO-380	High Definition Aerial (ESTAR UTB)	'65	1.6	500	1.5 mil ESTAR	Higher definition emulsion
SO-349	High Definition Aerial (ESTAR Thin Base	'69	2.5		2.5 mil ESTAR	Improved 3404
SO-236	High Definition Aerial (UTB)	'70	2.5		1.5 mil ESTAR	SO-349 emulsion 1414
SO-446	Aerial Film	'71	2	800	2.5 mil ESTAR	Half speed
SO-124	Aerial Film	'73	2	800	1.5 mil ESTAR	SO-446 emulsion
SO-121*	Aerial color film	'64	6	160	2.5 mil ESTAR	High Definition Ektachrome Aero
SO-242	Aerial color – ESTAR Thin Base	'69	2	200	2.5 mil ESTAR	High definition-improved SO-121
SO-255	Aerial color – ESTAR Ultra Thin Base	'69	2	200	1.5 mil ESTAR	High definition-improved SO-121
SO-356	High Definition Ektachrome	'64			4 mil ESTAR	SO-242 emulsion
SO-131	High Definition Aerochrome Infrared	'73	2	160	2.5 mil ESTAR	
SO-127	High Definition Aerochrome Infrared	'73	2	160	4 mil ESTAR	SO-131 emulsion
SO-130*	High Definition Aerochrome Infrared	'73	2	160	1.5 mil ESTAR	SO-131 emulsion

1 Aerial Film Index. 2 Resolving Power. * Revised Order Numbers.

Appendix C

PRIMARY LIST OF KODAK AERIAL FILMS USED IN THE GAMBIT & HEXAGON PROGRAMS

APPLICATION	AERIAL FILM CODE OR DESIGNATION	NAME	AFI	RP	BASE
B&W Acquisition Films	3404	KODAK Plus-X Aerocon II Film 3404 (ESTAR Thin Base)			
	3401	KODAK Plus-X Aerial Film 3401 (ESTAR Thin Base)	200	115	2.5 mil ESTAR
	3400	KODAK Panatomic-X Aerial Film 3400 (ESTAR Thin Base)	80	175	2.5 mil ESTAR
	3411	KODAK Plus-X Aerial Film 3411 (ESTAR Thin Base) - modified version of 3401	212	160	2.5 mil ESTAR
	3414	KODAK High Definition Aerial Film 3414 (ESTAR Thin Base)	15	720	2.5 mil ESTAR
	1414	KODAK High Definition Aerial Film 3414 (ESTAR Ultra-Thin Base)			
	SO-112	KODAK High Definition Aerial Film SO-112 (ESTAR Ultra Thin Base)	4.7	1020	1.5 mil ESTAR
	SO-124	KODAK Aerial Film SO-124 (ESTAR Ultra Thin Base)	6	805	1.5 mil ESTAR
	SO-132	3404 ESTAR BASE			
	SO-208	KODAK High Definition Aerial Film (ESTAR Ultra-Thin Base) SO-208			
	SO-209	KODAK High Definition Aerial Film (ESTAR Ultra-Thin Base) SO-209	1.2	1160	1.5 mil ESTAR
	SO-312	KODAK High Definition Aerial Film (ESTAR Ultra-Thin Base) SO-312	5.1	1015	1.2 mil ESTAR
	SO-315	KODAK High Definition Aerial Film (ESTAR Ultra-Thin Base) SO-315	9.3	924	1.2 mil ESTAR
	SO-349	KODAK High Definition Aerial Film SO-349 (ESTAR Thin Base)	15	720	2.5 mil ESTAR
	SO-380	KODAK Plus-X Aerocon II Film SO-380			1.5 mil ESTAR
	SO-409	KODAK High Definition Aerial Film SO-409	2.6	1160	1.2 mil ESTAR

APPLICATION	AERIAL FILM CODE OR DESIGNATION	NAME	AFI	RP	BASE
	SO-412	KODAK High Definition Aerial Film (ESTAR Ultra-Thin Base) SO-412			
	SO-460	KODAK Aerial Film SO-460 (ESTAR Ultra Thin Base)	6	805	1.2 mil ESTAR
	SO-464	KODAK High Definition Aerial film (ESTAR Ultra-Thin Base) SO-464	10	715	1.2 mil ESTAR
	FE-1250	KODAK Experimental SO-312 type Film			
	FE-1500	KODAK Experimental SO-315 type Film			
	QX-808	KODAK Low Speed Aerial Film QX-808			
B&W Duplication Films	8430	KODAK Fine Grain Aerial Duplicating Film 8430 (ESTAR Base)			
	2430	KODAK Fine Grain Aerial Duplicating Film 2430 (ESTAR Base)		691	4 mil ESTAR
	2420	KODAK Aerographic Duplicating Film 2420 (ESTAR Base)		165	4 mil ESTAR
	2421	KODAK Aerographic Duplicating Film 2421 (ESTAR Base)		516	4 mil ESTAR
	2422	KODAK Aerographic Direct Duplicating Film 2422 (ESTAR Base)		580	4 mil ESTAR
	2484	KODAK Pan Film 2484 (ESTAR AH Base)			
	SO-192	KODAK High Resolution Aerial Duplicating Film SO-192 (ESTAR Base)		722	4 mil ESTAR
	SO-239	KODAK Direct Duplicating Aerial SO-239 (ESTAR Base)			4 mil ESTAR
	SO-332	KODAK Aerial Type II Duplicating Film (ESTAR Base) SO-332		1400	4 mil ESTAR
Color Acquisition Films	SO-130	KODAK High Definition Aerochrome Infrared Film SO-130 (ESTAR Ultra-Thin Base)	7.5	183	1.5 mil ESTAR
	SO-131	KODAK High Definition Aerochrome Infrared Film SO-131 (ESTAR Thin Base)	7.5	183	2.5 mil ESTAR
	SO-242	KODAK Aerial Color Film SO-242 (ESTAR Thin Base)	7.5	285	2.5 mil ESTAR
	SO-255	KODAK Aerial Color Film SO-255 (ESTAR Ultra Thin Base)	7.5	285	1.5 mil ESTAR
	SO-315	KODAK High Definition Aerial Film SO-315 (ESTAR Ultra-thin Base)			

APPLICATION	AERIAL FILM CODE OR DESIGNATION	NAME	AFI	RP	BASE
	SO-360	KODAK Ektachrome Duplicating Film SO-360 (ESTAR Base)			
	FE-3916	Color Infrared Film			
	SO-205	KODAK Aerial Color Print Film SO-205			
Color Duplication Films	SO-287	KODAK Aerial Color Print Film SO-287		776	5.6 mil Acetate
	SO-356	KODAK High Definition Ektachrome SO-356 (ESTAR Base)		170	4 mil ESTAR
	SO-358	KODAK Aerocolor HS Film SO-358 (ESTAR Base)			
	SO-360	KODAK Ektachrome Aerographic Duplicating Film SO-360 (ESTAR Base)		105	4 mil ESTAR
	7271	Eastman Color Internegative Film 7271		300	
	7381	KODAK Color Teleprint Film 7381			5.6 mil Acetate w/ rem jet

In addition to these films another 25+ special order and experimental films were manufactured and used to meet special requirements and operational certification of new technologies.

Appendix D

CHRONOLOGY OF BLACK & WHITE FILM PROCESSING EQUIPMENT

NAME	YEARS IN SERVICE	DECRIPTION	OBJECTIVE
Eltrons 1 & 2	Mid 1950s	The original "kluged" deep-tank processors used to process U-2 original records, one for primary development and the other for secondary development	Become operational with pressure of time and cost
Speltron/ Grafton	Late 1950s	Modified Eltrons to include spray secondary development with each machine having a complete process	Establish a single pass process
Drape	Mid to late 1950s and early '60s	One of the original deep-tank processors for dupe films	Establish a duplicate process capability
Model 3	Mid to late 1950s and early '60s	A dupe film-processing machine that incorporated a spray developer cabinet, other stages deep-tank	Same as Drape but with spray development
Kongo	Mid to late 1950s and early '60s	A dupe film-processing machine used as a back up to the Drape and Model 3; All sections were spray	Redundancy
Trenton 1 & 2	Early 1960s through '70s	Newly designed and fabricated Original Negative processors incorporating spray primary, secondary, and tertiary development with density scanning capability between primary and secondary; Normal transported speeds were 20 ft./min; Installed at Bridgehead in 1962 and processed all subsequent Corona film records	Provide reliable and repeatable capability at Bridgehead
Dalton 3,4,7 & 8	Early 1960s through '80s	Newly designed and fabricated dupe film processors, with spray developer and finishing stages; Installed at BH in 1962; these machines transported film at 100ft./min.; in the mid 70s, the developer cabinets were converted to viscous; to allow high speed processing, the exposed film entered the developer cabinet via "twister rolls" to enable the film to be viscous coated at the center of a spiral and leave through a squeegee and stop unit	Improved reliability and capacity; Later to incorporate viscous development

NAME	YEARS IN SERVICE	DECRIPTION	OBJECTIVE
Yardleigh 5 & 6	Late 1960s, early 1970s	Original negative processors capable of frame-by-frame development at 20-30 ft./min.; accomplished by scanning the negative after primary development and then using hoppers to apply viscous developer, when required, to achieve a three-development level process capability on a frame-by-frame basis; in the mid '70s, they were converted to single hopper dual gamma process	Establish a three development level capability on a frame-by-frame basis to better handle original records with short frames; later, were chosen to incorporate single hopper process
Ontario 9 & 10	Late 1970s, and '80s	Original negative processors incorporating single stage viscous development made possible by developer design that produced dual gamma sensitometry; the developer was applied with a shell coater and finishing stages were of deep-tank design	Take advantage of the dual gamma process in an end-to-end design; better humidity/ temperature control, improved dryer design, etc.

Appendix E

CHRONOLOGY OF SPECIALIZED B&W PROCESSING EQUIPMENT

NAME	YEARS IN SERVICE	DESCRIPTION
Flintstone	1963-1965	A lab processor designed to process emulsion-coated glass plates duplicating negative images acquired for the mapping community
Snowflake	Late 1960s, early '70s	An early "kluge" used to evaluate viscous developer formulations
Dundee 1 & 2	1970s and '80s	Well designed and fabricated laboratory processors used to evaluate developer formulas, chemical thickeners for viscous layer development, viscous layer squeegee removal, etc. in a complete end-to-end process
VSSP	1970s and '80s	This viscous sensitometric strip processor was a laboratory processor capable of evaluating/certifying viscous mixes requiring a very small sample of the mix
Spriscus Fultron	1980s	A modified Fultron capable of being set up to incorporate either spray or viscous development
Poston	1980s	A coating machine that operated in white light to coat a very thin layer of gelatin, which included minute matte particles, onto the processed original negative record; it applied coating to minimize the formation of Newton's Rings during the transfer of images from originals to duplicate film during contact printing; the method was effective and avoided the complexity of adding liquid gates to contact printers with no significant loss of quality during the image transfer
Versamats	1960s, '70s and '80s	Commercially available roller transport processors used in many military photolab installations; BH kept Versamats operational so that, through testing, it was able to provide the field with machine-specific processing specs for many film products

Appendix F

CHRONOLOGY OF COLOR PRODUCTION PROCESSING EQUIPMENT

NAME	YEARS IN SERVICE	FUNCTION
Eltron	1962–1965 *	An early attempt to modify a discarded B&W processor to provide a color reversal process for early testing
Grafton	1965–1970 *	A discarded B&W machine modified to incorporate a color process for original acquisition films and duplicates
Ragdoll	1963—1978	A reconfigured machine used mostly for making color inter-negatives for briefing boards early in the program to evaluate the advantages of color
Multi-Purpose Modular Processor (MP^2)	1978–until dismantled	A machine designed for experimentation and process evaluation with extensive flexibility in configuration, temperature control, solutions handled, etc.
Color Production Processor (CP^2)	1982–until dismantled	A newly designed and fabricated color-processing machine used primarily for duplicate processing with much higher transport rates than other color machines provided
Kodak Color Aerial Film Processor, Model RT 1411; resulted in Model RT 1811 later	1962–to present	A commercially available roller transport color processor used at a few field military installations; Bridgehead kept one of these machines operational to be able to support field operations and to support requests for smaller color enlargements. The Model RT 1811 exhibited increased through-put rate with addition of a four-section tank.

*Indicates approximate use dates. Actual dates not recorded.

Appendix G

BLACK &WHITE AND COLOR PRINTERS

PRINTER	APPLICATION	LIGHT SOURCE(S)	EXPOSURE CONTROL	ACTIVE CONTRAST CONTROL	FILM HANDLING	MISC
Concord	B&W; 35-70mm	100 watt Ultra-Violet (UV)	Various slit sizes; variable voltage transformer lamp adjustment	None	Pressure roller/ small movable drum; 4 inch spindles	Table top unit; early Corona and Lunar Orbiter
Galaxie	B&W; 35-70mm; 5 inch	250/500 watt UV	Various slit sizes; variable voltage transformer lamp adjustment	None	Larger 5 inch movable drum; 5 inch spindles	Newer version of Concord; follow-on for Corona-very early use
Matrix Rainbow	Color; 70mm-9.5 inch	3 tungsten-iodine lamps; 3 Red, Green, Blue (RGB) filter trays	Independent lamp voltage controls; auto exposure correction matrix		Pressure roller/drum transport; 25-100 ft./min.	Anti-Newton ring liquid application capability
Niagara I	B&W; Color Mod. Kit; 70mm-9.5 inch	100 watt mercury vapor lamp; tungsten color printing capability	Indexed density wedge	None	Raisable pressure roller/drum transport; 25-100 ft./min.	
Niagara II (Redondo)	B&W; color Mod. Kit; 70mm-9.5 inch	400 watt mercury vapor lamp; tungsten color printing capability	Indexed density wedge	ABCC	Pressure roller/drum transport; 25-100 ft./ min.; raisable lamphouse	
Niagara III	B&W; color Mod. Kit; 70mm-9.5 inch	400 watt mercury vapor lamp; tungsten color printing capability	Indexed density wedge	ABCC	Pressure roller/ drum transport 25-100 ft./min.; raisable lamp house	Calibrated exposure control meter; in-line film cleaning

PRINTER	APPLICATION	LIGHT SOURCE(S)	EXPOSURE CONTROL	ACTIVE CONTRAST CONTROL	FILM HANDLING	MISC
Kingston	B&W; 70mm-9.5 inch	400 watt mercury vapor lamp	Indexed density wedge	ABCC	Pressure roller/drum transport; 25-100 ft./min.; raisable lamp house	Gimbaled transport rollers; large diameter print drum; designed for low distortion printing
Cayuga	B&W; 70mm-9.5 inch	400 watt xenon lamp	Electronically controlled lamp	ABCC	Pressure roller/drum transport; 100 ft./min.; raisable lamp house	In-line scanning with real time frame-by-frame or operation exposure and contrast control; anti Newton ring liquid application capability
Oneida	B&W; 70mm-9.5 inch	One 400 watt xenon lamp; one 400 watt doped xenon lamp	Electronically controlled vane modulators	Select Wave-length Printing (SWP) (ratio between 2 lamps)	Pressure roller/drum transport; 25-100 ft./min.; raisable lamp house	Computer controlled from off line exposure determination; frame mark detection; anti Newton ring liquid application capability
Selective Image Printer (SIP)	B&W; 70mm-9.5 inch	One 400 watt xenon lamp; one 400 watt doped xenon lamp	Electronically controlled vane modulators	SWP (ratio between 2 lamps)	Linear gate; ON slew with accumulators; printed ON images in predetermined order; up to 350 ft./min.	Computer controlled exposure determination; frame mark detection
Colorado	B&W; color	3 tungsten-iodine lamps; 3 RGB filter trays	Independent variable voltage transformer lamp voltage controls		Pressure roller/drum transport; 100 ft./min.	Compact design for small lab & shipboard use.
Seneca	Select frame printing; B&W	100 watt mercury	Independent variable voltage transformer lamp voltage control; used std. Niagara console	None	Step and repeat and/or multiple ON frames in a roll; raisable lamp house; air bag platen	Experimental; frame-by-frame printing

PRINTER	APPLICATION	LIGHT SOURCE(S)	EXPOSURE CONTROL	ACTIVE CONTRAST CONTROL	FILM HANDLING	MISC
Framingham	Color; B&W inter-negative	500 or 1000 watt tungsten	Neutral density and color filters in 3 filter trays; printer speed electronically controlled	Related to the RGB filters	Pressure roller/drum transport; 5-100 ft./min.	Permitted 50 and 100 ft/min printing; four to 10X faster than Rainbow; Anti-Newton ring application capability
Pocono	Electro-Photo-graphic Printer/ Processor; 5 inch roll capability		Independent variable voltage transformer lamp voltage controls			Liquid toner; operated in low light environment
Kokomo	B&W; color; 70mm-5.0 inch	Interchange-able mercury (B&W) & tungsten (color)	Independent variable voltage transformer lamp voltage controls		Pressure roller/drum transport; 100 ft./min.	Designed for table top applications
Texas	Enlarging roll printer-2X				70mm original film to 5 inch duplicating film	

Appendix H

EQUIPMENT DEVELOPMENT

The U.S. Government, working closely with Kodak operatives, never classified the specialized equipment that Design and Engineering (D&E) developed for use in Bridgehead operations and sold to government customers. Although the design occurred within a classified perimeter where the workforce readily confirmed designs and development as meeting operational needs, they manufactured the equipment in open shops from unclassified drawings. With few exceptions, the classified distinction applied only to the equipment installation locations and missions supported.

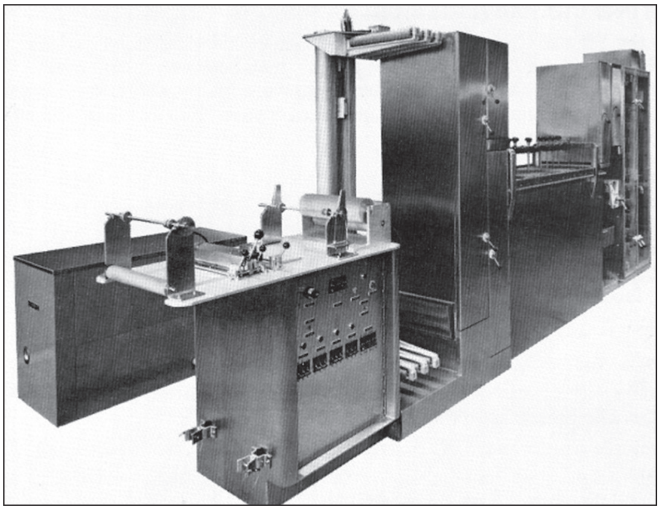


Figure 35: Fultron Film Processor. Ground Handling Equipment for Reconnaissance/Aerial Photography Fact Sheet, June 1967, produced by Bridgehead's Special Programs unit.

❖PROCESSORS

Fultron Film Processor

The D&E team designed the Fultron Processor for high quality continuous processing of both original negative and duplicate B&W films in semi-permanent installations. The Fultron possessed the capability to process films in widths of 70mm to 9.5 in. through a 170-ft. long traditional serpentine thread path at speeds from 5 to 50 ft./min. depending on the film and process in use. A feed-stand and supply elevator (accumulator) allowed repetitive splicing of rolls of film into the film path for continuous processing, while a similar arrangement at the take-off end of the processor allowed technicians to remove rolls of fully processed film without interrupting processor operation. The processor applied the developer and stop solutions in spray cabinets for maximum agitation while fix and wash steps utilized counter-current immersion agitation. Wet sections of the 19-ft. processor and all solution handling equipment were made of stainless steel for maximum corrosion resistance. A freestanding solution recirculation and temperature control module, located behind the machine, tied into chemical supply lines from a separate mix room facility and provided controls for filling and replenishing solutions. The engineers designed the processor and its recirculation module for operation in a common darkroom with appropriate safelights. Taking advantage of stainless steel fabrication technology used in the bulk-milk handling industry, factories in Wisconsin built 15 Fultrons, which technicians subsequently installed in various sites in the 1970s. NASA's Johnson Space Center in Houston, Texas housed two Fultrons to support space exploration programs. Bridgehead retained one Fultron and converted it to a Spriscus Fultron–a machine used as either a spray or viscous processor.

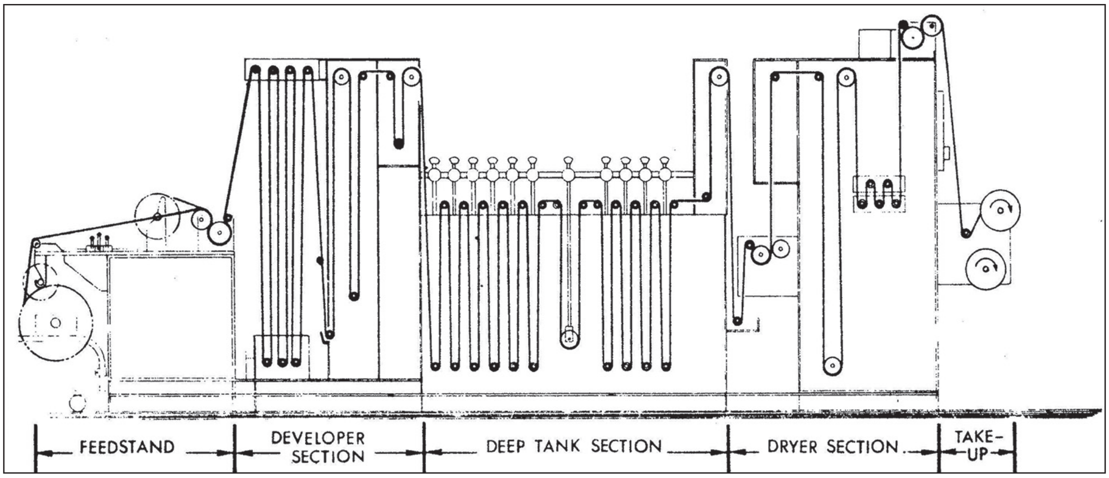


Figure 36: Fultron Film Processor's Film Path. Ground Handling Equipment for Reconnaissance/ Aerial Photography Fact Sheet, June 1967, produced by Bridgehead's Special Programs unit.

Viscous Fultron Processor

By replacing its spray developer cabinet with a viscous developer cabinet and making a few other relatively minor changes, engineers converted the Fultron Film Processor to a Viscous Fultron Processor. The newly assembled processor, now 23-ft. long, had a 310-ft. thread path. The viscous developer cabinet had an extended and convoluted thread path so that once it coated the film on the emulsion side with viscous developer, the emulsion side of the film did not contact any rollers until it reached the squeegee removal station and a stop bath. The cabinet also contained its own internal temperature and humidity control system.

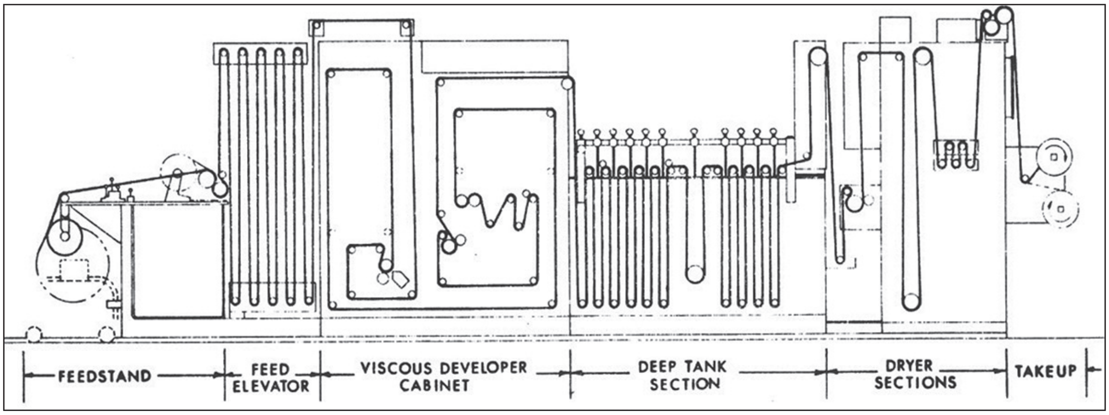


Figure 37: Viscous Fultron Film Processor Thread path.
From archives of Bridgehead's Special Programs unit.

Victor Film Processor

The Victor Processor combined viscous development with conventional fixing, washing, and drying to process continuous lengths of either original negative or duplicate B&W films at speeds up to 100 ft./min. Engineers designed this machine to apply the most advanced techniques in B&W silver halide processing technologies to produce optimum quality output in high volume around-the-clock production operations. Approximately 39-ft. long, this processor weighed nearly 14,000 lbs. (without solutions) with a thread path of 430 feet. The engineers designed all wet sections for fabrication from stainless steel, for maximum corrosion resistance. In a significant departure from conventional spray or immersion development processes, the processor utilized developer in a viscous formulation similar to the Viscous Fultron. Technicians prepared viscous developer in a chemical mix room by combining a water-soluble polymer with a specially formulated photographic developer. In the processor, it was heated to a pre-determined temperature (usually 90 degrees), and a precision hopper evenly coated a thin layer (about .06-in. thick) on the emulsion side of the moving film web. Because the viscous coating had sufficient resistance to shear, it maintained a static layer of uniformly concentrated developer along the length and width of the film undergoing processing. After a preset length of time, the web moved through a squeegee station that uniformly removed and discarded the developer. It then passed immediately into an acidic stop bath solution to terminate any residual development. During its travel through the viscous developer cabinet, the film web was only supported on its base side (no contact on the emulsion side). Operators maintained the air in the thermally insulated developer cabinet at the temperature of the applied developer (to maintain a stable development process) and at a high level of relative humidity (to prevent evaporative cooling of the warm developer). Located behind the processor, the conditioning unit re-circulated air to the developer cabinet. Although Bridgehead used similar processors for processing ON films, the company built and sold only four Victor Processors.

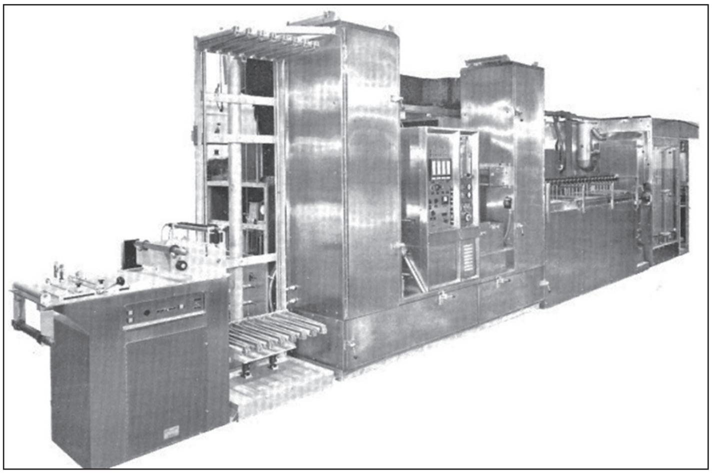


Figure 38: Victor Film Processor. Ground Handling Equipment for Reconnaissance/Aerial Photography Fact Sheet, September 1976, produced by Bridgehead's Special Programs unit.

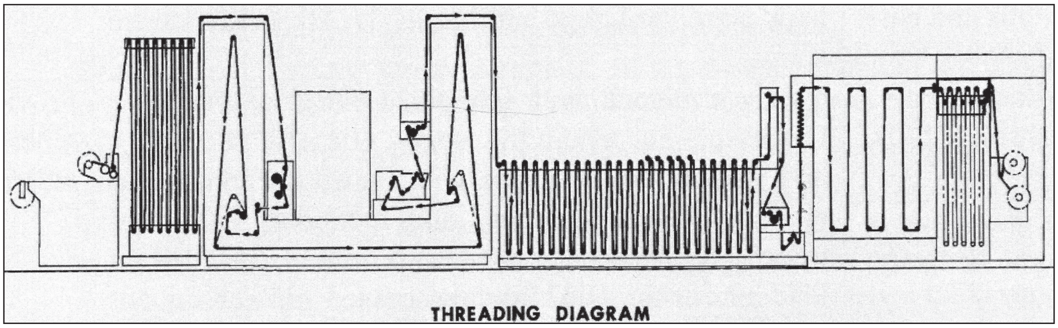


Figure 39: Victor Film Processor Thread path. From archives of Bridgehead's Special Program's unit.

❖TITLERS, CLEANERS, AND LACQUERERS

Tacoma Continuous Film Titler

The Tacoma was a simplified optical titler designed for use on Kodak Versamat Processors and Fultron Film Processors in customer facilities. When installed on the feed ends of these processors, it used an LED array to expose sequence numbers, index marks, and desired titling data along one edge of the unprocessed aerial film web as it entered the processor. This technique eliminated post-processing titling operations, and the photographic title became an integral part of the processed imagery. The titler consisted of a control console, a feed adapter, and an interconnecting cable. The console provided a keyboard, an illuminated display, and controls for setting fixed title spacing. As such, the titles were not frame-oriented, but using knowledge of the camera's frame exposure settings, technicians set title spacing to enable using at least one sequence number to identify each frame. This titler allowed the option of leaving the feed adapter in place for titling and non-titling processing.

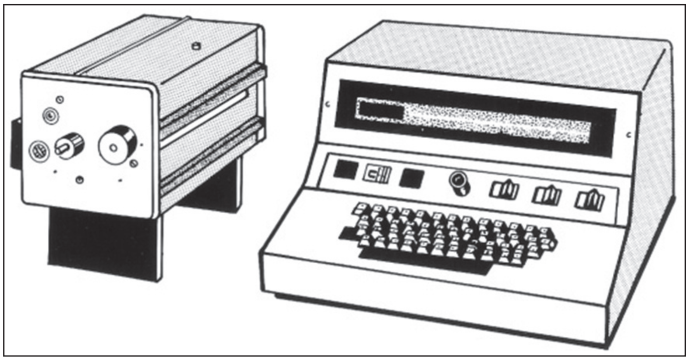


Figure 40: Tacoma Continuous Film Titler. Image Management Fact Sheet, 1986, produced by Bridgehead's Special Programs unit.

Delaware Portable Film Titler

Aimed at supporting compact military photo labs, this compact titler used heat and pressure to transfer opaque pigment from a titling tape to the surface of processed film–either along the web or across it (between frames). Machine operators manually indexed film passing between rolls over an illuminated translucent platen at the titling station. When in position, the operator actuated the pneumatic titler head to initiate a title transfer. Information transfer included a four-digit incremental frame number and a fixed field of repeated information. The possibility existed to generate titles either by lead type (for long runs) or by an embossed expendable plate (for maximum flexibility in short runs). It required an adjunct device known as an Embosser/Leveler to produce embossed plates for titling. Ordinary lead type required a selection of lead type (various fonts, etc.), a type holder, tools, and miscellaneous hardware used in handling lead type. The Delaware included a sturdy carrying case for protection during transport and storage.

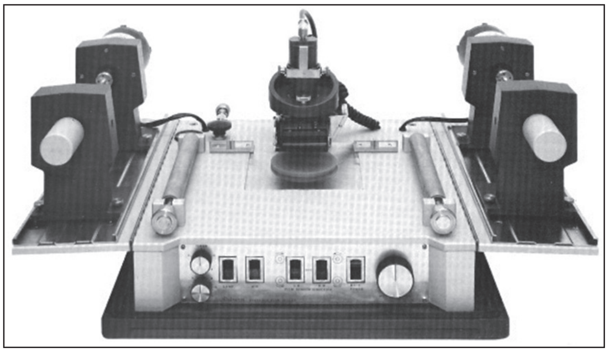
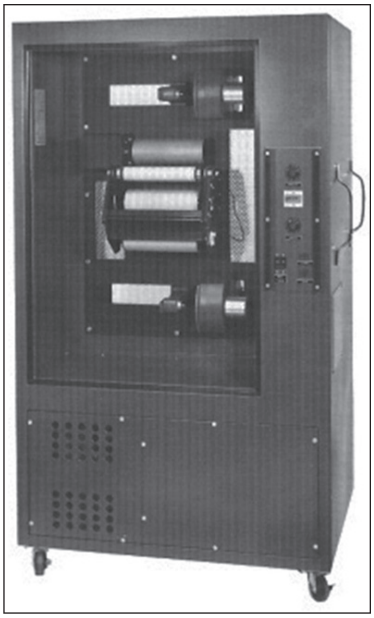


Figure 41: Delaware Portable Film Titler. Image Management Fact Sheet, 1986, produced by Bridgehead's Special Programs unit.

Stickney Film Cleaner

As its name suggests, the Stickney Cleaner used adhesive drums to remove surface and embedded particles from both sides of aerial roll films. Technicians wrapped the two disposable film-cleaning drums with eight layers of 9.7-in. wide single-sided adhesive tape. As the tackiness of an outer layer diminished, they removed it, leaving a fresh new surface available to continue the cleaning process. Static eliminators inhibited static build-up. On average, a single adhesive tape layer cleaned up to 40,000 feet of processed film. A highly effective film cleaner, the Stickney produced a loud sound during its operation as the film and adhesive rolls separated during the cleaning process. The Webster Film Cleaner quickly replaced the Stickney.



Figrue 42: Stickney Film Cleaner.
Image Management Fact Sheet, 1986,
produced by Bridgehead's Special Programs unit.

Webster Film Cleaner

Designed for clean room operation, the floor-standing Webster Film Cleaner was capable of cleaning films from 70mm to 9.5 inches in width. It utilized two webs of soft loosely woven fabric moving in light contact with both sides of the film web to pick up loose surface particles attracted to or adhering to rolls of processed B&W or color aerial films. The film roll moved through the cleaning station at 100 frames per minute (fpm) while the cleaning fabric moved in the opposite direction at 0.1 fpm. To contain the spread of particulates, workers isolated the cleaning chamber from room air by a rear-to-front laminar flow of filtered forced air. Static eliminators neutralized static build-up.

Figure 43: Webster Film Cleaner.
Image Management Fact Sheet, 1986,
produced by Bridgehead's Special Programs unit.

Lacquerers

Before the advent of optical titling (titling data added by light exposure of frame information along the edge of the original negative film web before it was fully developed in the processor), technicians added frame data to the ON after processing in a separate mechanical titling step. Early efforts concentrated on adding the titling along the film edge adjacent to the frame undergoing the identification process. They accomplished this task by mounting rolls of the original negative on a titling machine and by manually indexing the untitled frame into position under a titling head. When properly indexed, a foot switch tripped by the operator caused the printer head to transfer titling data using heat and pressure. It transferred data from a fixed field and a sequenced frame number through a web carrying a titling pigment (Brownsville tape). This process transferred the titling data to the ON. Although engineering and operations expended significant effort to optimize the durability of the titled data while minimizing the extent of film embossing, it was vulnerable to flaking and degradation through handling.

Protection of the titled data necessitated moving the titled film roll to an edge-lacquerer where the apparatus applied a continuous stripe of lacquer to the underside of the horizontal web as it moved at constant speed in contact with a lacquering wheel. Driven by the web, the ¾-in. wide x 4-in. diameter wheel picked up lacquer as it passed through a small reservoir beneath the wheel. It carried it up to the film away from the framed imagery but over the edge-titled data. Sufficiently volatile and thinly applied, the lacquer dried quickly, which allowed the expedient rolling up of the film shortly after the lacquering station. The "lacquered roll" of original negative film was then ready for printing and production handling. A modified version of the Clinton Cleaner/Waxer served as the equipment base for edge lacquering. This modification replaced the cleaner station with a lacquering wheel and reservoir. The waxing station was by-passed, and the film followed the remainder of the unit's web path, which gave the lacquer ample time to dry before take-up.

With some camera systems, as the frames became shorter and titled information expanded, it became necessary to place titling data between adjacent frames. Titlers easily accommodated this requirement, but the need to reliably coat a short (interrupted) stripe of lacquer over the between-frame titling data required new developments. In addition, to eliminate any possibility of the inadvertent transfer of the cross-frame titled data into an image area before it was lacquered, a roll of soft lightweight interleaving paper was mounted alongside the titler's take-up roll. The apparatus drew the paper into the titled film roll as titling progressed, temporarily protecting the titled data and insuring that there was no migration of any stray titling material into image areas.

The operation retained the use of a wheel to apply lacquer as in edge lacquering, as the simplest and most reliable way to apply the lacquer. The D&E team devised a mechanism to cause the wheel to begin rotation and pick up lacquer before making contact with the near underside edge of the stationary web. Then, as a mechanism drove the rotating wheel across the underside of the web, it deposited the desired thin stripe of lacquer over the titled data. When the wheel reached the end of its travel at the far film edge, it required a low-level vacuum to evaporate off a small amount of excess lacquer that characteristically formed at the trailing edge of the stripe. After removing the excess lacquer through a slot in the periphery of the wheel, the machine's wheel dropped down away from the web, and returned to a position before the near film edge as the machine's operator positioned the next inter-frame title into place. As the operator indexed the film into position, a take-up spindle mounted adjacent to the lacquerer's supply roll took up the used disposable interleaving paper. To meet production needs, they developed a breadboard unit to demonstrate the feasibility of the cross-frame lacquering process and pressed it into service until the production of units with integral dryers. Kodak subcontracted Dynametrics Corporation of Pasadena, California for the design and assembly of the units, named LaCrosse Lacquerers.

❖PRINTERS

Continuous Contact Drum Printer

Printing was a major step in the film reproduction process. It involved placing the processed original negative film (with its attached header and trailer) in emulsion-to-emulsion contact with a duplicate film while projecting "light" of the proper wavelength (UV radiation for B&W and visible light for color) through the negative, generating a positive latent image in the duplicate film. To accomplish this task in a high-volume production environment, operators threaded film from a roll of unexposed duplicate film over a printing drum (emulsion up) and onto a take-up spool. Similarly, they threaded the ON emulsion side down from its supply roll over the duplicate film on the printing drum and onto its take-up spool. Then, a pressure roller pressed the two films into intimate contact on the printing drum and held them in contact through a combination of web tension, partial vacuum, and electrostatic and molecular attraction. Simultaneously, the equipment projected "light" of the proper wavelength and intensity through a slit above the drum and onto the "film sandwich" as it was transported by the rotating drum. After exposure, separate web tensions pulled the two films apart as they were taken up on their respective film spools — the duplicate film containing a positive latent image of the ON imagery. A variety of drum-type continuous contact printer applications used this generic configuration for applications for crucial safe handling of the original negative, in addition to the need for high quality image transfer during the printing of duplicate films. Highly skilled operators were trained to operate these machines to fulfill rigorous mission demands. The D&E team developed several other printer configurations for specialized duplicating tasks.

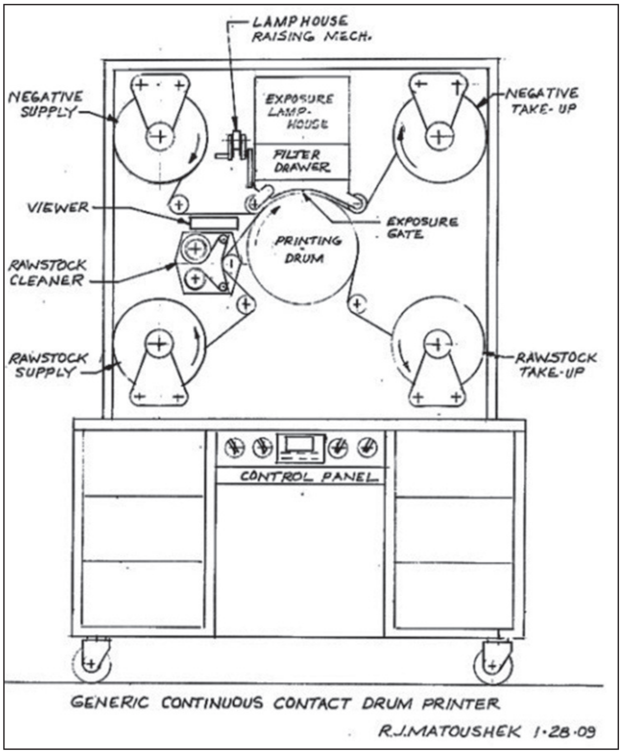


Figure 44: Generic Continuous Contact Drum Printer. Illustration by R. Matoushek.

Niagara Printers

The Niagara family of printers served as the workhorse in Bridgehead B&W production operations. They were floor-standing units (74 ½-in. tall weighing up to 1400 lbs.) capable of operating at 25, 50, or 100 ft./min and specially designed for operation in reduced safelight for the films being printed with one or more in a single print room. The printer's spatial image quality specifications required a minimum of 400 cycles/mm from a high contrast (1000:1) reticle target using Kodak High Resolution Aerial Duplicating film (ESTAR Base) SO-192.

Figure 45: Niagara Printer, Model II. Ground Handling Equipment for Reconnaissance/Aerial Photography Fact Sheet, September 1976, produced by Bridgehead's Special Programs unit.

The most advanced version of the Niagara Printer series featured:

- A raisable lamp house to permit slewing of the ON
- Interchangeable mercury-arc or tungsten light sources to handle high density imagery and some color printing
- A log intensity meter to monitor mercury lamp intensity
- Footage and copy counters
- Easy-load spool spindles to accommodate film in widths from 70mm to 9.5 inches and roll diameters up to 10.5 inches on MS 26565 Aerial Film Spools
- End-of-ON film detection to minimize duplicate film waste
- A uniformity mask to ensure balanced exposure across the film web
- Neutral density filters for uniformly adjusting "light" source attenuation across the full width of printable film
- Bias filters and a continuous density wedge for comprehensive "light" source attenuation
- Other optional accessories

Rainbow Continuous Printer

The Rainbow Printer was a color drum-type printer aimed at high-speed printing of color reversal and color print films. This floor-standing machine (73 in. tall, weighing 1500 lbs.) was accompanied by a Lamp Control Unit (300 lbs.) that regulated the output of the printer's three separate light sources. Both units were designed to operate in total darkness because of the broad sensitivity range of color films.

Figure 46: Rainbow Continuous Printer. Ground Handling Equipment for Reconnaissance/Aerial Photography Fact Sheet, October 1978, produced by Bridgehead's Special Programs unit.

Outputs from three tungsten iodine-cycle quartz lamps (housed in a common raisable lamp house) each channeled through heat absorbers before passing through three different color filters to form narrow spectral bands of red, green and blue light. The separate bands of light combined at the lamp house's slit aperture by a system of mirrors. The Lamp Control Unit knobs allowed the independent, manual adjustment of the three lamps output intensities. Technicians obtained overall color balance and density changes by varying the voltage to each lamp. Like the Niagara Printer, this printer had speeds of 25, 50, and 100 ft./min., and spindles accommodating MS 26565 Aerial Film Spools in widths of 70mm to 9.5 inches, and up to 10.5 inches in diameter. The Rainbow Printer also utilized other film-handling features and several of the accessories found on the Niagara Printer.

Colorado Continuous Printer

The D&E team designed this compact drum-type printer to meet high quality and high volume production requirements in military land-based and shipboard installations. To facilitate installation in restricted spaces, it had a compact design that readily separated into three easy-to-carry modules each of which could pass through 26 in. x 40 in. openings. The Colorado could reproduce photographic images on color or B&W films and photographic paper at speeds up to 100 ft./min. Although compact, it handled standard width films up to 10.5 in. in diameter on MS 26565 spools. The Colorado lamp house contained three tungsten iodine-cycle quartz lamps. White light from each lamp passed through a heat-absorbing glass and a color filter to form narrow spectral bands of red, green, and blue light, which combined at the printing slit by a system of mirrors. Operators achieved color balance and printing densities by adjusting the voltage to each lamp, thereby controlling the light intensity of each color. To aid in the set-up and monitoring process, the printer included a MacBeth Photometer (mounted on the side of the printer cabinet) to readout lamp intensities while making adjustments.

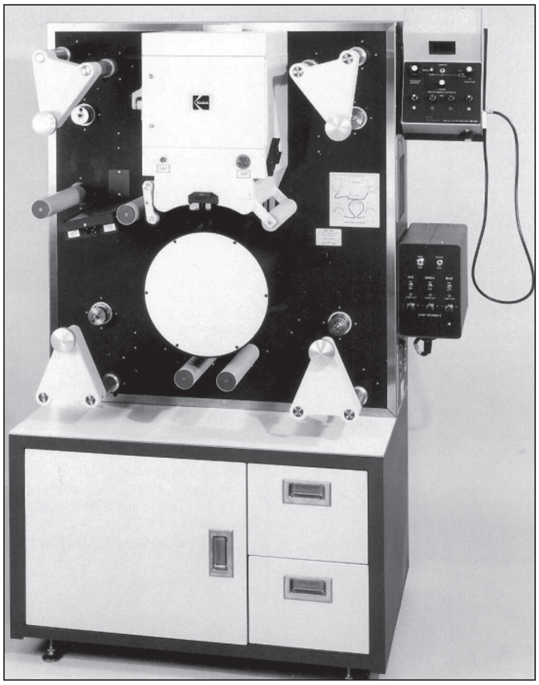


Figure 47: Colorado Continuous Printer.
Image Management Fact Sheet, April 1994,
produced by Bridgehead's Special Programs unit.

Figure 48: Kokomo Continuous Printer.
Image Management Fact Sheet, 1986,
produced by Bridgehead's Special Programs unit.

Kokomo Continuous Printer

The Kokomo, a tabletop drum printer, handled only 70mm and 5.0-in. wide films. The compact (37-in. high) and lightweight (200 lbs.) design enabled use in portable and compact photographic labs where it was frequently teamed with Kodak's Versamat Film Processors. With its slanted work-surface, it allowed printing of both B&W and color films and selected papers in a safe-lighted darkroom environment. Interchangeable tungsten and mercury lamps and mirrors accommodated a wide range of light-sensitive duplicating materials. It had a fixed operating speed of 100 ft./min. and a resolution transfer capability of over 350 cycles/mm.

Oneida Continuous Printer

The Oneida Printer—Bridgehead's first application of a digital computer—controlled continuous roll printing in a production environment. Using floppy discs and a Data General computer, it provided the capability to produce frame-by-frame or intra-frame density and contrast-corrected B&W contact prints. It handled roll films in widths of 70mm to 9.5 in. at speeds of 25, 50, or 100 fpm. A unique dual-lamp, high-intensity lamp house provided the energy required for contact printing of fine grain, high-resolution duplication films. Vane modulator assemblies, located in the upper portion of the lamp house, independently controlled exposure levels of the printing lamps for selective wavelength printing. Additionally, they equipped the Oneida with a frame-mark detection system that operated in conjunction with an encoder connected to the printing drum to synchronize density and contrast changes between and within frames. A system known as the Computer Assisted Control (COMAC) produced floppy disks of density data taken during inspection of first duplicates. Bridgehead operations used this data for producing subsequent duplicate copies on the Oneida, which technicians optimized for both density and contrast on a frame-by-frame or within frame basis.

Figure 49: Oneida Continuous Printer. Image Management Fact Sheet, 1986, produced by Bridgehead's Special Programs unit.

Selective Image Printer

The Design and Engineering Team developed the complex and formidable-looking Selective Image Printer (SIP) for specialized production printing. Using a linear gate (instead of a conventional printing drum) and a mini-computer for control, they designed it to print copies of selected frames from a continuous roll of B&W print-master film onto a continuous roll of duplicate film in the sequence and quantity defined by an operator or the photo lab's production control system. It handled the normal complement of film widths and lengths at printing speeds up to 350 ft./min in a darkroom environment. Unlike a drum printer, the linear gate quickly and simply separated the print-master from the duplicate printing stock between exposures. It also allowed the location of sensors below the gate where they could detect transmitted light-energy during exposure – a capability not possible with drum printers and one that allowed dynamic control of exposure levels within the frame undergoing printing. Finally, the linear gate minimized duplicate film waste inherent in frame-by-frame printing from a continuous print-master roll.

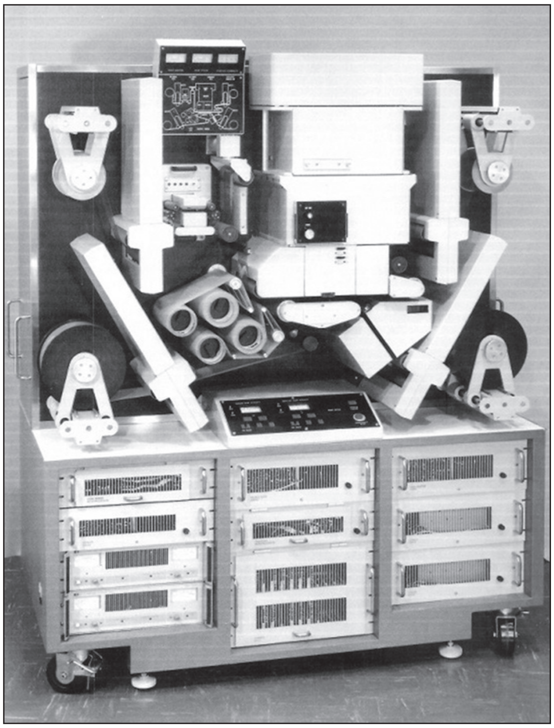


Figure 50: Selective Image Printer. From archives of Bridgehead's Special Programs unit.

Frame mark detectors automatically indexed the print-master into position for the next exposure while the apparatus held the duplicate film in position. The linear gate then closed, bringing the two film webs into intimate contact. After the film sandwich rapidly ramped up to printing speed, a focal plane shutter opened to allow exposure as the frame passed through the exposure area. After the frame printed, the printer closed the shutter, stopped and separated the film webs, and again indexed the print-master into position for the next printing step. Frame-by-frame printing required repetitive slewing of the print-master and incremental advancement of the duplicate material in the printing process; therefore, both supply and take-up film paths utilized film accumulators. Engineers designed these devices to remove the inertial masses of the rotating supply and take-up film spools from the printer's frame-by-frame mode of operation. Once set up, this printer demanded minimal operator interaction. The mini-computer either controlled the printer directly or prompted the operator to perform specific tasks, such as loading and unloading the print-master or duplicate film stock.

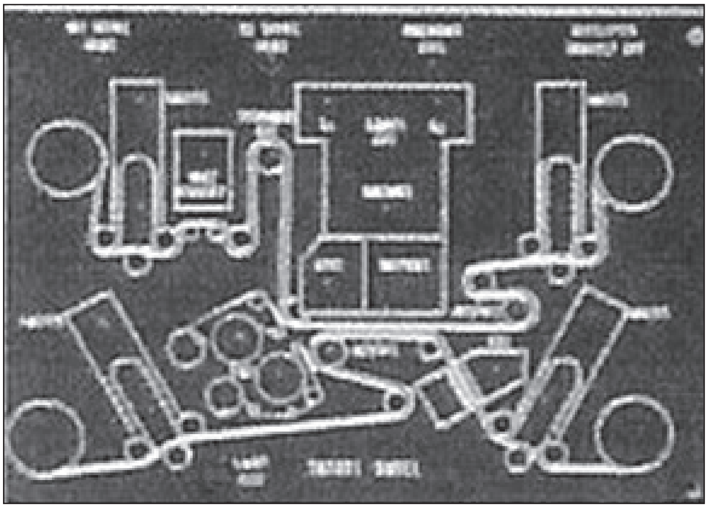
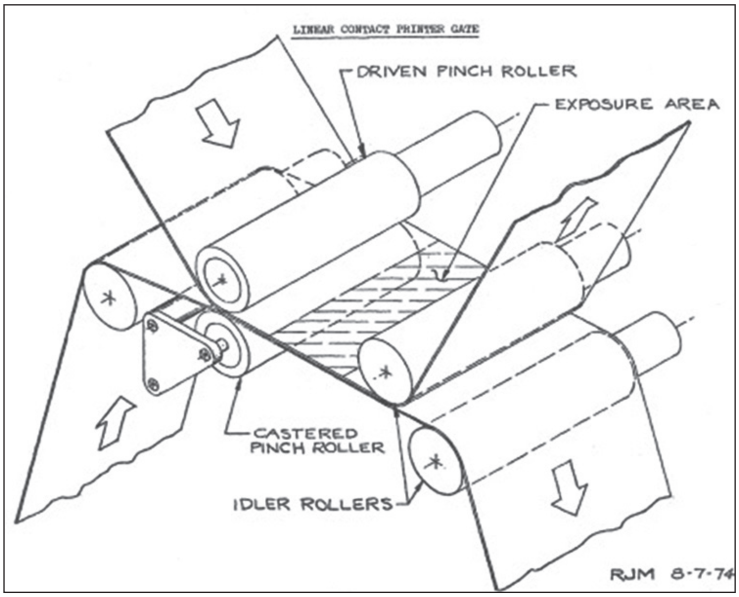


Figure 51: Selective Image Printer Threading Diagram.
From archives of Bridgehead's Special Programs unit.

Figure 52: Selective Image Printer Linear Gate Schematic. From archives of Bridgehead's Special Programs unit.

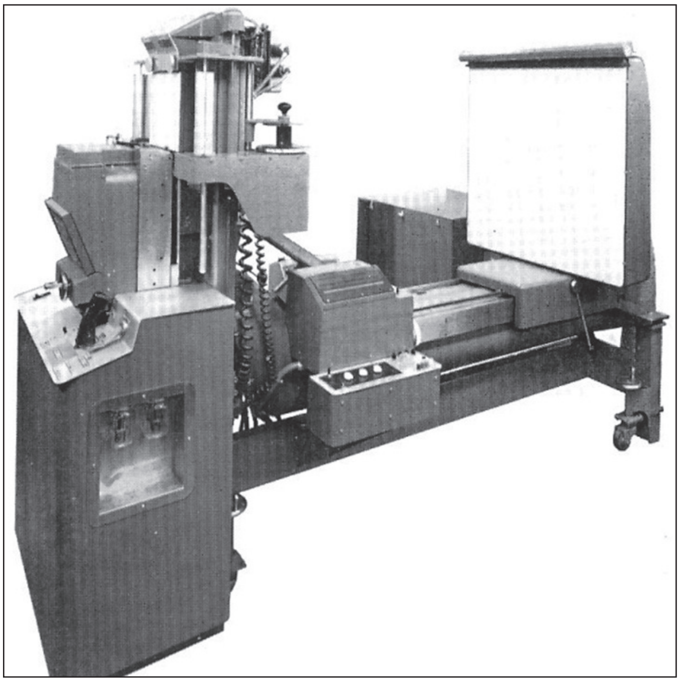


❖ENLARGERS

Beacon Precision Enlarger (BPE)

The Bridgehead operation used the BPE, a precision horizontal enlarger, to make enlargements of selected areas of B&W and color aerial film imagery primarily for extremely high quality briefing boards. A series of eight interchangeable lenses provided magnifications from 2.95X up to 153X. The design included five color-corrected lenses to permit production of B&W or color enlargements up to 40 inches by 40 inches. Resolving powers up to 828 cycles/mm at the negative were transferred at high magnification.

Figure 53: Beacon Precision Enlarger. Ground Handling Equipment for Reconnaissance/Aerial Photography Fact Sheet, July 1977, produced by Bridgehead's Special Programs unit.



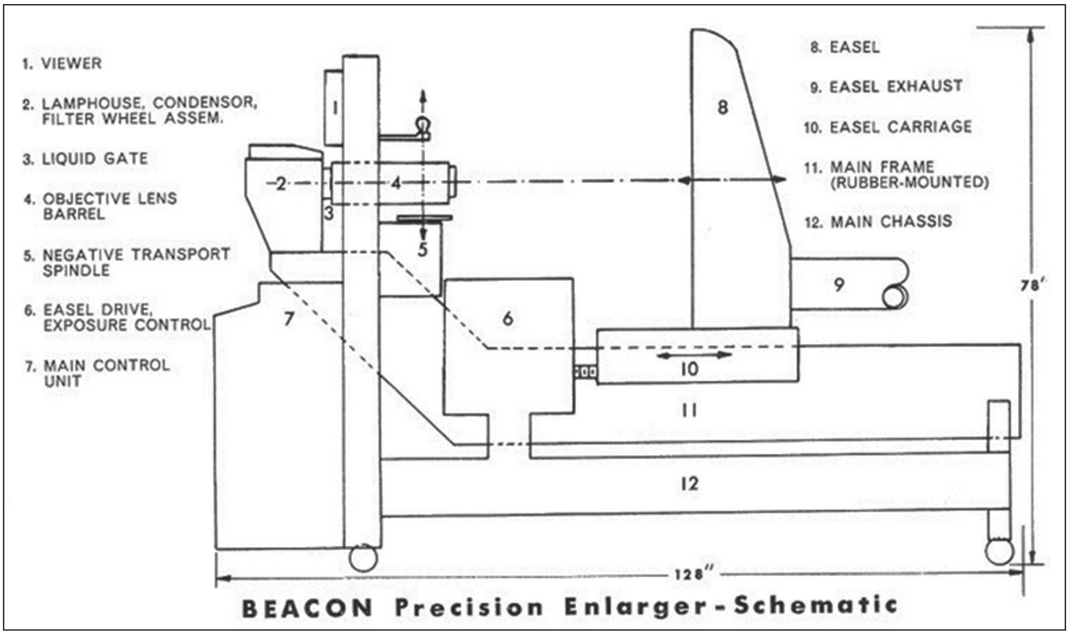
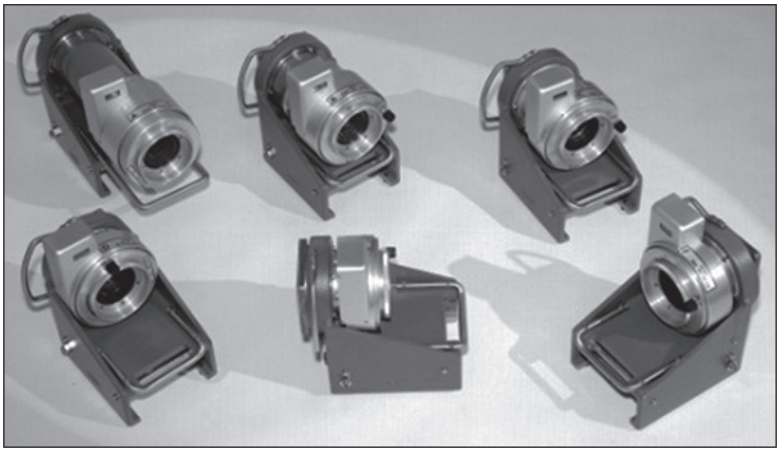


Figure 54: Beacon Precision Enlarger Schematic. Ground Handling Equipment for Reconnaissance/ Aerial Photography Fact Sheet, July 1977, produced by Bridgehead's Special Programs unit.

Negative field diameters from .32 in. to 3.7 in. could be printed from 70mm to 9.5 in. film rolls on MS 26565 Aerial Film Spools up to 7.6 in. in diameter. Operators clamped the film area to be enlarged between glass plates after injecting a coating of an index-matching fluid onto each side of the film to minimize the effects of scratches and abrasions and to eliminate Newton's rings. On the output side, the BPE handled cut sheets of film or paper up to 40 in. square on its vacuum easel. A separate enclosure housed the air handling system for the easel, which could be located outside the enlarger's darkroom. Operating aids included a semi-automatic system for selecting magnification and focusing, and a photometer helped establish correct exposure for the print stock in use. The intensity of the printing light source was adjustable to yield exposure times from one to 111 seconds. Because briefing boards remain an essential part of image information transfer, Bridgehead contracted the build of over 20 BPEs for installation in numerous government facilities. Several of them remain in use as of this writing.



Figrue 55: Beacon Precision Enlarger Lenses.
From archives of Bridgehead's Special Programs unit.

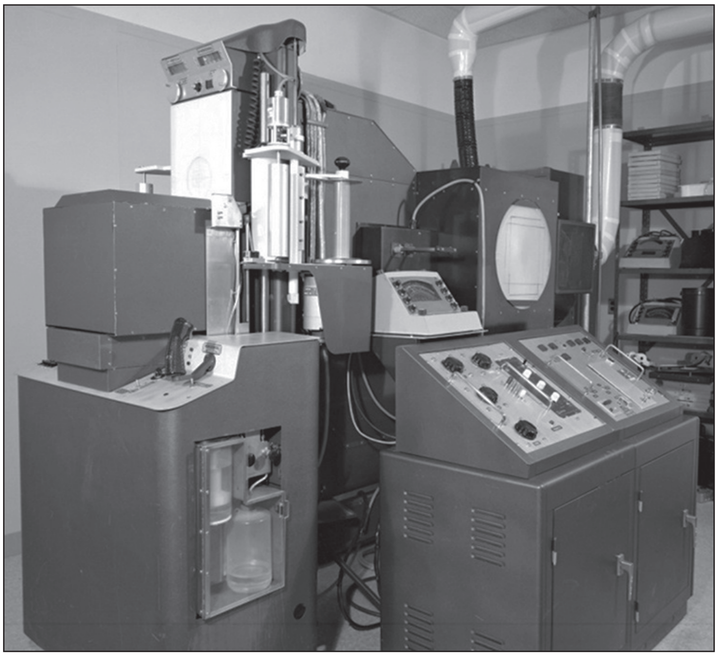
Standard Lens	Magnification	Field Diameter Negative	Print	Resolving Power At Negative With High Magnification
		(In.)	(In.)	(Cycles/MM)
A	2.95 — 5.3X	3.7	10.9 — 19.5	89
B	4.8 — 9.0X	3.7	17.6 — 33.	127
C	8.5 — 15.0X	3.7	31. — 54.	226
D	14.5 — 24.7X	2.1	30. — 51.	372
E	24.2 — 40.0X	1.24	30. — 50.	465
F	38. — 62.5X	.79	30. — 49.	660
Optional Lens				
G	60.0 — 97.X	.507	30.4 — 49.	741
H	95. — 153.X	.32	30.4 — 49.	828

Figure 56: Beacon Precision Enlarger Lens Chart. Ground Handling Equipment for Reconnaissance/Aerial Photography Fact Sheet, July 1977, produced by Bridgehead's Special Programs unit.

Pocatello Color Enlarger (POCE)

The D&E team designed the Pocatello, a one-of-a-kind precision horizontal enlarger, to make color enlargements of selected areas of film rolls. Its horizontal design shared a similarity to the Beacon Precision Enlarger. The Pocatello had an identification frisket in the printer gate for inclusion of information on the enlargement. The Pocatello operated with enlargement magnifications of 10X or 20X and a liquid gate capability. The original film roll and enlarger platen could rotate 90 degrees left or right to align the desired target on the enlargement. The three tungsten lamps were filtered to provide red, green, and blue illumination, and variable voltage transformers controlled each lamp, allowing rapid corrections for color balance and exposure.

Figure 57: Pocatello Color Enlarger. From archives of Bridgehead's Special Programs unit.



❖TABLES

A variety of specialized film-handling tables, all capable of handling films in widths of 70mm to 9.5-in. on Dexter or MS 26565 spools, were developed to support production operations.

Pre-Process Inspection Table

Skilled workers used this table for inspecting and preparing exposed, unprocessed rolls of film for processing. They repaired or removed damaged sections for separate processing, and used a pressure-sensitive tape splicer for rejoining the web. Short film rolls, idents, sensitometric strips, headers, and trailers could also be spliced into the main web. Cameras and RVs supplied exposed film, and the assembled films were taken-up on large floor-standing dollies, which also interfaced with processor feed-stands. Designed for darkroom use, motor-driven take-up spindles controlled by a foot switch allowed operators to keep their hands free to sense both edges of the film for nicks, tears, etc., for extended periods as it passed over the table.

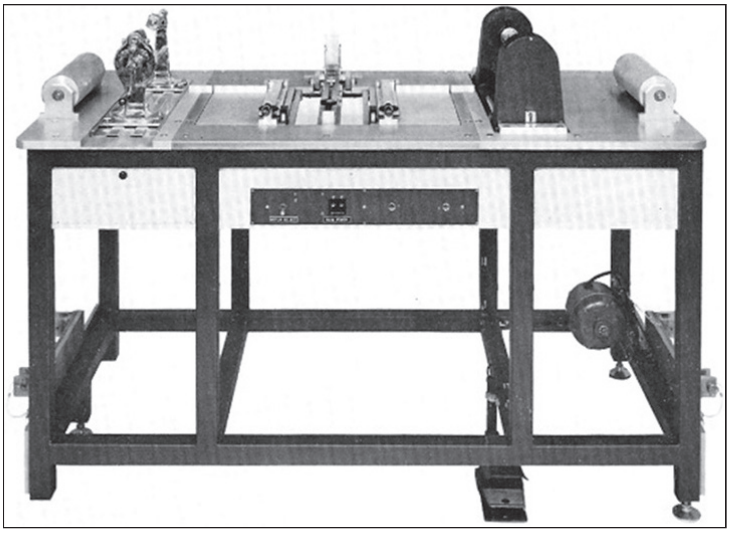


Figure 58: Pre-Process Inspection Table. Ground Handling Equipment for Reconnaissance/Aerial Photography Fact Sheet, May 1972, produced by Bridgehead's Special Programs unit.

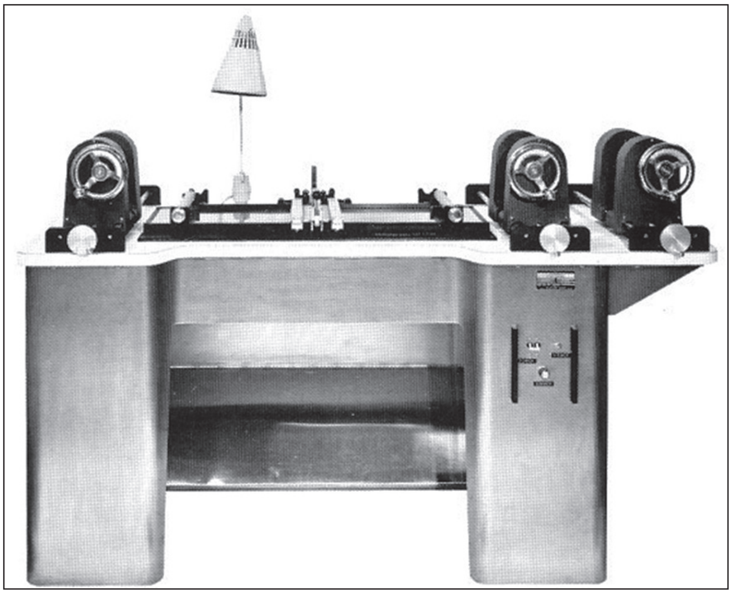


Figure 59: Editing Table. Ground Handling Equipment for Reconnaissance/ Aerial Photography Fact Sheet, September 1978, produced by Bridgehead's Special Programs unit.

Editing Table

With a smooth stainless steel base designed for clean-room use, operators used these tables for editing, inspection, evaluation, and assembly of processed film rolls. Available with either hand or motor-driven spindles, the tables included dual take-up spindles to accommodate editing operations. With a 30-in. wide viewer with variable light intensity and adjustable masks to control light flare along film edges, a film cutter and pressure-sensitive tape splicer, and an overhead viewing lamp for reflective viewing, Bridgehead operations greatly relied on these tables to achieve mission objectives.

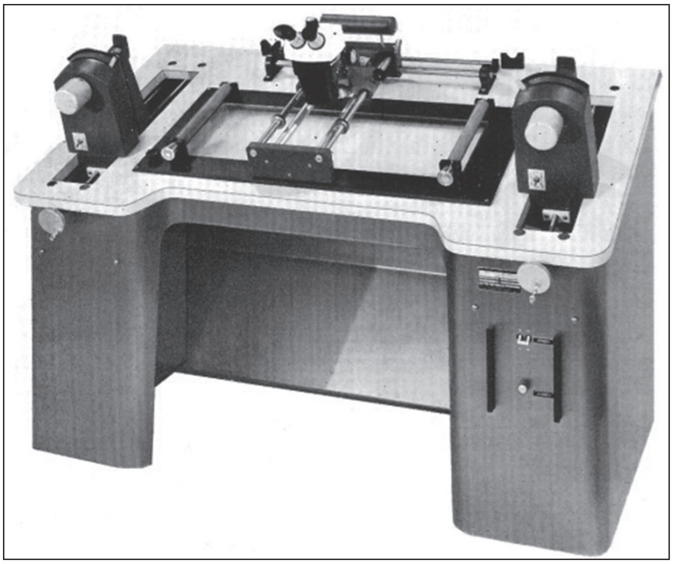


Figure 60: Microscope Viewing Table. Ground Handling Equipment for Reconnaissance/Aerial Photography Fact Sheet, April 1976, produced by Bridgehead's Special Programs unit.

Microscope Viewing Table

These tables carried a Bausch & Lomb binocular microscope with a 7:1 zoom feature and magnification from 10 to 280X for critical examination and evaluation of processed films. Motorized or manual rewind spindles, mounted on the inclined top, ensured operator ease and comfort during extended use periods. Ergonomically designed motorized rewinds facilitated exact positioning of the film web for magnified viewing. A 30-in. wide viewer with variable light intensity and adjustable masks provided illumination for viewing film transparencies. When not needed, they swung the microscope and supporting slide rails up and completely out of the way.

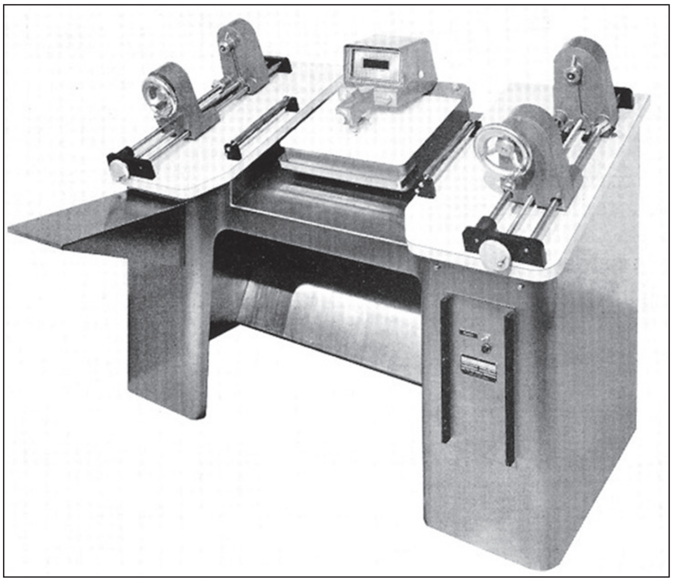


Figure 61: Densitometer Table. Ground Handling Equipment for Reconnaissance/Aerial Photography Fact Sheet, September 1976, produced by Bridgehead's Special Programs unit.

Densitometer Table

This slope-topped table carried a MacBeth Quantalog Densitometer with digital display for measuring diffuse transmission densities of half-millimeter areas of either B&W or color-processed films. An integral viewing surface, adjustable for ambient lighting conditions and overall film densities, aided in selecting image areas for taking density measurements. Manually controlled rewind spindles or, for handling long lengths of film, ergonomically designed motorized spindles were available. An easily detached writing surface allowed either right or left-handed operators to record densitometric readings.

Forty-Inch Evaluation Table

One of the most versatile tables designed and developed by D&E, this table enabled critical examination and interpretation of processed original and duplicate aerial film images. By moving the microscope from the film path and putting a pressure-sensitive tape splicer in place, its versatility allowed cross-utilization for film editing. It also introduced a type of opposing manual rewind spindle in which the film remained in a constant viewing plane to eliminate the need for gross focus adjustments in the microscope. Its 40-in. viewer, with built-in masks and variable brightness, made it ideally suited for examining and viewing long frames of imagery.

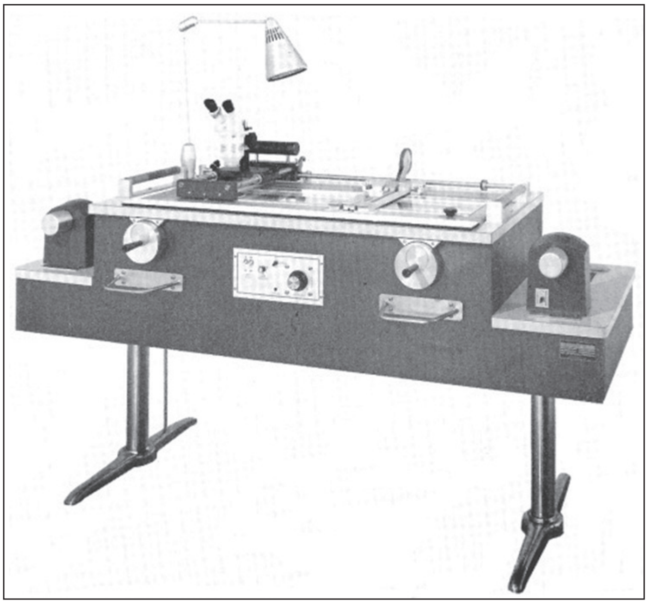


Figure 62: Forty-Inch Evaluation Table. Ground Handling Equipment for Reconnaissance/Aerial Photography Fact Sheet undated, produced by Bridgehead's Special Programs unit.

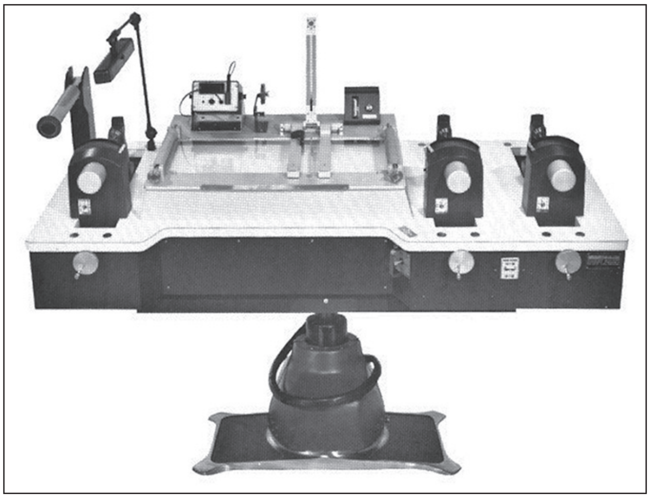


Figure 63: Camden Inspection Table. Ground Handling Equipment for Reconnaissance/Aerial Photography Fact Sheet, October 1978, produced by Bridgehead's Special Programs unit.

Camden Inspection Table

The Camden table departed from all prior designs by placing the working elements needed for film handling, inspection, splicing, etc., on an electrically driven adjustable base – a base originally developed for mounting dental chairs. Controlled by a single switch, the table-top could be raised or lowered through a 12-in. range and tilted up to 20 degrees from level – all aimed at maximizing operator comfort and accessibility. An elevated idler roller could be swung into position below an overhead inspection lamp to permit reflected-light inspection of film bases, while three ergonomically designed motor-driven supply and take-up spindles maintained a constant tension on the film web at all times for maximum product safety. To avoid the strobe-like effect experienced by operators while inspecting film during transport, direct current powered the viewer. To optimize print evaluation, a brightness control feature for the viewer was also available. Finally, the table provided a Reading Densitometer to read duplicate print density patches as a check of printer-processor system performance.

Make-Up Table

The workforce used this general-purpose table for making-up film rolls for subsequent operations or breaking-down rolls from prior operations. Designed for white-light or darkroom use, its cutter and pressure-sensitive tape splicer handled random or continuous lengths of film, leader, flashed stock, and processed or unprocessed film. Manual rewinds controlled the film rolls on Dexter or MS 26565 spools.

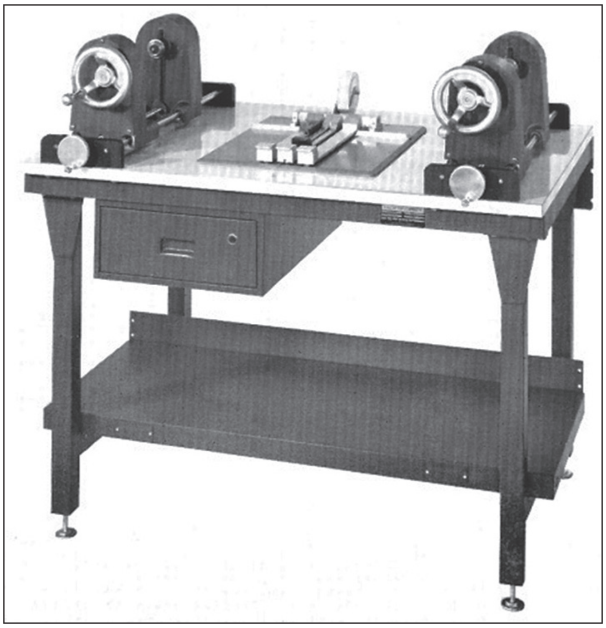


Figure 64: Make-Up Table. Ground Handling Equipment for Reconnaissance/ Aerial Photography Fact Sheet, September 1976, produced by Bridgehead's Special Programs unit.

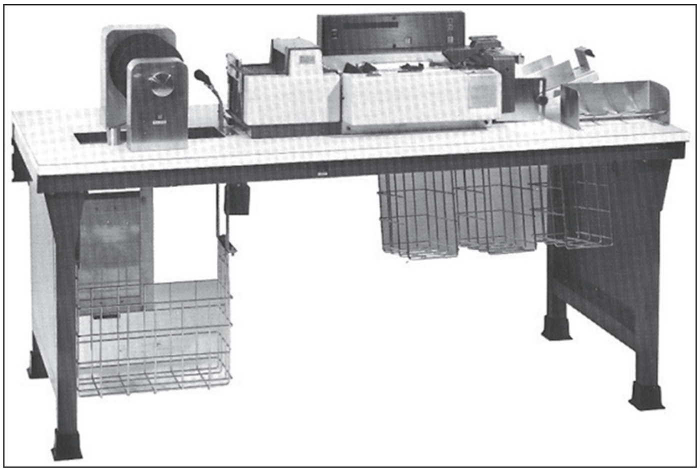


Figure 65: Flats Cutting Table. Image Management Fact Sheet, 1986, produced by Bridgehead's Special Programs unit.

Flats Cutting Table

This table provided a means for cutting a roll of processed duplicating film into flats of variable lengths. Bridgehead developed the flats-handling table for external customers, and the table was never used at Bridgehead. With the film web threaded through a film drive mechanism, a cursor could be aligned on an "electronic micrometer" in a position corresponding to an intended cut location. When activated, the machine automatically advanced the film under the blade and cut it. The operation deposited the resulting flat into a shuttle, and the next image automatically moved into the cutting position. The set-up included static eliminators, a viewer, film guides/supports, and storage compartments for consumables. The flats handling operation made up to 1800 cuts per hour.

Flats Packaging Table

Customer production operators relied on the Flats Packaging Table to package, evacuate, and seal varying quantities of processed film flats at up to 100 flats per hour. It contained a bin for holding pre-made shipping bags, a rack for holding the flats shuttle, a trans-illuminator for verifying flats to be packaged, a vacuum/thermal impulse sealer, and racks for storing spare shipping bags. They compared the flats to a customer manifest for accuracy, and once verified as correct, placed them into a bag using a transfer device. The loaded bag was then placed into a vacuum sealer chamber that evacuated all air, and the bag was sealed. After sealing, the device equalized chamber pressure to ambient air pressure. The bag was then removed, and the cycle repeated.

Figrue 66: Flats Packaging Table. Image Management Fact Sheet, 1986, produced by Bridgehead's Special Programs unit.

❖AUXILIARY EQUIPMENT

Intensity Scale Sensitometer

Operators used the Intensity Scale Sensitometer to make precise exposures through either a standard stepped density tablet or a continuous density wedge onto various types of light-sensitive film emulsions. They used the resulting sensitometric strips for primary sensitometric tests of B&W or color emulsion characteristics, or for sensitometric control of photographic processing equipment.

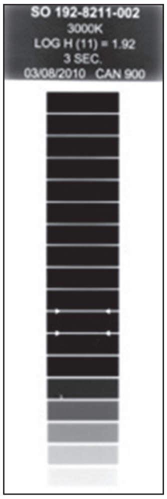
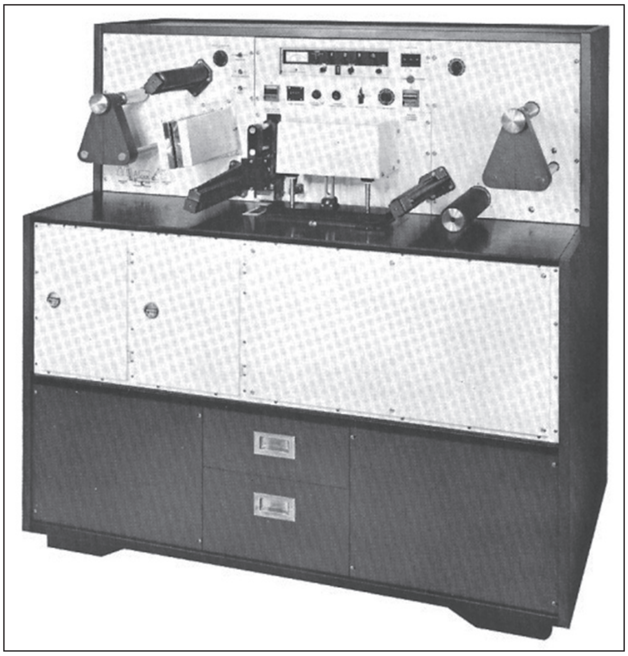


Figure 67: Sample Processed Sensitometric Step Wedge exposed on the 1-B Sensitometer. From archives of Bridgehead's Special Programs unit.

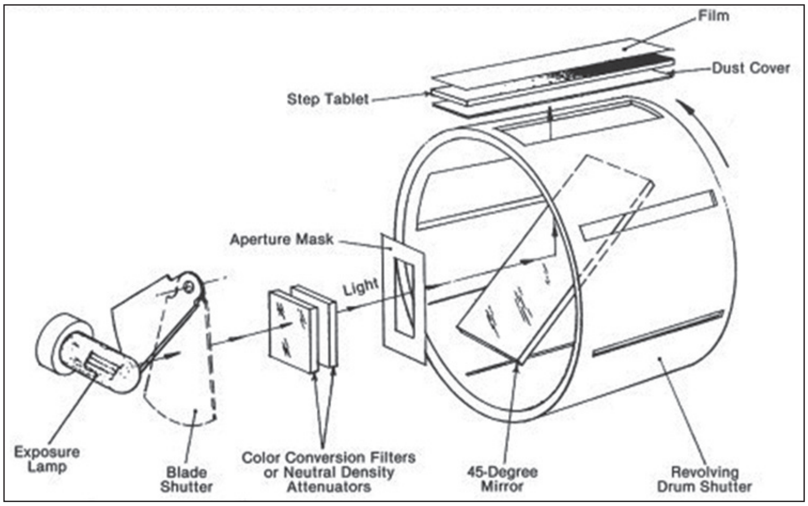
Figure 68: Intensity Scale Sensitometer, Type 1-B, Model V. Ground Handling Equipment for Reconnaissance/Aerial Photography Fact Sheet, May 1979, produced by Bridgehead's Special Programs unit.



As shown in the schematic, the sensitometer used a revolving drum shutter with preset slit widths to expose either a 21-step wedge or a continuously variable density strip onto selected films. Using the drum allowed selection of exposure times of 1/100 to ½ second. An electrical timing circuit allowed exposure times from one to 999 seconds.

The exposure lamp was calibrated against a standard lamp certified by the National Bureau of Standards, and a closely regulated direct current power supply provided power to the lamp. Color conversion filters and special separation filters were available to test various wavelength sensitivities of particular emulsions. All filters and light attenuators were individually calibrated to exacting national standards. A preset counter permitted programming for any number of identical exposures on a continuous roll, and an edge punch notched the film edge between exposures that allowed detection and cutting of the film in total darkness between latent images. The sensitometer was a sturdy unit standing 62 in. tall and weighing 1375 lb.

Figure 69: Light Path Through Intensity Scale Sensitometer, Type 1-B, Model V. Ground Handling Equipment for Reconnaissance/Aerial Photography Fact Sheet , May 1979, produced by Bridgehead's Special Programs unit.



Continuous Raw Stock Flasher

The Bridgehead workforce used this machine to generate long uniform exposures on continuous lengths of B&W film in a darkroom environment. They ran the flashed film through processors to confirm readiness for image processing and to identify any processing anomalies. The processed film was also used to detect equipment-induced film scratches. A 500-watt halogen-tungsten lamp, combined with a uniquely designed mask, provided exposure uniformities surpassing the capability of continuous contact printers. A six-speed motor provided regulated speeds up to 200 ft./min. for numerous exposure options.

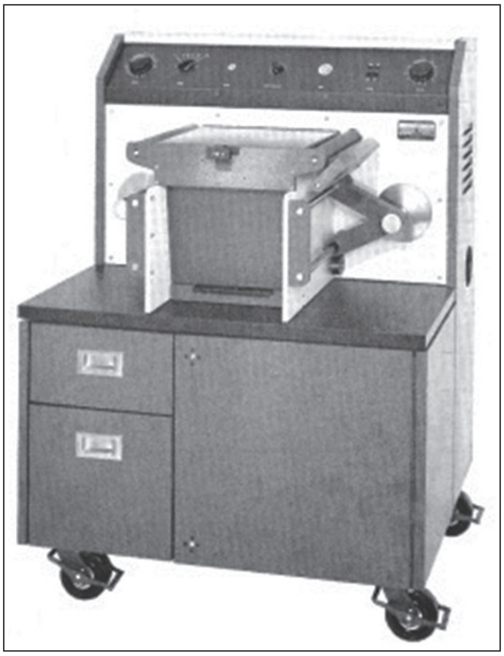
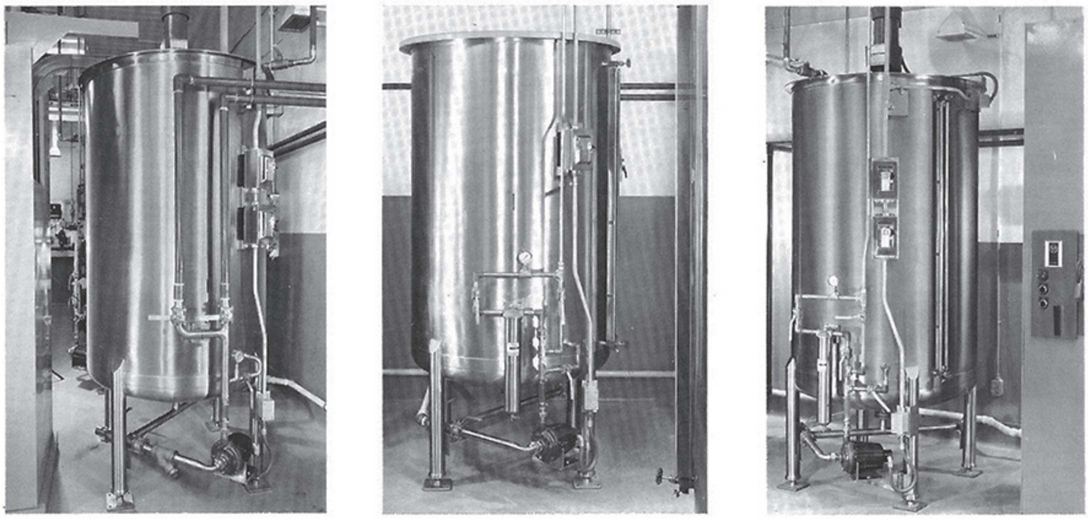


Figure 70: Continuous Raw Stock Flasher. Ground Handling Equipment for Reconnaissance/ Aerial Photography Fact Sheet , September 1976, produced by Bridgehead's Special Programs unit.

Chemical Solution Mixing and Storage Equipment

The D&E team developed a line of heavy-duty stainless steel (Type 316) chemical mix and storage tanks to prepare and store liquid chemicals for use in film processing machines. Tanks were available in 500, 1000, and 2000-liter volumes. Operators accomplished mixing through a combination of pump recirculation and separate electric mixers mounted on the lip of the tank. The same pump also transferred mixed volumes to storage tanks where integral recirculation pumps kept solutions agitated for uniform dispersion and transfer to the processing machines as needed. The tanks incorporated floating lids into their design to minimize oxidation of stored chemicals, and external sight tubes assisted operators in monitoring fluid levels. Due to the height of the larger mix tanks and the volumes of mixing fluids, operators used mechanical lifters to assist in getting dry chemicals into the tanks. See Appendix I for a typical chemical mix formulation sheet.



Solution Mix Tank

Solution Storage Tank

Combination Mix-Storage Tank

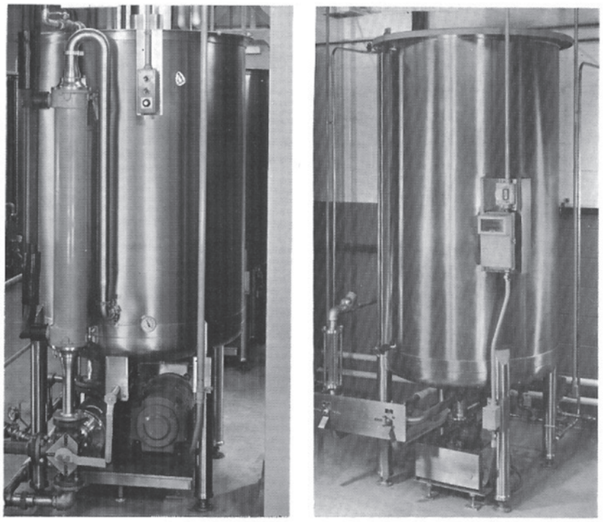
Figure 71: Chemical Solution Mixing and Storage Equipment. Image Management Fact Sheet, 1986, produced by Bridgehead's Special Programs unit.

Viscous Developer Mix & Delivery Systems

Viscous Film Processors required Viscous Developer Mix and Delivery systems for support. These systems provided the capability of mixing, straining, storing, and delivering viscous developer to the processors plus disposal of unused developer. A 1500-liter mix tank mixed between 500 to 1500 liters of viscous developer in a non-conventional manner. By using a progressing cavity pump (vs. a standard impeller pump) to circulate the mix through a high velocity, liquid jet nozzle submerged inside the tank, severe agitation could be generated.

With that amount of energy introduced to the mix, a heat exchanger worked to cool the viscous solution and re-dissolve any gas bubbles generated during recirculation. It took approximately one hour of mixing for a batch of any size to hydrolyze completely. To ensure uniform consistency of mixed developer, this process used a strainer assembly to filter out impurities and any un-dissolved particulate down to .006-in. in diameter. A variable speed pump on each storage tank delivered viscous developer at constant pressure to coating hoppers via a temperature control system in the processor.

Figure 72: Viscous Developer Mix & Delivery System. Image Management Fact Sheet, 1986, produced by Bridgehead's Special Programs unit.



KODAK Viscous Mix Tank Assembly KODAK Storage Tank Assembly

❖MISCELLANEOUS EQUIPMENT

Denver Tabletop Film Handling Units

The D&E team designed the Denver series of equipment for field installations where clean-room space was limited and mobility was essential. The Denver equipment handled film in widths from 70mm to 9.5 inches on MS26565 Aerial Film Spools up to 10.5 inches diameter. Their interchangeable assemblies provided a high degree of flexibility aimed at small or start-up aerial photo labs. Although compact and lightweight, they were ruggedly constructed, and they needed minimum table or bench-top space for setup and operation. A single base assembly (36-in. wide by 24-in. deep) provided space for locating different modules between two rewind spindles, which allowed a motor-driven capability or manual operation using a unique self-centering handle. By selecting a module or combination of modules to mount in the common base assembly, it allowed technicians to view, edit, clean, and densitometrically measure film.

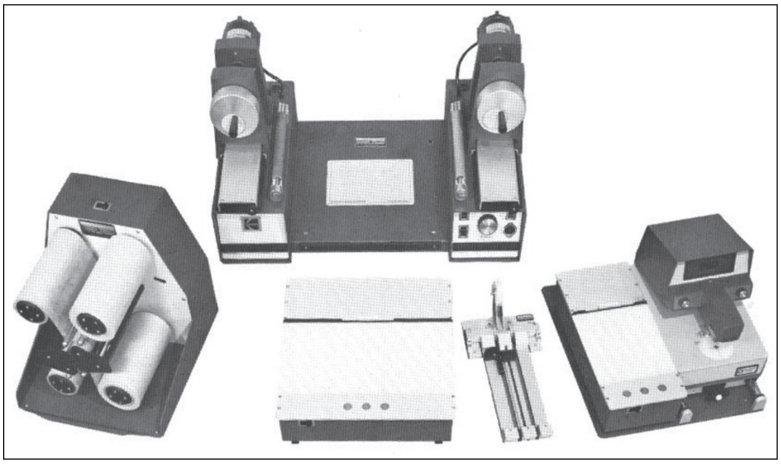


Figure 73: Denver Table-Top Film Handling Units. Ground Handling Equipment for Reconnaissance/
Aerial Photography Fact Sheet, December 1978, produced by Bridgehead's Special Programs unit.

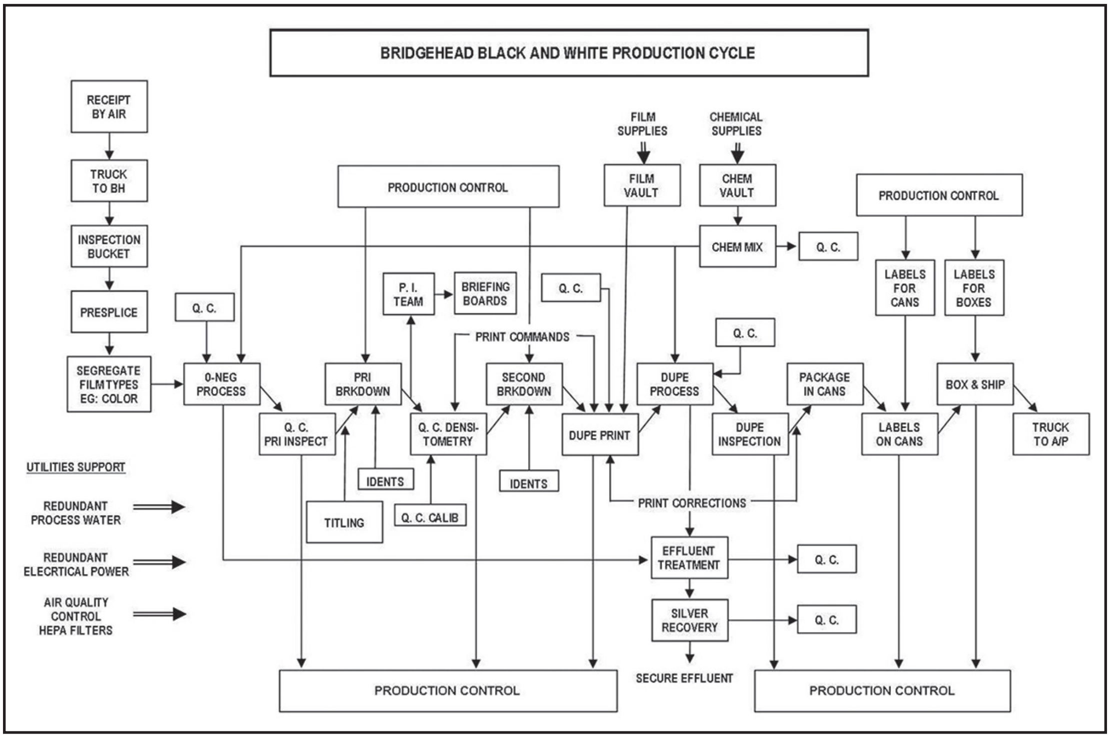
Appendix I

TYPICAL CHEMICAL MIX FORMULATION SHEET

B&W DEVELOPER: FORMULA SIZE				
MIX IN ORDER LISTED	1 LITER	250 LITERS	500LITERS	1500 LITERS
Water at 120^{o}F	800 mls	200 liters	400 liters	1200 liter
Anti-Cal #6	1 gm	250 gms	500 gms	1.5 kgs
Sodium Sulfite (Na_2SO_3)	40.2 gms	10.05 kgs	20.1 kgs	60.3 kgs
11VC	3 gms	750 gms	1.5 kgs	4.5 kgs
BD-84	10.3 gms	2.6 kgs	5.2 kgs	15.6 kgs
Tri-sodium Phosphate	30.1 gms	7.5 gms	15 kgs	45 kgs
Sodium Hydroxide (Granular)	2.8 gms	700 gms	1.4 kgs	4.2 kgs
OR				
Sodium Hydroxide (50% Solution)	3.7 mls	925 mls	1.9 liters	5.7 liters
Potassium Bromide (KBr)	5 gms	1.25 kgs	2.5 kgs	7.5 kgs
Water to make	1 liter	250 liters	500 liters	1500 liters

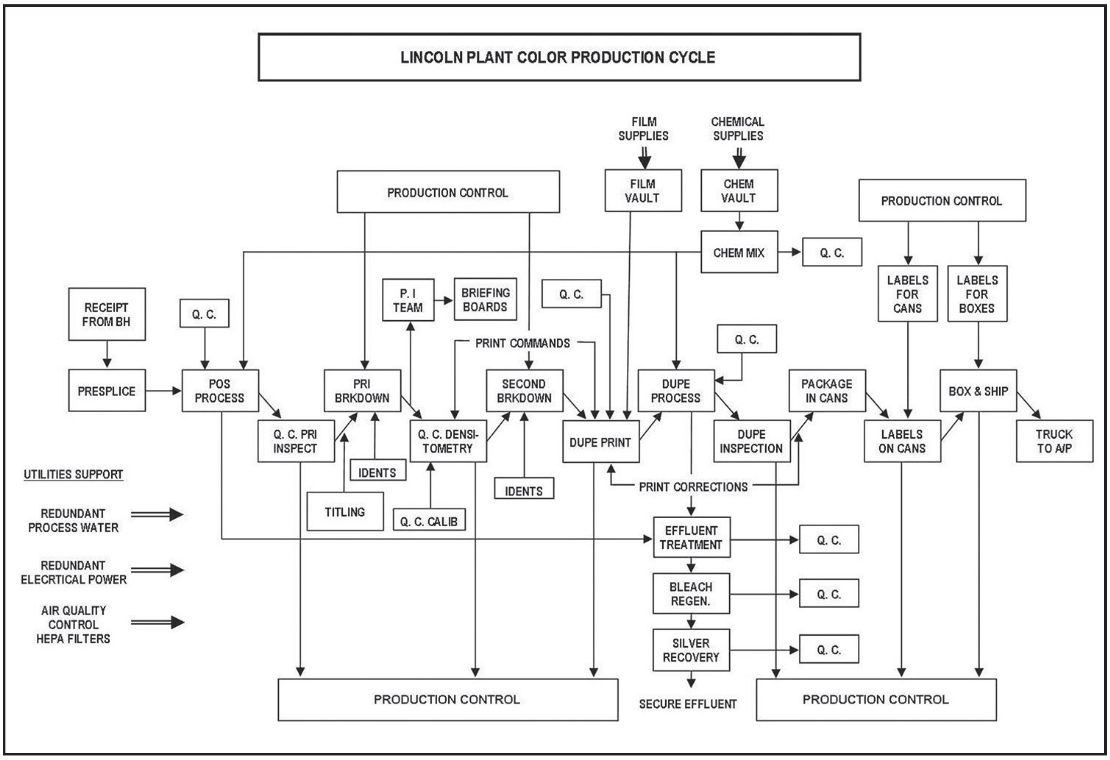
Appendix J

BLACK & WHITE PRODUCTION CYCLE



Appendix K

COLOR PRODUCTION CYCLE



Appendix L

COMMENDATION LETTER FOR EXEMPLAR STUDY

THE SECRETARY OF THE TREASURY

WASHINGTON. D. C. SO22O

APRIL 10, 1984

Dear Mr. Chandler:

Thank you very much for meeting with Robert Leuver of the Bureau of Engraving and Printing and other officials of the Secret Service and Federal Reserve System to discuss the development of advanced copiers and printers and their threat to U.S. currency, The information derived from that meeting will be invaluable to us as we continue to study the problem. You can be certain that we will respect the confidentiality of the information you provided and restrict the number of people who will be privy to it. I appreciate, too, Kodak's research for the Federal Government regarding counterfeit deterrence.

Please accept with my best wishes the enclosed memento.

Sincerely,

Donald T. Regan

Mr. Colby Chandler
Chairman of the Board
Eastman Kodak Company
343 State Street
Rochester, New York 14650

Enclosure

Appendix M

LIST OF CONTRIBUTORS

Motivation for creating this document came from a desire to tell the generally unknown story of Bridgehead, to record it for its historical value, and to chronicle a legacy that families of the participants and Kodak can take pride in. If not for the contributions recorded by several of those who participated in it, the story would be lost forever. Documenting the story began in the spring of 2008, with serious compilation starting in September of that year. From that time on through the winter of 2008-2009, the principal contributors met semi-monthly on a fairly regular basis to critique previously compiled narratives, make changes and additions, identify other contacts to generate additional narratives, and identify action items to verify collected information, gather additional data, etc. E-mailing via the Internet was a principal method of communication and greatly aided the effort. The authors completed work on the first edition of this document in April 2009 (revision work on a second edition continued in collaboration with the NRO-Center for the Study of National Reconnaissance from 2010 – 2013). Contributors are particularly grateful to ITT Industries for allowing access to historical information retained in company archives, and to Bill Naylor, Chief/Recognition, Exhibits, & Outreach, Center for the Study of National Reconnaissance, for his encouragement and agreeing to guide the completed document through government review channels. At the risk of omitting anyone who may have contributed even the smallest amount of information to documenting the Story of *Bridgehead,* here is a listing:

Dominic Arillotta
John Baccoli
Howard Belt
Frank Bezek
Larry Boyd
Milt Bryant
Craig Butz
Bob Carr
Larry Christensen
Bob Cosgrove
Tom Cross
Paul Denenberg
John Freund
Gary Fulmer
Bill Gaffney
Don Gagner
Art Gaston
Bob Golembe
Bob Green
Jeanie Havens
Tom Havens *
Glen Irish
Norm Karsten
Harvey Kidder
Al Kubber
Bob Matoushek
Phil McCabe
Jim Moser
Neil Ratzel
Joe Russo *
Mark Sampson
Ron Sandford
Bob Schoenfeld
Don Schoessler *
John Schroth
Dick Sherwood *
Jennifer Sherwood
Dick Stowe *
Tom Troxell
John Tuller
Lee Van Ocker
Brian Vick
Paul Vogt
Rand Warner *
Charlie Williams

* Principal contributors

Appendix N

ACRONYMS

A&OD	Apparatus & Optical Division (at Kodak)
ABCC	Actinic Butterfly Contrast Control
AEI	Aerial Exposure Index
AFI	Aerial Film Index
B&W	Black & White
BEP	Bureau of Engraving & Printing
BPE	Beacon Precision Enlarger
COMAC	Computer Assisted Control
CCB	Contract Control Board
CRT	Cathode Ray Tube
D&E	Design & Engineering Group
DIA	Defense Intelligence Agency
D-Log E	Plot of Density vs. Log Exposure
DN	Duplicate Negative
DP	Duplicate Positive
EPA	Environmental Protection Agency
FEAT	Film Evaluation and Test (Lab)
FEATS	Film Evaluation and Test Services (Lab)
H&D	Hurter & Driffield (Curve; plot of density vs. exposure)
IC	Intelligence Community
LED	Light Emitting Diode
MTF	Modulation Transfer Function

NASA	National Aeronautics and Space Administration
NPIC	National Photographic Interpretation Center
NRO	National Reconnaissance Office
ON	Original Negative
OP	Original Positive
OVD	Optical Variable Device
PET	Polyethylene Teraphthalate
POCE	Production Operations Color Enlarger
PSO	Production Shipping Office
QC	Quality Control
R&D	Research and Development
RBC	Rotating Biological Contactor
RGB	Red, Green & Blue (filters)
RMS	Root Mean Squared
RP	Resolving Power
RV	Recovery Vehicle
SAC	Strategic Air Command
SCAT	Scene Atmospheric Model
SIP	Selective Image Printer
SO	Special Order (films)
SPPF	Special Projects Processing Facility (Westover AFB)
SWP	Select Wavelength Printing
TA	Technical Assistance
TP	Tuttle Project
UTB	Ultra-Thin Base (film)
UUTB	Ultra-Ultra Thin Base (Film)
UV	Ultra Violet

CSNR

CENTER FOR THE STUDY OF
NATIONAL RECONNAISSANCE

JULY 2014