Plowshares into Swords: How Astronomers and Telescope Makers Helped Win The Cold War

Joseph B. Houston, Jr.

and

John W. Briggs

The Stellafane Centennial Convention

August 2023

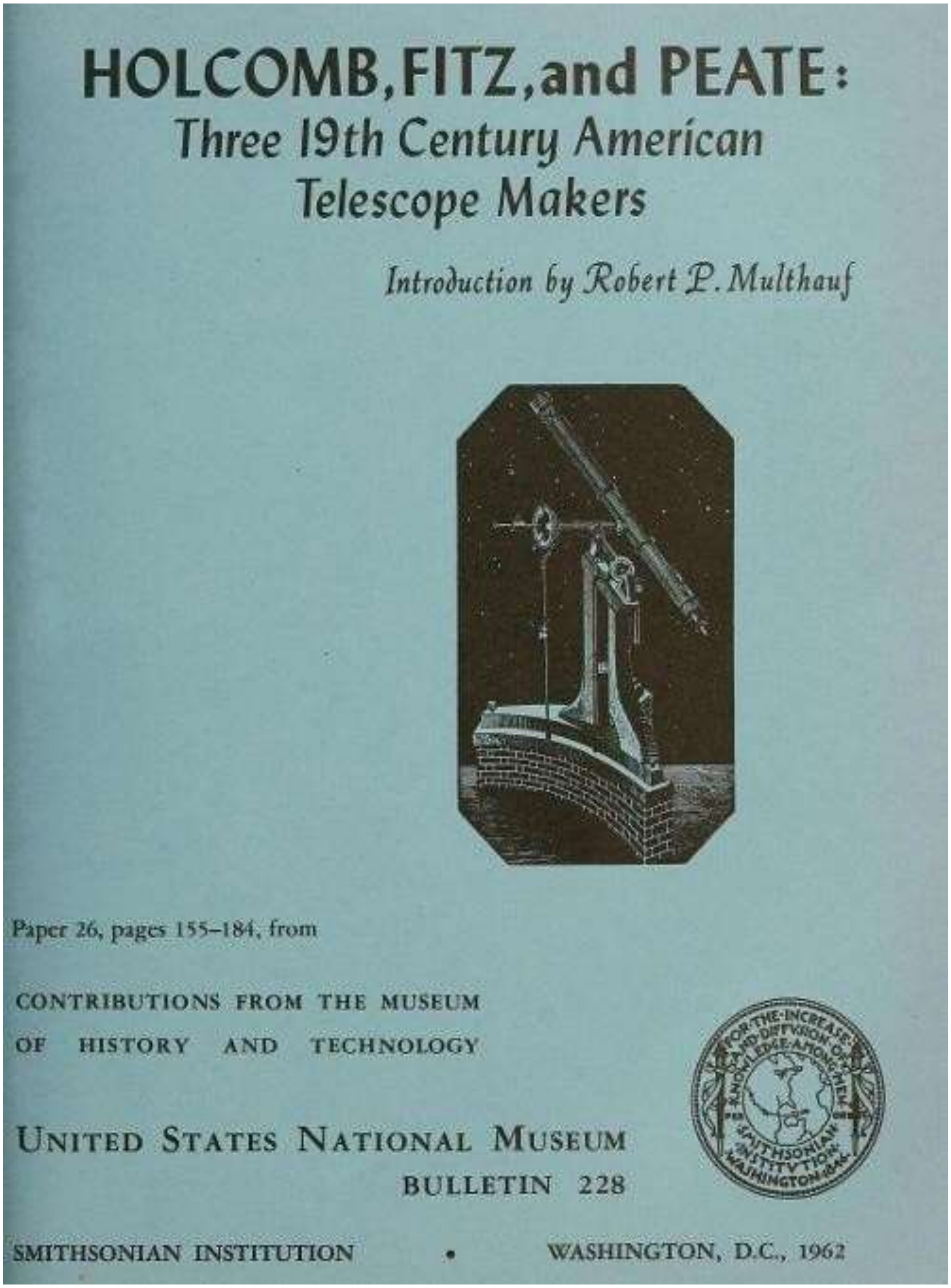
“He will judge between the nations and will settle disputes for many peoples. They will beat their swords into plowshares and their spears into pruning hooks. Nation will not take up sword against nation, nor will they train for war anymore.”

- Isaiah 2:3-4

The Prequel

Prior to the beginning of the Cold War and the famous “Iron Curtain” speech given by Winston Churchill on March 5, 1946, in Fulton, Missouri, hundreds of Americans were building their own telescopes for viewing the heavens. Astronomy Clubs were being formed throughout the country. Popular publications such as *Sky & Telescope, Scientific American* and Ingall’s *Amateur Telescope Making* Volumes One, Two and Three, were available to guide the dedicated; telescope mirror making kits were affordable and could be ordered by mail.

Making telescopes in America was not a new phenomenon. There were famous telescope makers in the 1800s. The story of three individuals, Holcomb, Fitz and Peate , is told by Robert P. Multhauf.

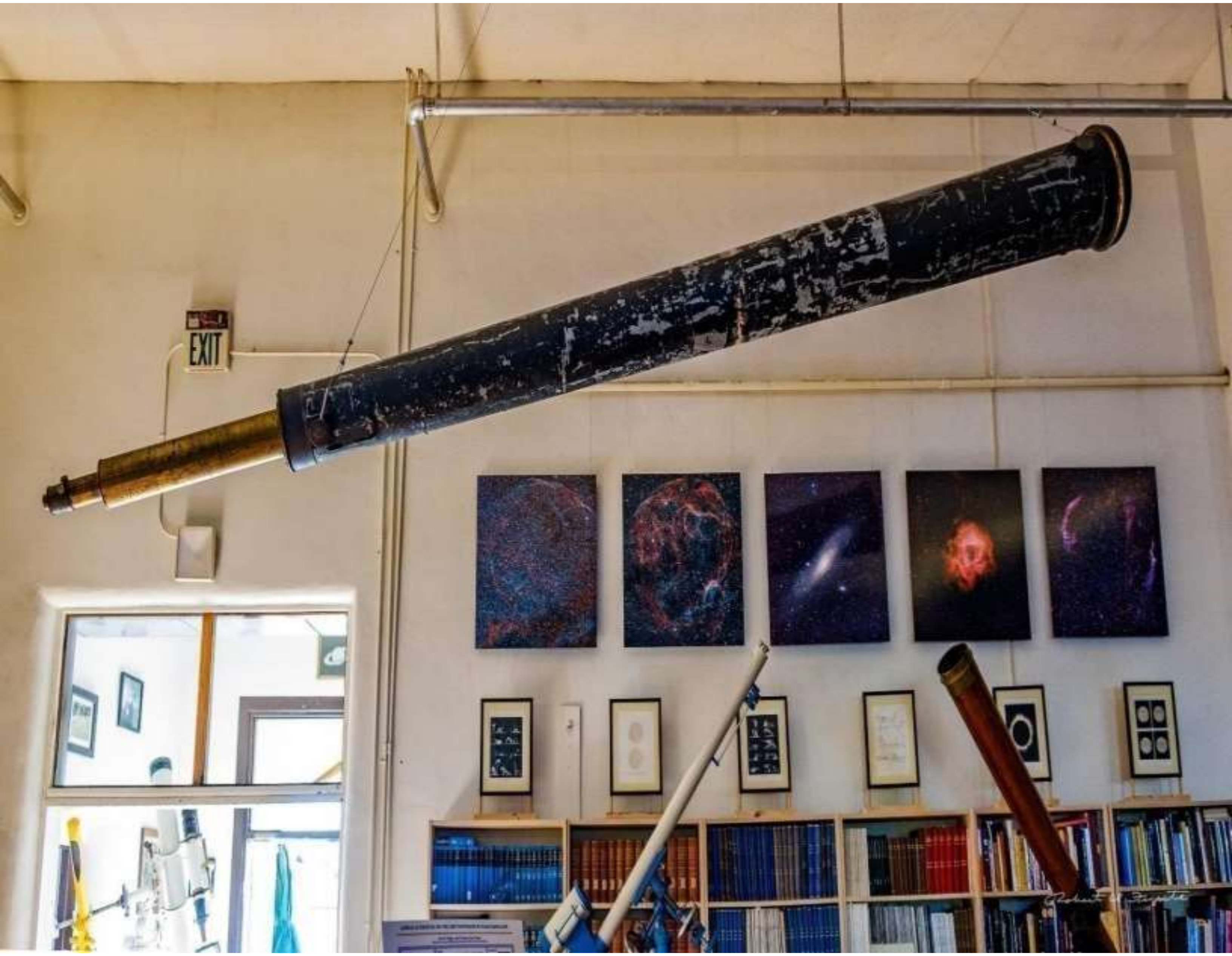


Alvan Clark and James Brashear also joined the movement in the 19th Century. The Astronomical Lyceum in Magdalena, New Mexico, houses many both historical as well as contemporary and rare instruments.

The Lyceum is in this 1936 WPA Project gymnasium in Magdalena, New Mexico. The next several slides illustrate the variety of telescopes that have been collected and assembled for both on-going viewing, restoration, and serious research.

The following slide presents a panoramic view of what has been referred to as a workshop, an artist's studio and on some occasions, a warehouse. Immediately below this slide is a picture of John Briggs at his desk.

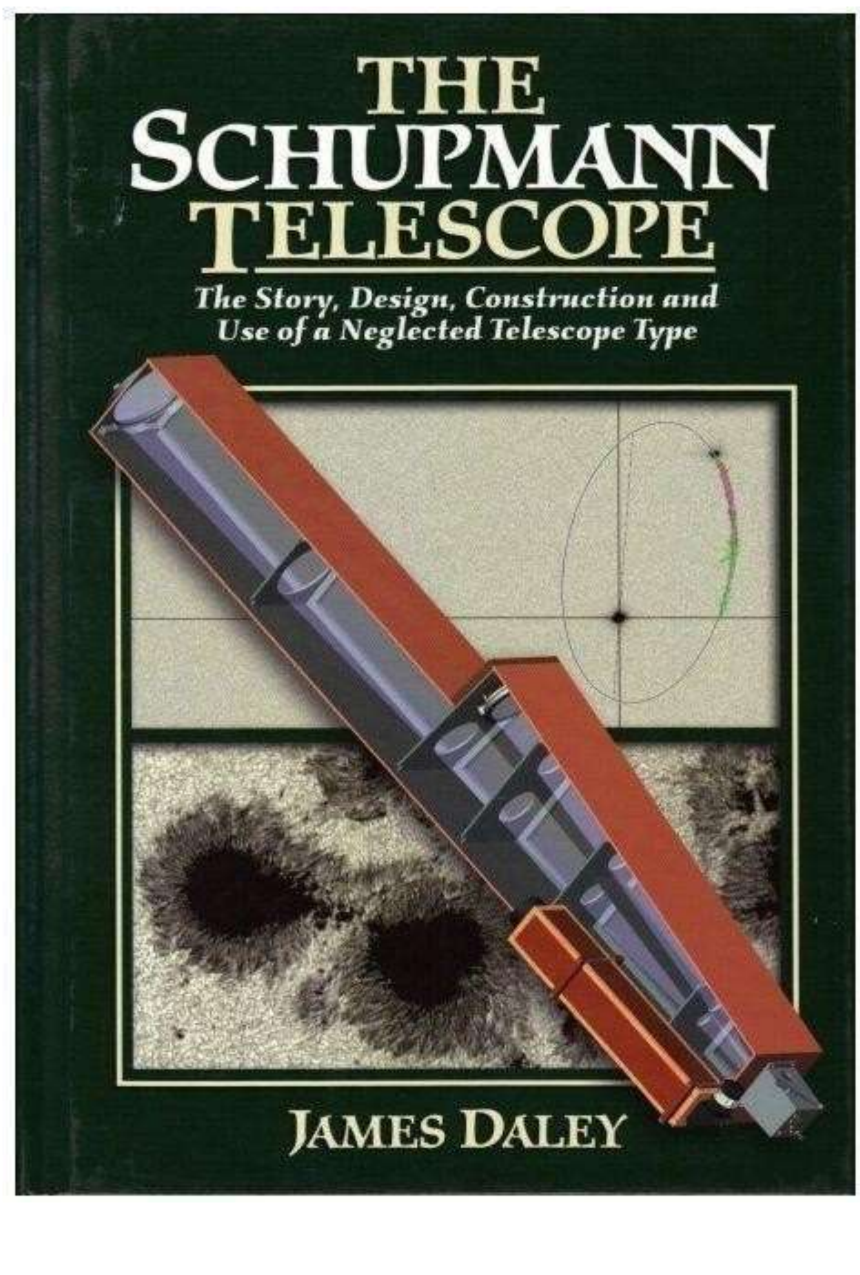
The third slide illustrates a Rutherford 13-inch refractor circa 1868.



The following slide shows rows of bookshelves, which in addition to holding a vast collection of books on Astronomy, also house the core collection of observing publications and journals donated by Swarthmore College. These retired publications contain records of the Sproul Observatory’s 24-inch, f/18 refractor with lenses made by John Brashear in 1912.

Atop the central two bookshelves is a Schupmann unobscured 10-inch telescope in a wooden housing.

Details of the Schupmann design can be found in this book by James Daley, a prominent telescope designer.



This beautiful, traveling transit telescope was made by the Fauth Company in Washington, D.C. in 1884. It was used to establish accurate timing for transportation systems and knowing the exact time, provide accurate latitude and longitude coordinates for its location.

The instrument featured below is a 16-inch, all spherical design by Donald Dilworth, who built it in his basement and displayed it many years ago at a Stellafane meeting. It could easily grace the halls of a Museum of Modern Art.

Next is a rack of a variety of astronomical instruments recently referred to as a “telescope twilight zone.”

The next slide features a 6-inch refracting telescope in a wooden tube built by Henry Fisk in about 1855. Fisk was famous for his wooden tubes.

Featured below is a quiet area and informal reading room in the Lyceum which has been set aside for “reflecting” on topics and projects involving telescopes and astronomy.

This old refracting telescope, featured in a desert setting, is a relic of Abbot Academy, which was established as a school for girls and women in 1829. In 1973, it merged with Phillips Academy in Andover, Massachusetts.

The telescope is shown below in its original setting, on campus, with a student making observations at the eyepiece.

A final example of early telescopes is the “Overlook” 9 1/2-inch John A. Brashear refractor c. 1902 acquired from the Athur Otis Granger family in Cartersville, GA: by way of a sale to a traveling circus, according to Tony Smith, the great-grandson of the overseer of the Granger Estate. A. O. Granger died in 1914. In 1932, the President of the University of Texas, Dr. H.Y. Benedict, paid $15,000 for the optics and the Warner Swasey mount. The name “Overlook” comes from the name of A. O. Granger’s grand mansion which was built on Granger Hill and “overlooked” the town of Cartersville. Granger served as General Sherman’s military secretary during Sherman’s “March to the Sea” and returned from Philadelphia to Cartersville after the war where he housed this instrument in an astronomical observatory on the third floor of the mansion house under a revolving dome.

In the 1930s, this telescope was placed atop the Physics Building, now known as Painter Hall, on campus in Austin, and was the work horse of the Math & Astronomy Department until 1953, when the University first established the curriculum for an undergraduate degree in Astronomy. The co-author is seen preparing to photograph the transit of the planet Mercury. (This clipping was obtained from a copy of the Austin Statesman newspaper.)

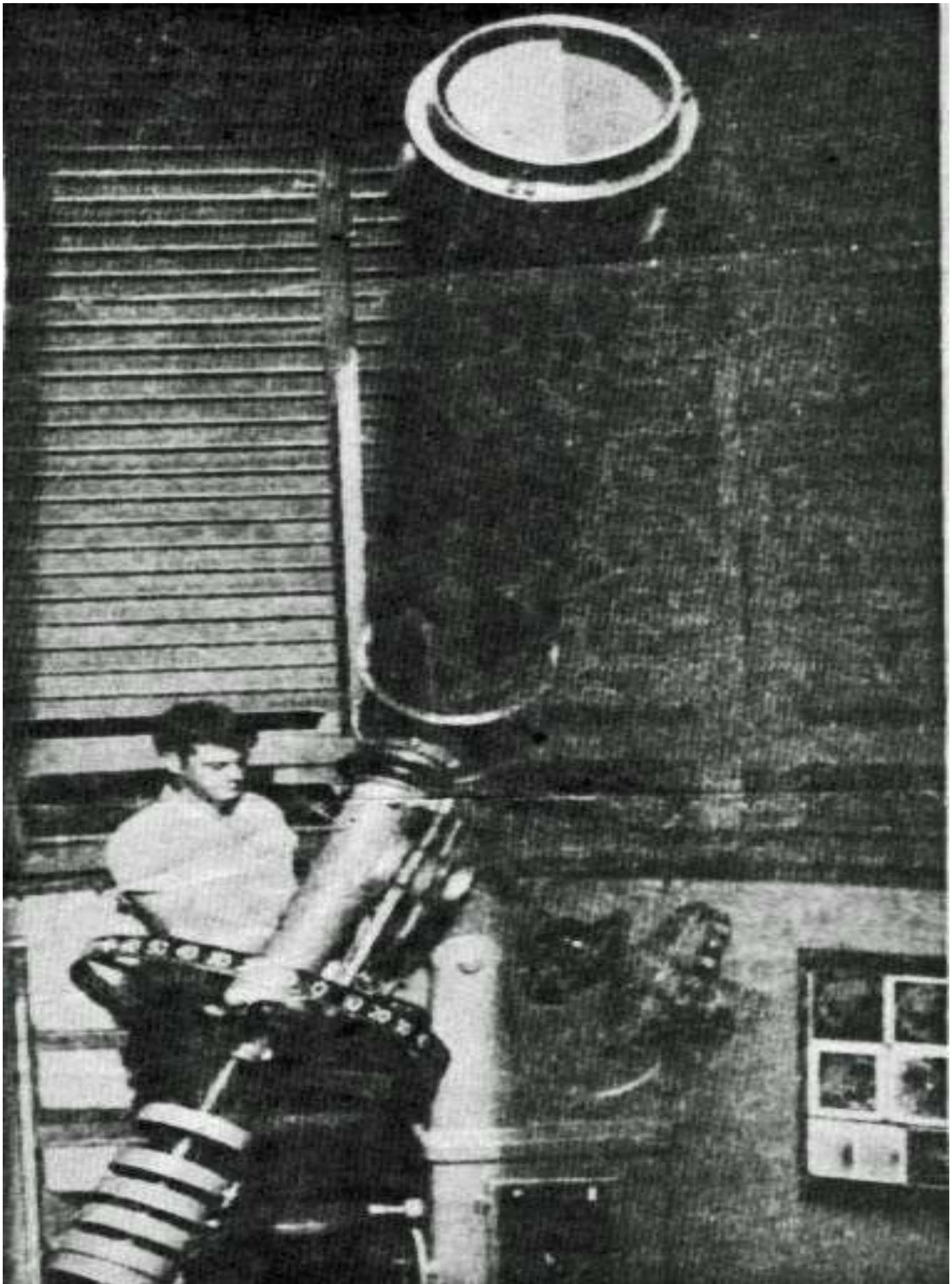


Photo by Paul D. He

JOE HOUSTON
. . . a universal view

To learn more about the Astronomical Lyceum and the History of American Telescopes visit the following sites:

"A Walking Tour of Optical History - - Artifacts and Anecdotes from the Astronomical Lyceum"

https://www.cloudynights.com/topic/726427-spie-2020lecture- on-classic-telescopes-and-related-stuff/

https://vimeo.com/451287860/e8c9ac6db3

"The Significant Influence of the Amateur Telescope Making Movement in the United States"

March 2021: John Briggs of the Astronomical Lyceum

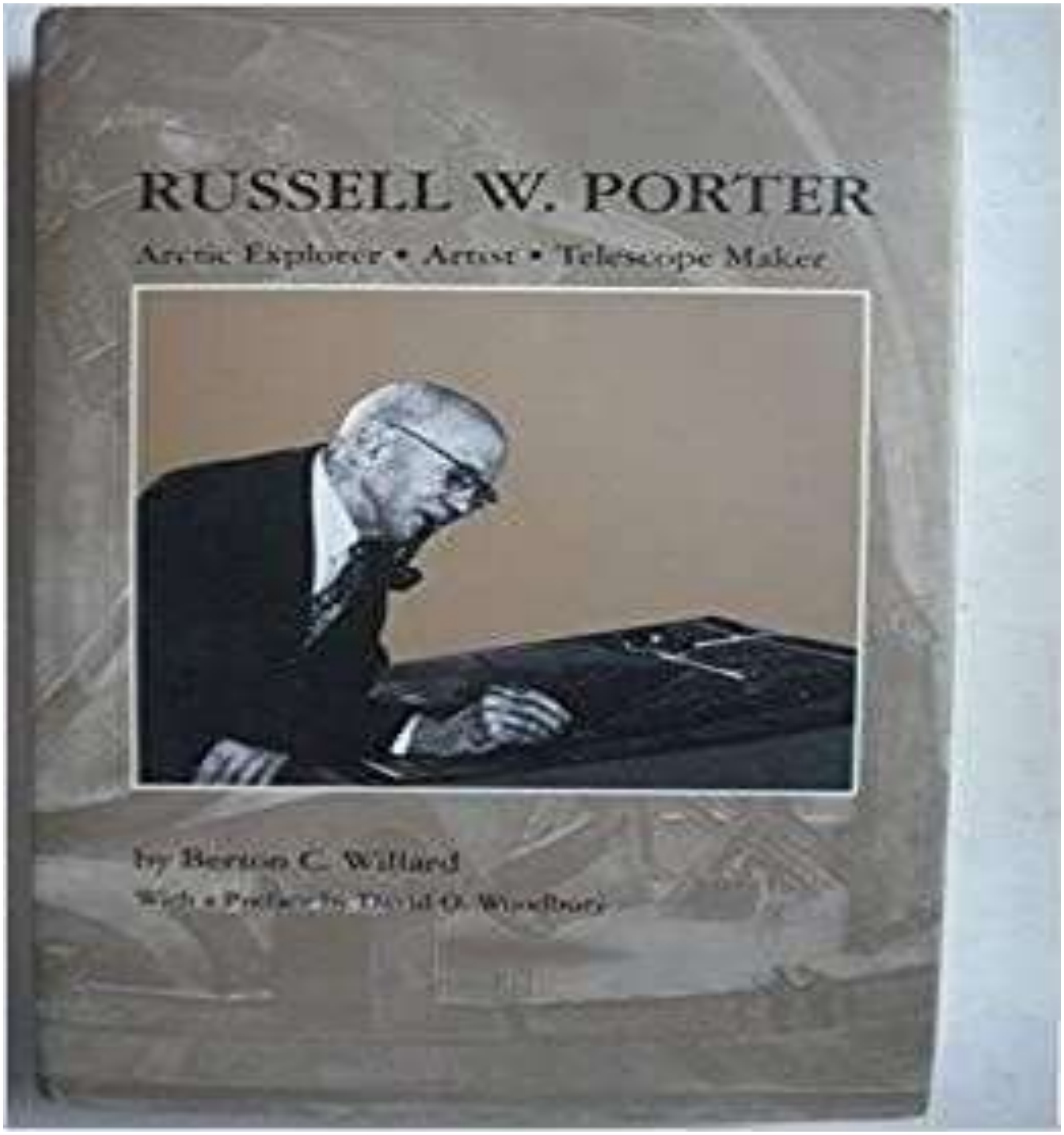
https://nesosa.org/news

https://youtu.be/xiwRtqv772s

STELLAFANE AND RUSSELL W. PORTER

Amateur Telescope Makers began to organize and visit Stellafane after the end of World War I. Below is a photograph of a small group of 13 men and one woman, Gladys A. Piper, taken in October 1920.

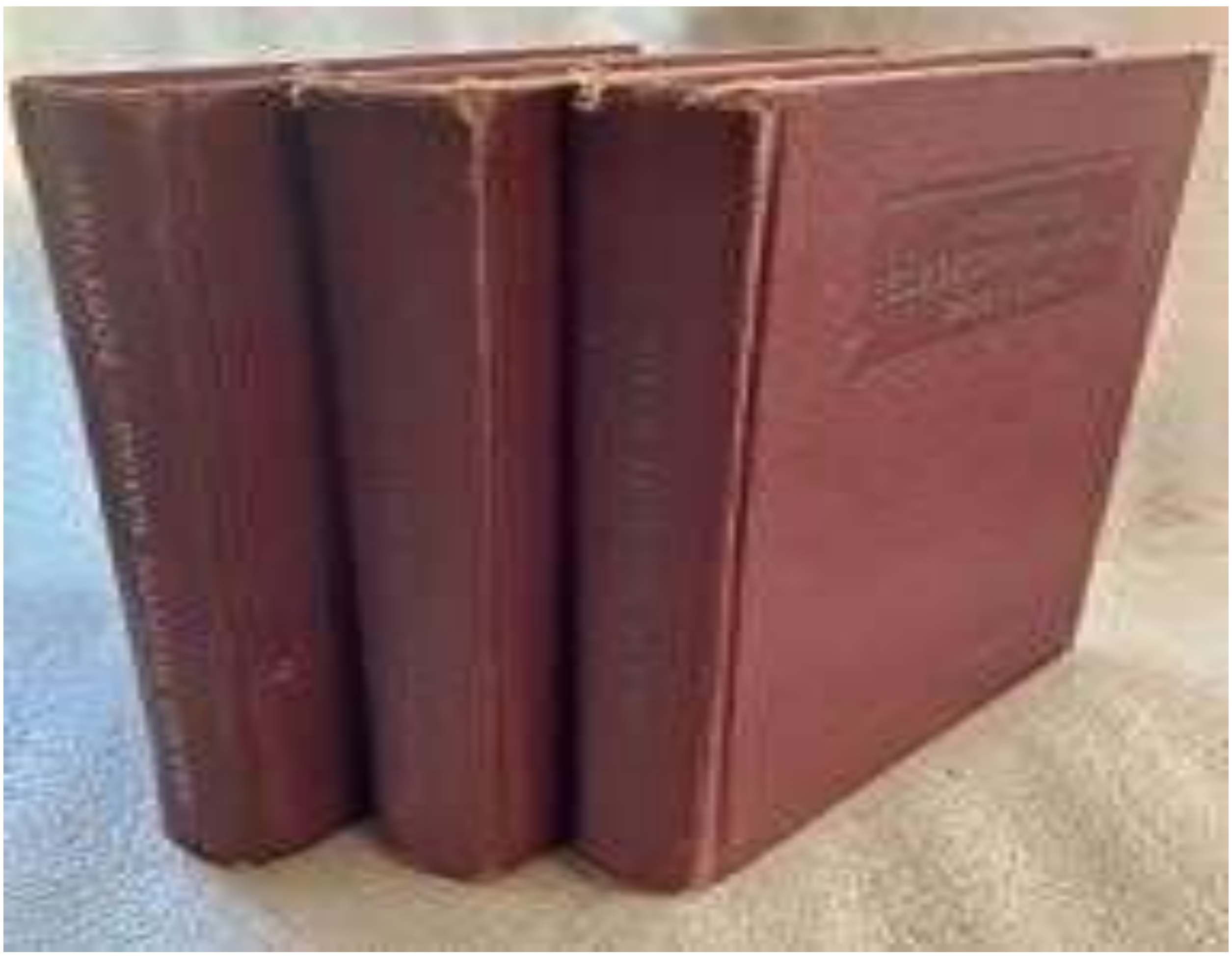
This photograph appears in Berton C. Willard's seminal work entitled *Russell W. Porter: Artic Explorer, Artist, Telescope Maker* published by The Bond Wheelwright Company of Freeport, Maine.



According to Willard’s historical account, the first official meeting of the Springfield Telescope Makers took place in the home of Oscar Marshall on the evening of December 7th, 1923. The first order of business included acquiring a club house. This was eventually accomplished on property inherited by Porter known as Breezy Hill.

The 1926 Convention (The First). Russell Porter & Albert Ingalls at far right.

The club began to grow and attract visitors such as Albert G. Ingalls, who was editor of *Scientific America.* As Willard notes, Ingalls was struggling to build his own telescope and visited Oscar Marshall at his home the weekend of June 12-14, 1925. The result of this visit had profound and lasting consequences. One of the major contributions to supporting telescope building in America was the impressive three volume series *Amateur Telescope Making.*



In 1927, Porter and members of the Springfield Club traveled to Boston to meet with Harlow Shapley at Harvard Observatory as guests of the Bond Astronomical Club. This continuing growth of interest in building telescopes for astronomers led to a meeting between representatives of Cal Tech and Porter to discuss the design and construction of a 200-inch instrument. Porter moved to California in December 1928 and began work on the giant Hale telescope. Owing to the delay caused by World War II, the project was not completed until 1947.

One of the best sources of information about this period in Porter's life is described in the book by David O. Woodbury entitled *The Glass Giant of Palomar.*

Early Days of ATM Clubs and Optical Companies

In 1934, the Amateur Telescope Makers of Boston was formed. Details of this event and the early history of this club have been chronicled by the club's historian, Anna Sudarich Hillier, in her manuscript dated 1995. Members of the club and sponsors at that time included Dr. Harlow Shapley of Harvard Observatory and Wagn Hargbol, its first president. This is a picture of Wagn Hargbol with his 16-inch Newtonian telescope.

Roughly 3 years after the Boston group got underway, Richard S. Perkin and Charles W. Elmer decided to get into the optics business and opened an office in lower Manhattan. According to the author, Thomas P. Fahy, in his book *Richard Scott Perkin and The Perkin-Elmer* Corporation, “there were only a few small, family-owned optical shops in the United States.” Names like Arno Smith, Alvan Clark, Brashear, Fecker & Schmitt and William Mogey & Sons were cited in Fahy’s book. Fahy writes that the shop of William Mogey & Sons was selected for producing the optics and assembling the telescopes.

As the popularity of amateur telescope making increased over the years, publications emerged, such as Sky & Telescope, and promoted the hobby. *Gleanings for ATMers* by Robert E. Cox and *Deep Sky Wonders* by the co-author's cousin, Walter "Scotty" Houston, provided valuable insights into the details of telescope building and special attractions in the night sky. More recently, web sites such as *Cloudy Nights* have provided an outlet to ATMers for an exchange of useful information. A major provider of information and a pillar of the ATM community, Paul Valleli, has always been on hand to guide the beginners, encourage the experienced, and congratulate the old-timers.

Thus, the stage was set in America prior to World War II for the mass production of telescopes, reconnaissance cameras and critical war fighting, optical weapon systems; the modern era of turning of "ploughshares" into "swords" had begun.

JIM BAKER, OPTICAL LENS DESIGN & FABRICATION AND THE U-2

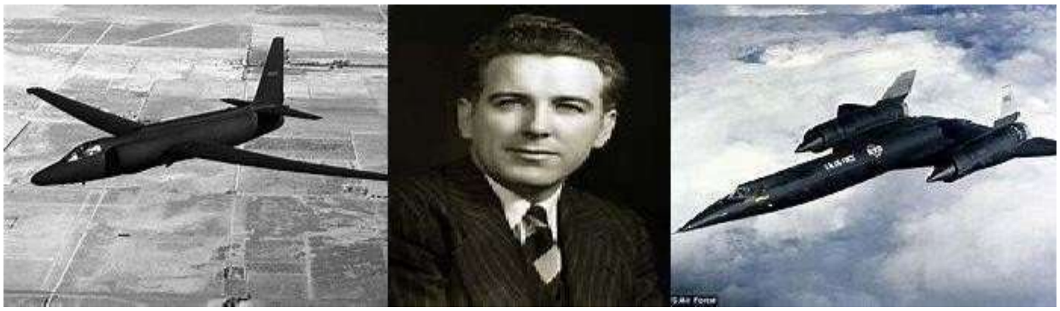
James G. Baker made significant contributions to the growth of satellite reconnaissance, He attended the University of Louisville, U.S., where he majored in mathematics. During his time at the university, Baker became interested in astronomy and grinding his own mirrors. In 1931 he helped to form the Louisville Astronomical Society. He graduated with a B.A. in 1935.

Pursuing his interest in astronomy, Baker studied at the Harvard College Observatory, U.S. He earned his M.A. in 1936 and served as a Junior Fellow of the Harvard Society from 1937 until 1943. He developed the Baker-Schmidt telescope, a modified version of the Schmidt camera, and earned his Ph.D. in astronomy and astrophysics from Harvard. Much of his work at the observatory involved designing, fabricating, and calibrating lenses for aerial cameras used in reconnaissance and mapping. After the start of World War II, Baker was recruited to be a civilian optical designer for the Army's newly formed aerial reconnaissance branch under Col. George W. Goddard. After the war, Baker became a consultant for the Air Force Photographic Laboratory, Perkin-Elmer Corporation, Eastman Kodak, and the Boston University Optical Research Laboratory.

Teaming up with Edwin Land, Baker persuaded President Dwight Eisenhower to approve Project AQUATONE to create the U-2 spy plane. Baker designed the lenses and most of the cameras used on the U-2 spy plane and later the SR-71 Blackbird.

He is also known for the famous Baker-Nunn telescope and the SX-70 Polaroid camera lens design.

JAMES G. BAKER

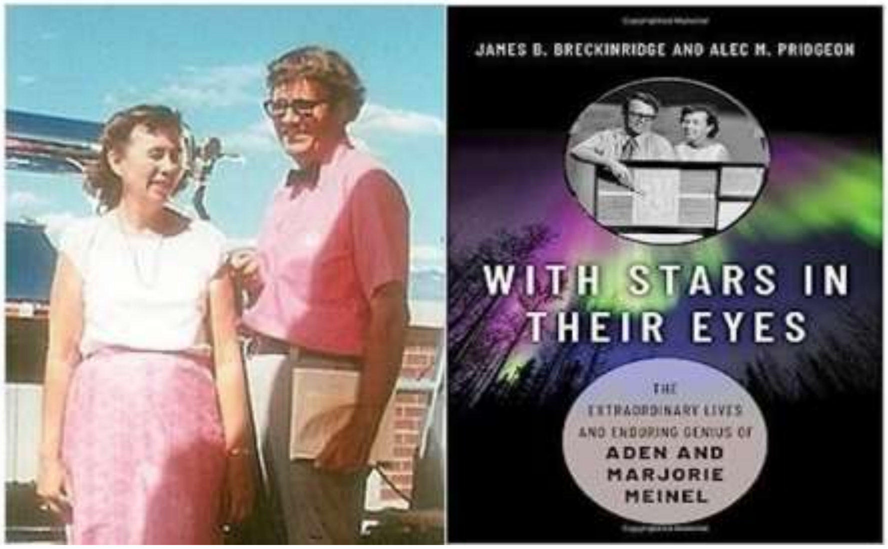


ADEN & MAJORIE MEINEL – UNIVERSITY OF ARIZONA

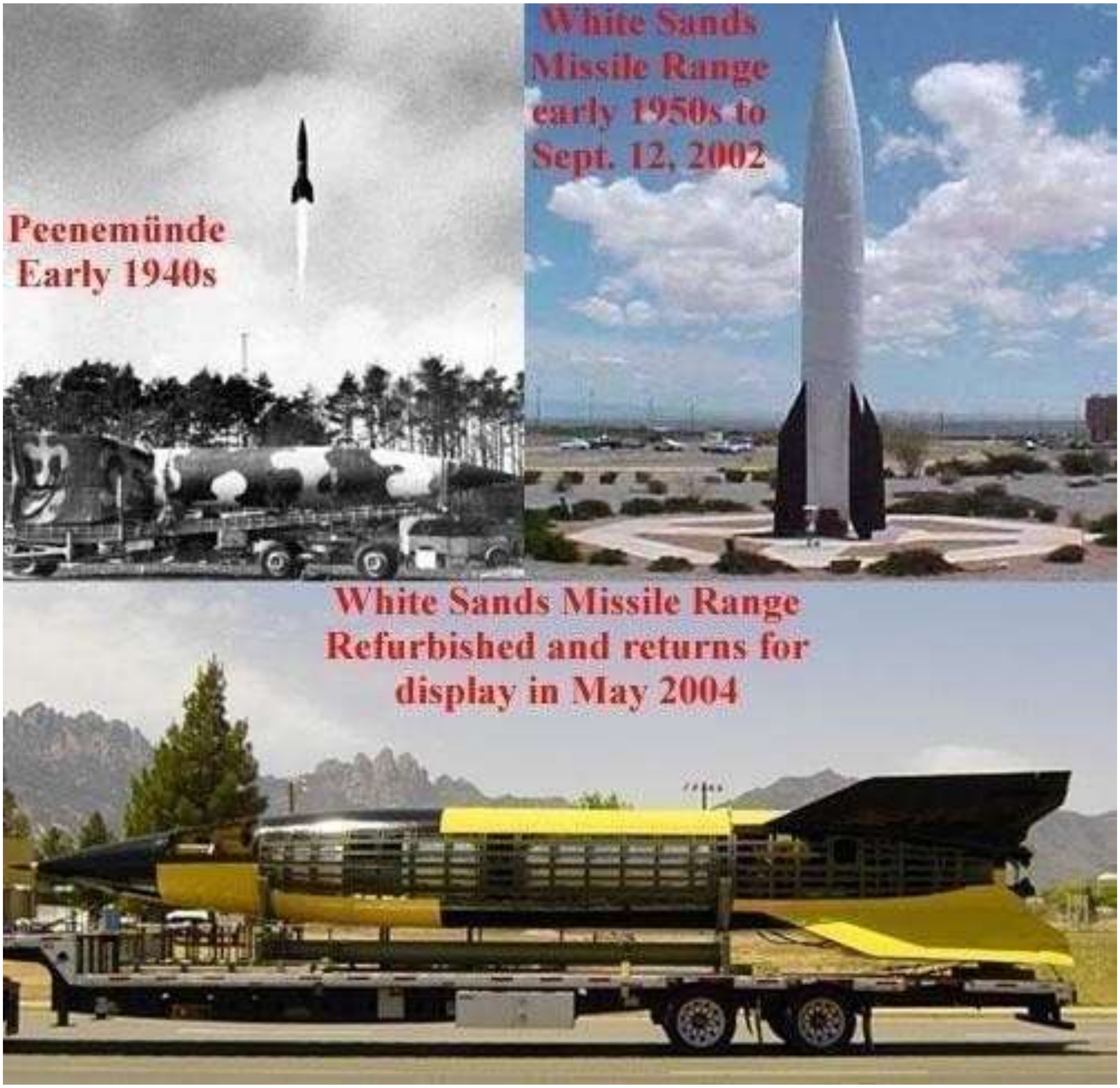
Aden apprenticed at Roger Hayward's optical fabrication lab, where he learned to make aspheric plates for Schmidt cameras. This work would inspire him to study Schmidt plates for his doctoral dissertation. In the early 1940's, he joined a highly classified rocket project and worked on training, timing, trajectories, and fuses—including the time-delay fuses for what would become "the Gadget" at the first test detonation of a nuclear device. When Marjorie finished her master's degree at Claremont College in 1944, she joined him on the rocketry team. In 1944, the pair married. He graduated with a PhD in 1947 and accepted an appointment to Yerkes Observatory of the University of Chicago. In 1955, the NSF appointed Aden to search potential sites for a national observatory to provide telescope access for all astronomers in the country. He was the founding

Director of the new Kitt Peak National Observatory, where he invented a slumping process for the honeycomb Pyrex mirror to build an innovative 84-inch telescope. In 1960 Aden became Director of the University of Arizona's (UA) Steward Observatory and astronomy program. He designed the UA-Smithsonian MMT that proved that segmented telescope mirrors were practical. Meinel started the expansion of the UA astronomy department that has led today to the Large Binocular Telescope and Dr. Roger Angel's mirror lab, which has produced many of the world's large telescope mirrors. Aden recognized the need for an interdisciplinary academic center of excellence in optical science. In 1964 Aden became the founding director of the UA's Optical Science Center and created a graduate degree program in optics. Aden Meinel joined JPL in 1983 to work on concepts for a 50-m diameter submillimeter segmented space telescope. His work laid the foundation for today's James Webb Space Telescope. In 1986 the JPL director, Dr. Lew Allen, asked Aden for his ideas on future missions for NASA. Aden concluded that although extremely difficult, the characterization of exoplanets using space telescopes was feasible. These efforts became the NASA Exoplanet Program today.

ADEN AND MAJORIE MEINEL

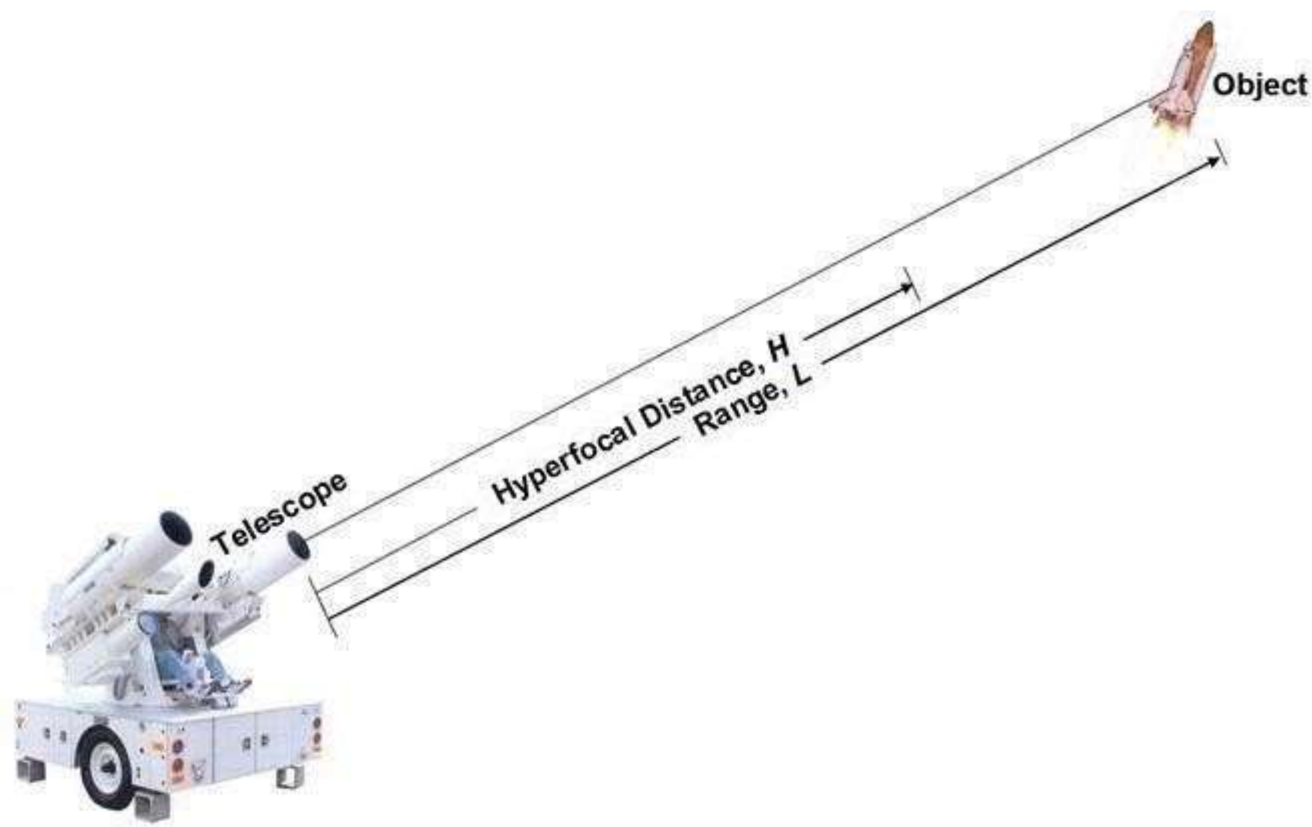


WHITE SANDS MISSILE RANGE: The Range Commanders Council, Clyde Tombaugh, and the Society of Photo-Optical Instrumentation Engineers(SPIE)


Peenemünde
Early 1940s
White Sands
Missile Range
early 1950s to
Sept. 12, 2002
White Sands Missile Range
Refurbished and returns for
display in May 2004

For years, the Society of Photo-Optical Instrumentation Engineers (SPIE), hosted Seminars-in-Depth, emphasizing the reduction-to-practice phase of optical lens and camera design and optical tracking and imaging technologies.

The illustration below depicts a typical range scenario and was created by Dr. Jim Harvey of the University of Central Florida, for one of several, annual workshops organized and conducted at Patrick Air Force Base by Dr. Harvey and manager, Joe Salg.



Cooperation with the National Ranges was critical. Inevitably, the Society rapidly expanded its conferences to include airborne and space-based reconnaissance and space surveillance topics, oftentimes scheduling its meetings to coincide with highly classified government sponsored meetings in the same locale.

Background: In the late 1940s and into the 1950s, the U.S. Government missile R & D community sought high-speed, photo-optical instrumentation. In 1952, Photo-Sonics, Inc. was founded to provide this type of hardware to the National Ranges. In 1955, engineers and technicians working in New Mexico, California and Florida, led by Jack Kiel of Photo-Sonics and colleague, Charles DeMund, founded SPIE as a 501-C3 non-profit society. The society elected its first officers from this pool of "Range Rats." At the same time, a government sponsored organization, the Range Commanders Council, was formed to assist the many ranges in technology as well as tracking instrumentation and equipment transfers; the Council provided a means of improving range capabilities while saving costs in building new hardware. During this time, White Sands became the center for innovation on the ranges.

A great example of this capability was the introduction in 1973 of a state-of-the-art telescope known as the Distant Object Attitude Measurement System (DOAMS). Designed in Boston by Dave Grey and supported by George Economou, Ray Delgado, and the co-author, the contract for 12 systems was awarded to Contraves Company of Pittsburgh, PA (dating back to John Brashear Company, circa 1881). The history of this experience is highlighted in a paper entitled "Range Instrumentation" by Raymond F. Delgado, published in *Physics* on 1 October 1981. As stated in the introduction:

“The history of the tracking telescope used at missile ranges is traced as both a metric and surveillance instrument. The history begins with the Askanias in 1937 and ends with the Distant Object Attitude Measuring System (DOAMS) in 1981. The history and capabilities of the cinetheodolites are discussed, as are fixed metric systems and mobile tracking mounts. All are discussed from a historical perspective to the state-of-the-art. The direction in which we must head to really advance the overall capabilities of photo-optical range instrumentation is briefly addressed.”

Scott Smith, optical engineering manager at Contraves, spent his initial years at Contraves standardizing the parts and components of the DOAMS. His work led to the ability to arbitrarily select any given part and replace it seamlessly, with another DOAMS part. Note: Scott was also responsible for the Subaru Telescope. The Subaru Telescope is a very large 8.2-meter, optical/infrared telescope constructed during 1991-1999 and has been operational since 2000 on the summit area of Maunakea, Hawaii; managed by the National Astronomical Observatory of Japan (NAOJ)12. Construction on Subaru began in 1992, and the first observations were made in 1993. Subaru is the Japanese name for the Pleiades.

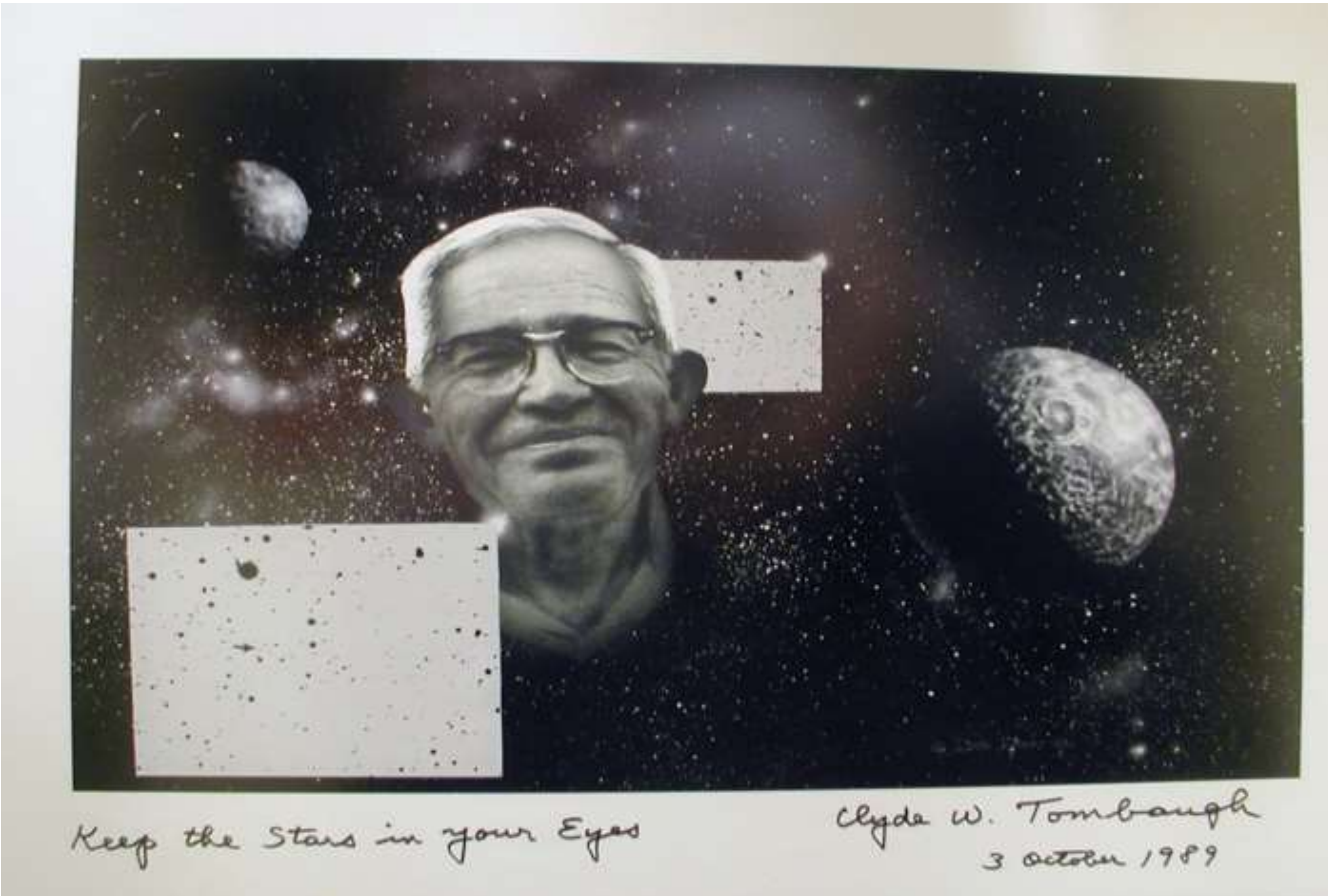
Some of the DOAMS were deployed to White Sands, NM, Patrick AFB, FL, and Vandenberg AFB, CA. The latter two locations are illustrated below:

This is the DOAMS installed near Cape Kennedy, FL, at Patrick Air Force Base. The two telescopes are of different focal lengths thus allowing the operators to quickly change magnification by a factor of 2X as the target flies out downrange, e.g., the latest space station supply rocket, SpaceX (a Dragon spacecraft full of science experiments, supplies and equipment for the ISS.)

The next slide features the newly modified infrared version of DOAMS which is located on Tranquillon Peak at Vandenberg Air Force Base, in Lompoc, CA.

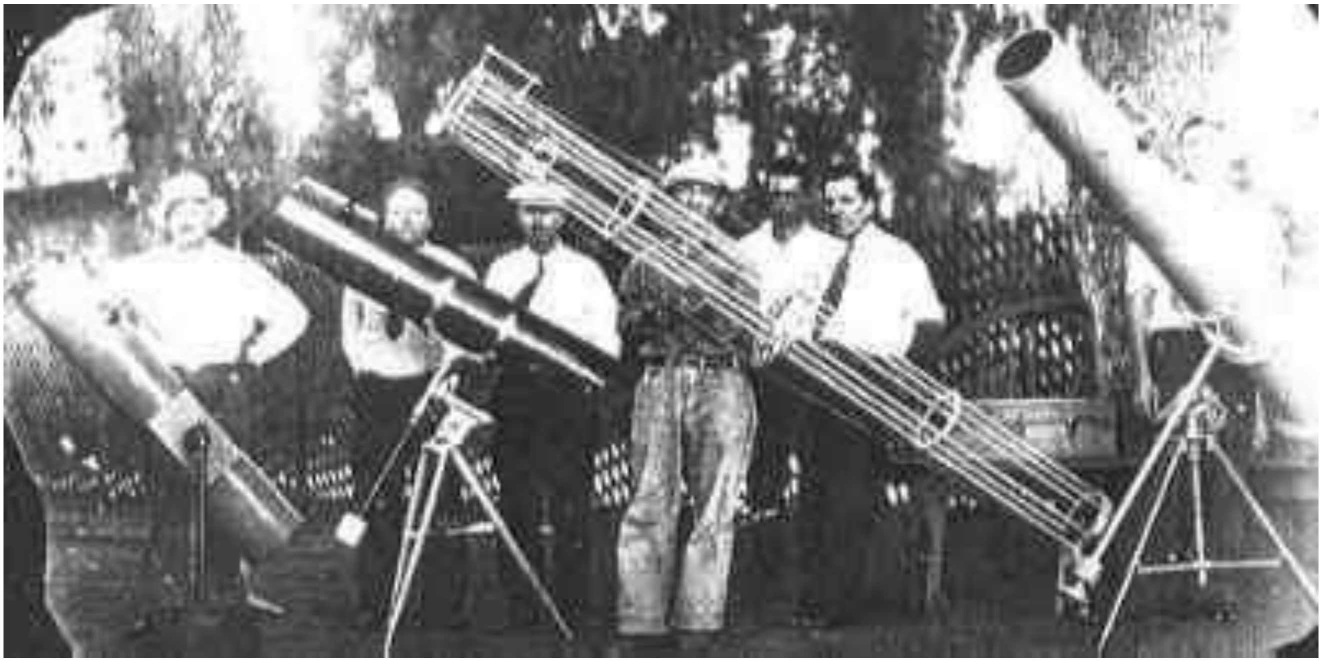
White Sands Missile Range is also the repository for surplus range tracking equipment as well as a museum of missiles and optical range-tracking equipment.

By far, the most notable astronomer who led the early efforts to develop telescopes and exploit the location of White Sands as a national missile development research and development facility, was Clyde Tombaugh, a former amateur telescope maker and discoverer of the Planet Pluto.



He was also on the faculty of New Mexico State University from 1955 to 1973 in Las Cruces, NM.

One of his favorite students was Gene Cross, who was an avid ATMer and known to many ATMers at Stellafane and the Riverside Astronomical Society.



Gene passed away in December 2020.

(THE FOLLOWING SECTION IS INCLUDED FOR ADDITIONAL READING. AN OUTLINE FOLLOWS THIS SECTION AS A SLIDE PRESENTATION)

A TURNING POINT IN OPTICAL FABRICATION & TESTING –

An Eyewitness* Account of the Decision to Create an Entirely New Methodology for Fabricating and Testing Space Optics

PRINCETON UNIVERSITY & PERKIN-ELMER CORPORATION

Martin Schwarzchild, Stratoscope II

Roderic M. Scott, VP and Chief Scientist

In the 1960s, Dr. Martin Schwarzchild of Princeton University served as the Program Manager for Lyman Spitzer's Project Stratoscope II, the predecessor to the Hubble Space Telescope. A contract for this balloon-borne telescope system had been awarded to the Perkin-Elmer Corporation located in Norwalk, CT.

Following a failed attempt to appease Dr. Schwarzchild with the term "diffraction limited" and dozens of Foucault Knife Edge test results (plus a master optician's word that the Foucault test was definitive), the primary and secondary mirror fabrication and testing effort was withdrawn from the Engineering Division during the summer of 1961 and reassigned to the office of the Vice

President and Chief Scientist, Dr. Roderic M. Scott. *As I had just joined the company in June and was new to the shop, I was directed to report to Dr. Scott and offer to provide technical and engineering support as required. This assignment required vetting by Dr. Schwarzchild, who serendipitously was a mentor of my professor at the University of Texas in 1956, Dr. Frank N. Edmonds, Jr.; I passed the vetting process. In my new role I would create a work plan which would be approved by both Drs. Schwarzchild and Scott. The goal was to achieve a surface figure of roughly 1/40th wave root-mean- square in the visible portion of the electromagnetic spectrum, over the entire 36-inch diameter aperture of the primary mirror. (The same quality was to be achieved on the surface of the ellipsoidal secondary mirror as well as the folding flat; the design was a Gregorian configuration.)

The first meeting of this newly formed mirror fab & test management team occurred in Dr. Scott's office. The following commentary is based on my engineering notes and my recollection of the conversation at that time. Note the emphasis that Dr. Schwarzchild placed on the value of a contour map which was based on using a practical interferometer and his concerns about the deleterious effects of atmospheric turbulence and vibration.

M.S.: Rod, I must have a quantitative reason to accept the Stratoscope II primary and secondary mirrors. Not Foucault. I want a topographic map of the surface of each of the two mirrors, good to 1/100th wave light in the visible.

R.S.: Alright, Martin. In preparation for this meeting, Joe has a list of tasks that he and I put together last week; these tasks must be accomplished to make that kind of data available to you and to guarantee sign-off.

J.H.: I've put together a list of EIGHT tasks. #1 – We must use a practical interferometer. Jim Burch visited us from NPL in the UK recently and taught me how to make and use a scatterplate. From my initial tests, it would be ideal. I can easily package it with a Kohler style illuminator operating in Hg green and get high contrast, circular rings at the vertex radius of an f/4 parabola. #2 – We have to buy a large, 8-foot diameter by 24-foot-long vacuum tank with a pump capable of achieving a 1mm vacuum in order to eliminate atmospheric turbulence and stratification. #3 – The tank must be mounted in a vertical position; this will minimize mirror sag effects. Further, #4 – an 18-point cantilever-type support must be used to minimize the effect of gravity. #5 – A chiller unit capable of -40 degrees F. and a 36-inch copper coil enclosure must be built to hold the fused silica mirror and to simulate temperatures at 80,000 feet. Also, a cold trap will have to be designed for the pump to eliminate the possibility of oil contamination on the mirror surface.

#6 – A large bearing with a precision ball-race will have to be installed under the mirror and cell assembly for achieving high accuracy in figuring operations and for positioning the mirror accurately during each of the test cycles. #7 – A temperature monitoring system will have to be constructed to ensure that an array of thermocouples can be attached to the mirror surfaces for

gathering data on the thermal profile of the mirror during low temperature operation (when the interferograms are being recorded). #8 – Probably the most important task involves mounting the vertical vacuum tank, with everything installed, in a vibration isolating structure that completely removes it from the dynamics of the building in which it is located.

In sum, the result of these improvements must be obtained with the improvement not only in terms of quantitative data about the mirror surface but also, in terms of turn-around efficiency regarding testing and figuring. We must be able to "unbutton" and "reinstall" the mirror with a minimum of effort. Thus, the bottom portion of the tank must carry the cell, bearing, and cold enclosure with thermocouples and should be easily detached and reattached to the tank. Further, the copper coil enclosure should have a remotely operated lid that can expose the mirror to the interferometer "on command" from a control room that will be constructed atop the new building (just being built in Wilton, CT); this control room will house the interferometer instrumentation and recording equipment (a Hasselblad camera using high resolution glass plates.)

Note that this lid/cover concept was used later with the Hubble Space Telescope.

This presentation by the co-author was followed by a status report on an algorithm recently created for reducing the rings of fringes produced by a parabola versus the interferometer's spherical wavefront. The purpose of this algorithm was to generate a topological map of the mirror surface sufficient to provide the *optician, Ben Gay, with the ability to identify the high spots for polishing and figuring. It employed a least-squares, best fit analysis and generated a root-mean-square value; something that M. S. could use for acceptance criterion.*

R.S.: So there, Martin, you have our proposed path to satisfying your need for a quantitative evaluation of the primary mirror, and the secondary mirror as well. However, I warn you that this will be expensive.

M.S.: I understand, Rod, but do not worry. The customer and I will work with Mr. Perkin (President of Perkin-Elmer) to resolve the expense issues. I need you and Joe to see to it that you have everything you need to get me the best result.

R.S. (chuckles): Absolutely, Martin.

R.S.: Joe, I guess we have our work cut out for us. Let me know who in the engineering division you'll need to help you get the job done within the next several months. I'll contact Bob Brooks (optical shop manager) and make certain that Ben (Gay) is available to you full time. I'll also make sure that Lloyd McCarthy's (chief lens designer) best computer programmer is available to you as soon as this meeting adjourns. Meanwhile, pick our top experimental tool and die maker and we'll put him to work immediately. Harold Hemstreet (overall Stratoscope II program engineering director) will provide the necessary mechanical and electrical engineers that you need.

Comment: The co-author believes that this verbal exchange highlighted Dr. Schwarzchild's vision of fabricating and testing* *future large, space optics and represents clearly the earliest and most comprehensive documentation of Dr. Shwarzchild's contribution to the optical industry at large. Further, it supports the viewpoint that Dr. Martin Schwarzchild should be acknowledged as the "Father of Modern Optical Fabrication and Testing Practices" at the beginning of the Space Age. It is noteworthy that beginning in 1963, ALL space optics assets and large ground-based telescope optics such as Keck, Subaru, and the Giant Magellan Telescope, were conducted in accordance with the new Schwarzchild-based Fabrication and Testing Protocol; every manufacturer and government laboratory was required to use the most advanced interferometers and software. Additionally, space optics were subjected to vacuum and cold tests as part of the quality assurance process. Examples include the KH-9 (Hexagon), the Optical Bar Panoramic Camera for the Apollo Lunar Survey and the James Webb Space Telescope.*

THE EIGHT GOALS FOR OPTICAL FAB & TESTING

1 – USE A SCATTERPLATE INTERFEROMETER WITH A HG GREEN SOURCE

2 – DESIGN & BUILD A VACUUM TANK 8' DIAMETER x 24' LONG

2a – DESIGN & INSTALL A VACCUM PUMP CAPABLE OF 1mm ATMOSPHERE.

3 – INSTALL THE TANK IN A VERTICAL POSTION AND PROVIDE ACCESS FOR TEST INSTRUMENTATION IN A CONTROL ROOM LOCATED AT THE UPPER END

4 – BUILD AN 18-POINT CANTILEVER MOUNT FOR THE 36-INCH PRIMARY MIRROR

5 – DESIGN & BUILD A CHILLER UNIT AND MIRROR CAGE CAPABLE OF -40 F.

5a – DESIGN & BUILD A COLD TRAP TO ELIMINATE OIL CONTAMINATION

6 - BUY & INSTALL A 36-INCH PRECISION BALL BEARING RACE

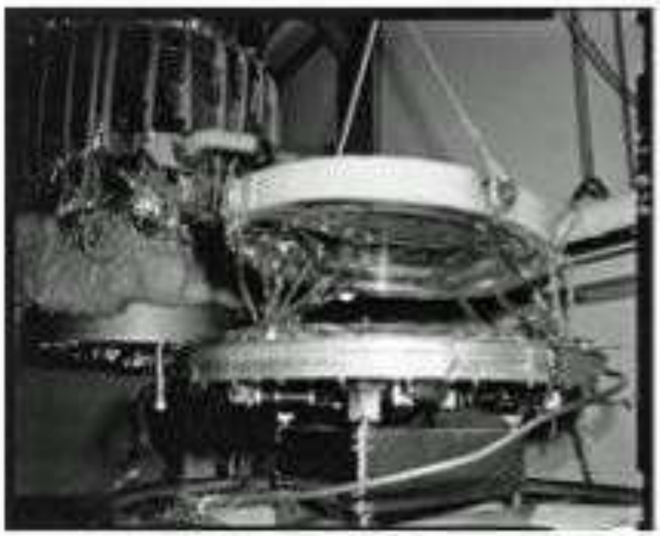
7 – DESIGN & PROVIDE FOR THERMAL MONITORING OF THE 36-INCH MIRROR

8 – MOUNT ALL INTEGRAL TESTING HARDWARRE ON VIBRATION ISOLATORS

ILLUSTRATED BELOW IS THE FINAL RESULT:

STATUS OF OPTICAL SYSTEMS TESTING IN 1962
Princeton University and Perkin-Elmer Corporation

Vertical Vacuum Tank with ARC Refrigeration
(lowest limit 2 mm Hg and -40 degrees F.)



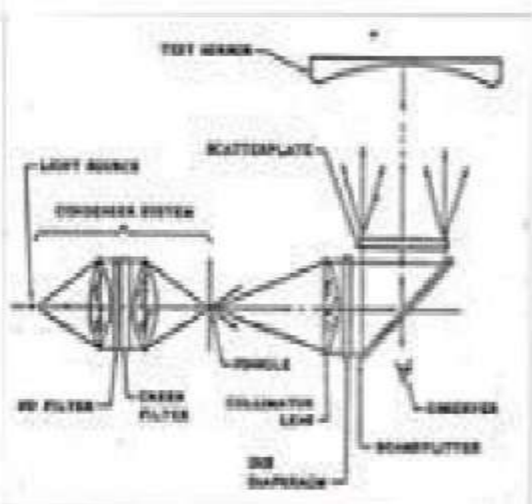
Final surface contour map of 36-inch Mirror
(in fractions of wavelength of white light)

*Eyewitness is the co-author. The 36-inch mirror is being prepared for a vacuum cold test. The mirror will be evaluated by a Burch Scatterplate interferometer mounted on the other end of this 24-foot long, tank.

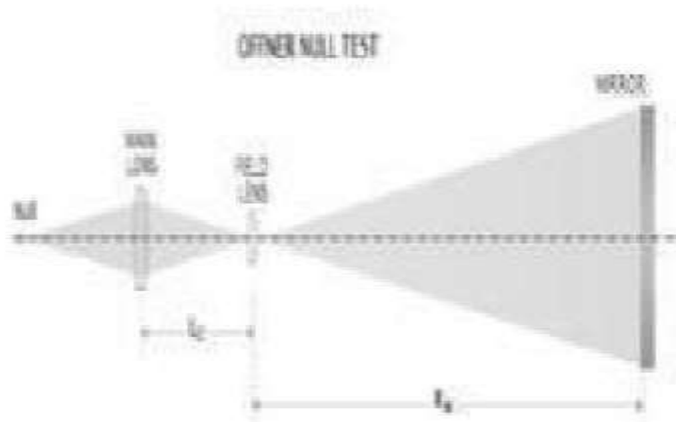
The basic configuration of a Burch Scatterplate interferometer c. 1962 and a layout of the recording instrumentation (mounted atop the vibration isolated vacuum tank), are shown in the next two slides. See below:

STATUS OF OPTICAL SYSTEMS TESTING IN 1962
Princeton University and Perkin-Elmer Corporation

Burch Scatterplate Interferometer



Offner Refractive Null Lens



Scatterplate Interferometer

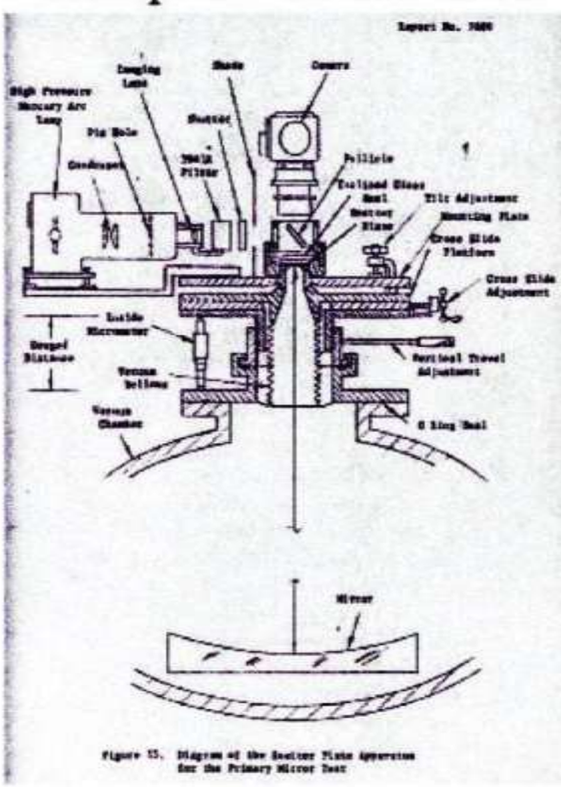


Figure 15. Diagram of the Scatter Plate Apparatus for the Primary Mirror Test

Fringe Scanning Digitizer

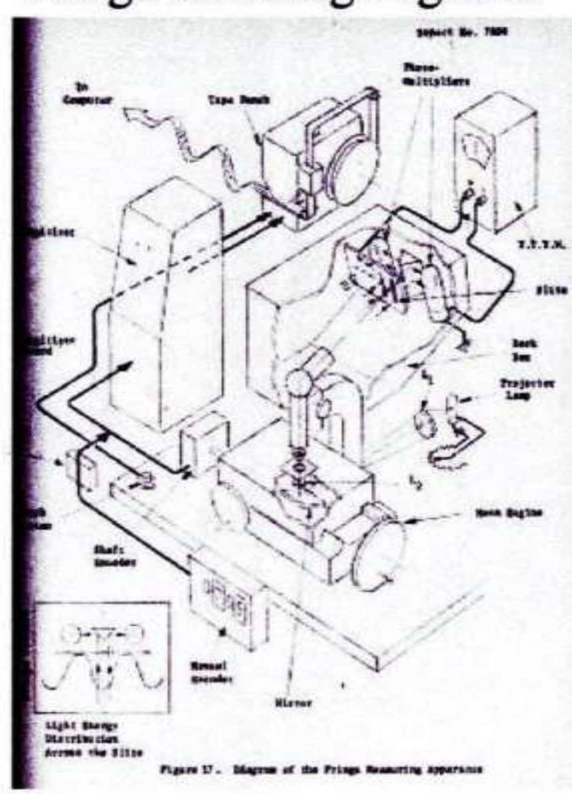


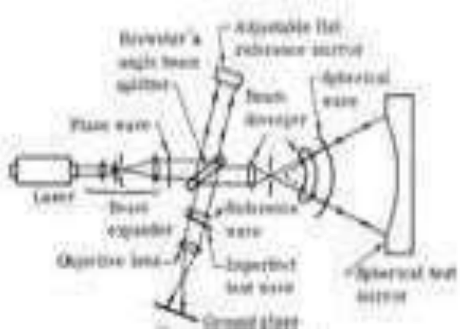
Figure 17. Diagram of the Fringe Measuring Apparatus

THE EVOLUTION OF LARGE MIRROR FABRICATION AND TESTING METHODOLOGY FROM 1961 TO 1965

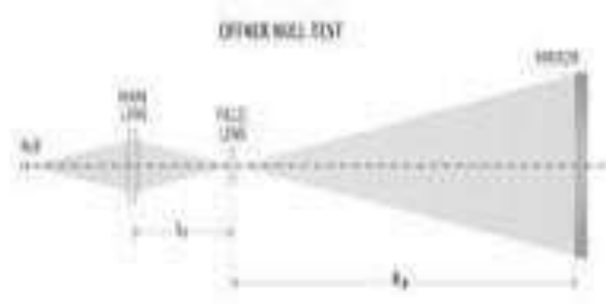
The new Schwarzchild-based fabrication and testing protocol led eventually to the invention of laser unequal path interferometers (LUPIs) and the routine application of computer assisted optical surfacing (CAOS). With the advent of the Perkin-Elmer HeNe gas laser, and the use of Polaroid film, shop turn-around times from spindle to vacuum testing tank and back to spindle of less than one hour meant that large mirror manufacturing schedules could be reduced by an order of magnitude or more. Spin casting of large mirror blanks using the Roger Angel process at the Mirror Lab in Tucson, AZ, also played a major role in advancing the state-of-the art and significantly reducing schedules for manufacturing large telescope mirrors. A layout of the first LUPI is shown below:

STATUS OF OPTICAL SYSTEMS TESTING IN 1966
ITEK CORPORATION

Laser Unequal Path Interferometer



Offner Refractive Null Lens

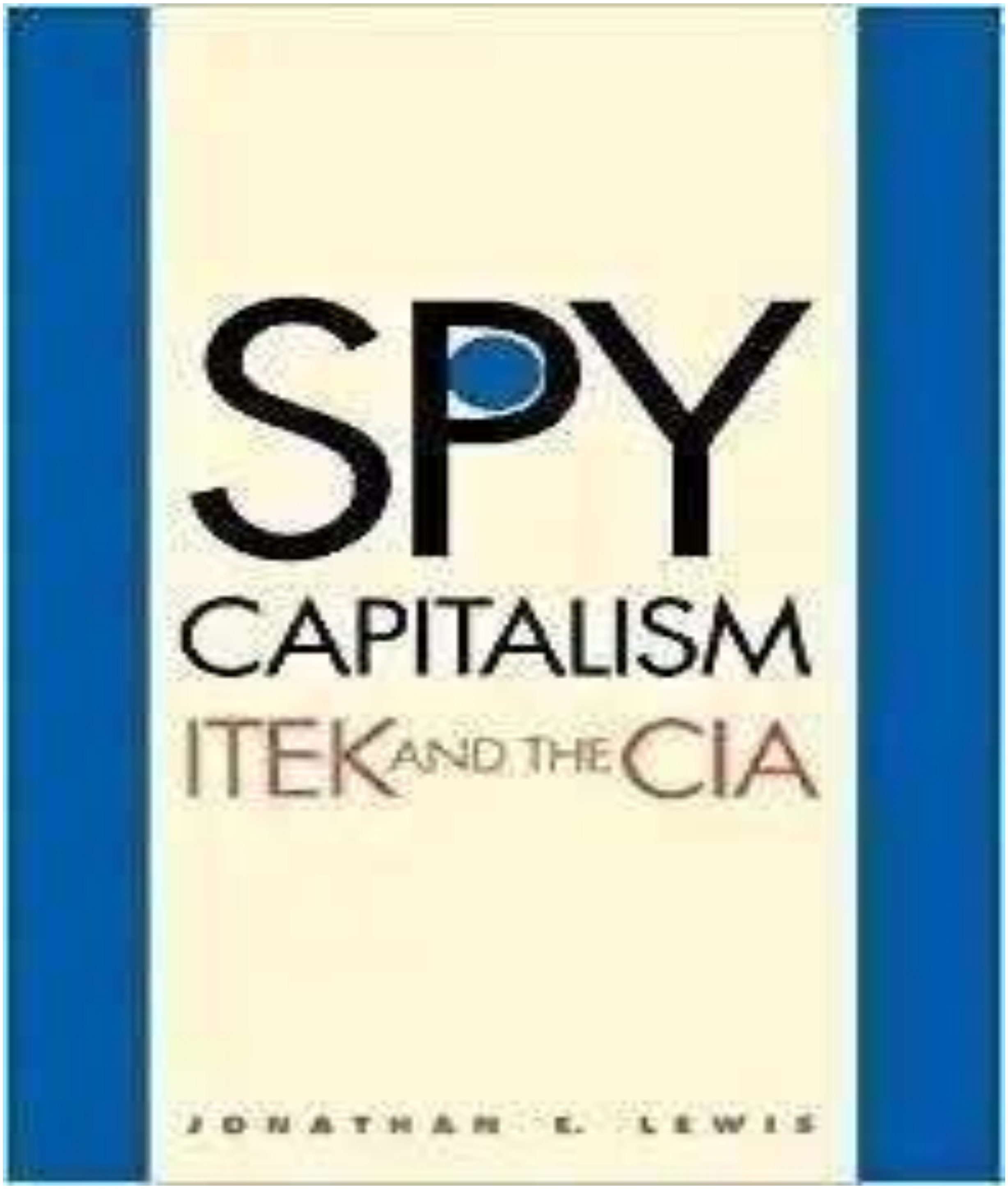


ITEK CORPORATION AND PROJECT CORONA

Itek Corporation was founded in 1957 by Lt. Col. Richard S. Leghorn, (top left) a USAF expert in aerial reconnaissance and Teddy Walkowicz (top right), an associate of venture capitalist Laurance Rockefeller (not shown). The purpose of the company from the outset was to provide a source of optical cameras for the Central Intelligence Agency. Director of the CIA was Allen Dulles (pictured center below.) To create a product and deliver hardware, the Boston University Physical Research Laboratories was purchased. Dr. F. Dow Smith (bottom left) was Director of Research Programs in Optics at Boston University and became Vice President and Corporate Scientist. Other important players (featured together) included B/G George Goddard, USAF (Ret.), a pioneer and inventor of aerial and space photography systems, and Dr. Duncan MacDonald, Chief of R&D at Itek.

ITEK CORPORATION & SPY CAPITALISM

A wealth of information about the people and their venture is contained in the book entitled *Spy Capitalism – ITEK and the CIA*, authored by Jonathan E. Lewis.



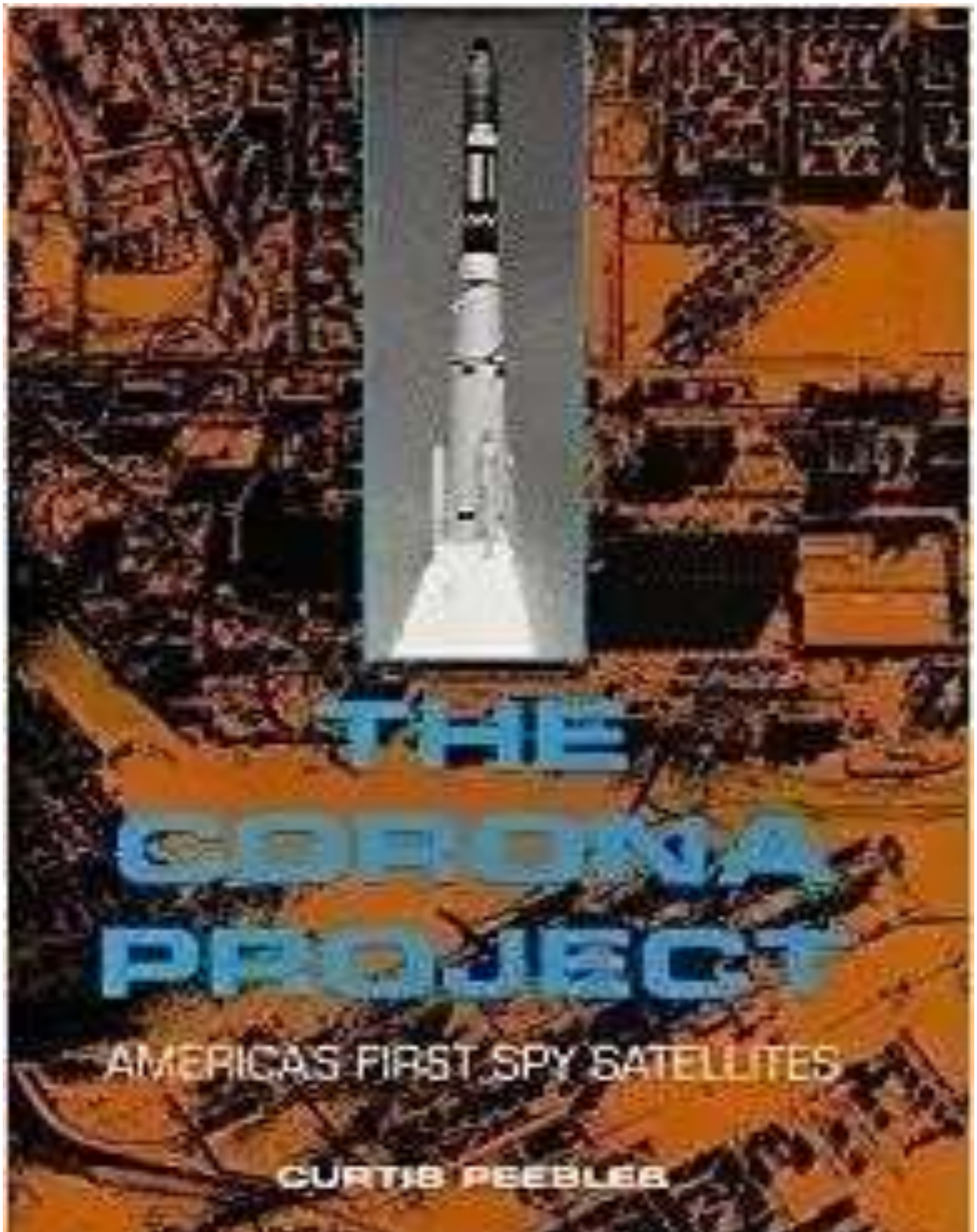
Management of Project Corona

The Project was managed by a team of USAF and CIA professionals. USAF management was provided by Colonel Lew Allen, later to become Director of the Jet Propulsion Laboratory.

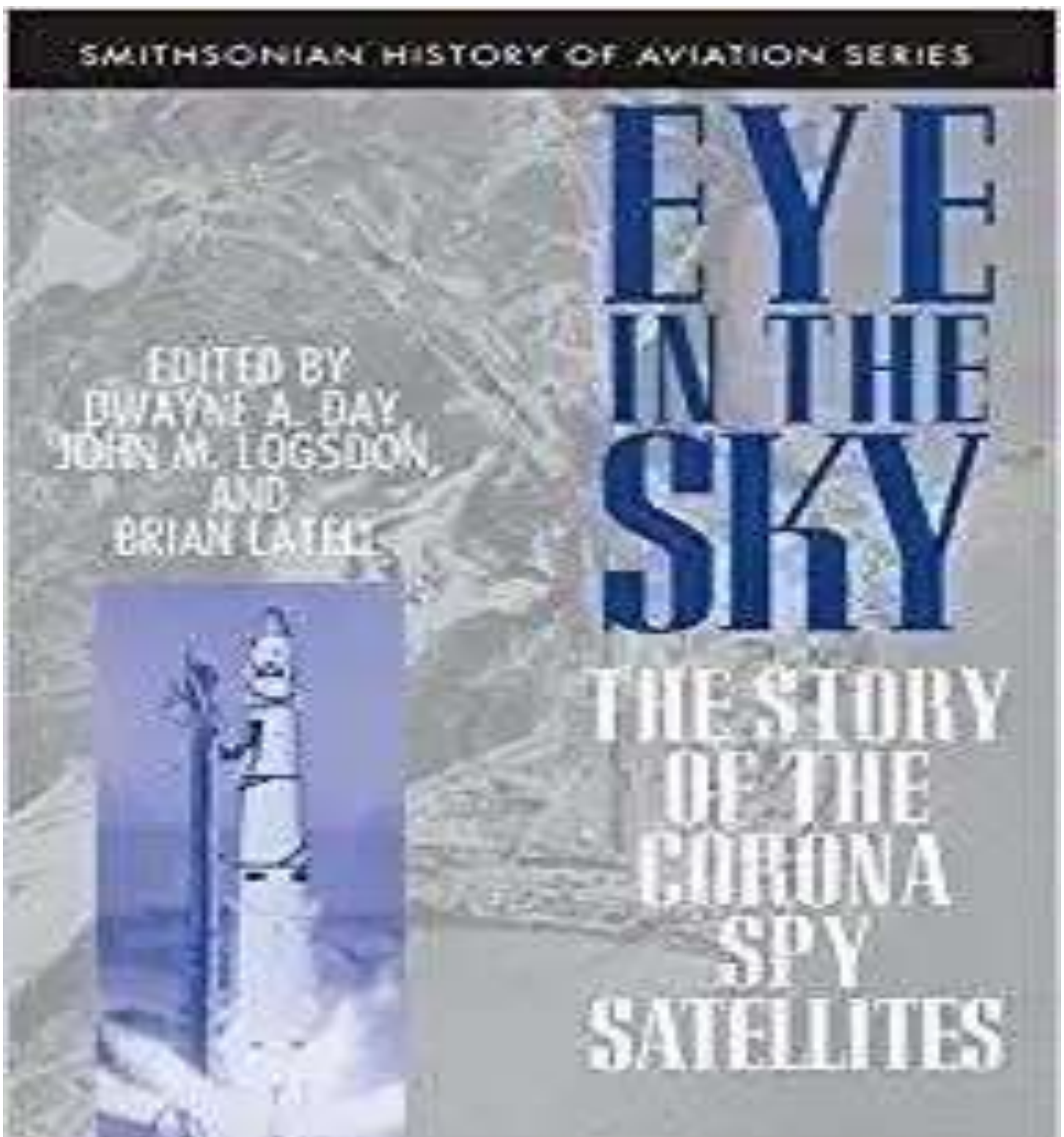
The Deputy Director for Science & Technology, Carl Duckett, and Program Manager, John Parangosky (also referred to as “Mr. P”), represented the Central Intelligence Agency.

ALLEN DUCKETT PARANGOSKY

Recommended reading material for details about the project and its results includes two definitive, declassified accounts:


THE
CORONA
PROJECT
AMERICA'S FIRST SPY SATELLITES
CURTIS PEEBLES

and *Eye in the Sky: The Story of the Corona Spy Satellites* (Smithsonian History of Aviation and Spaceflight.



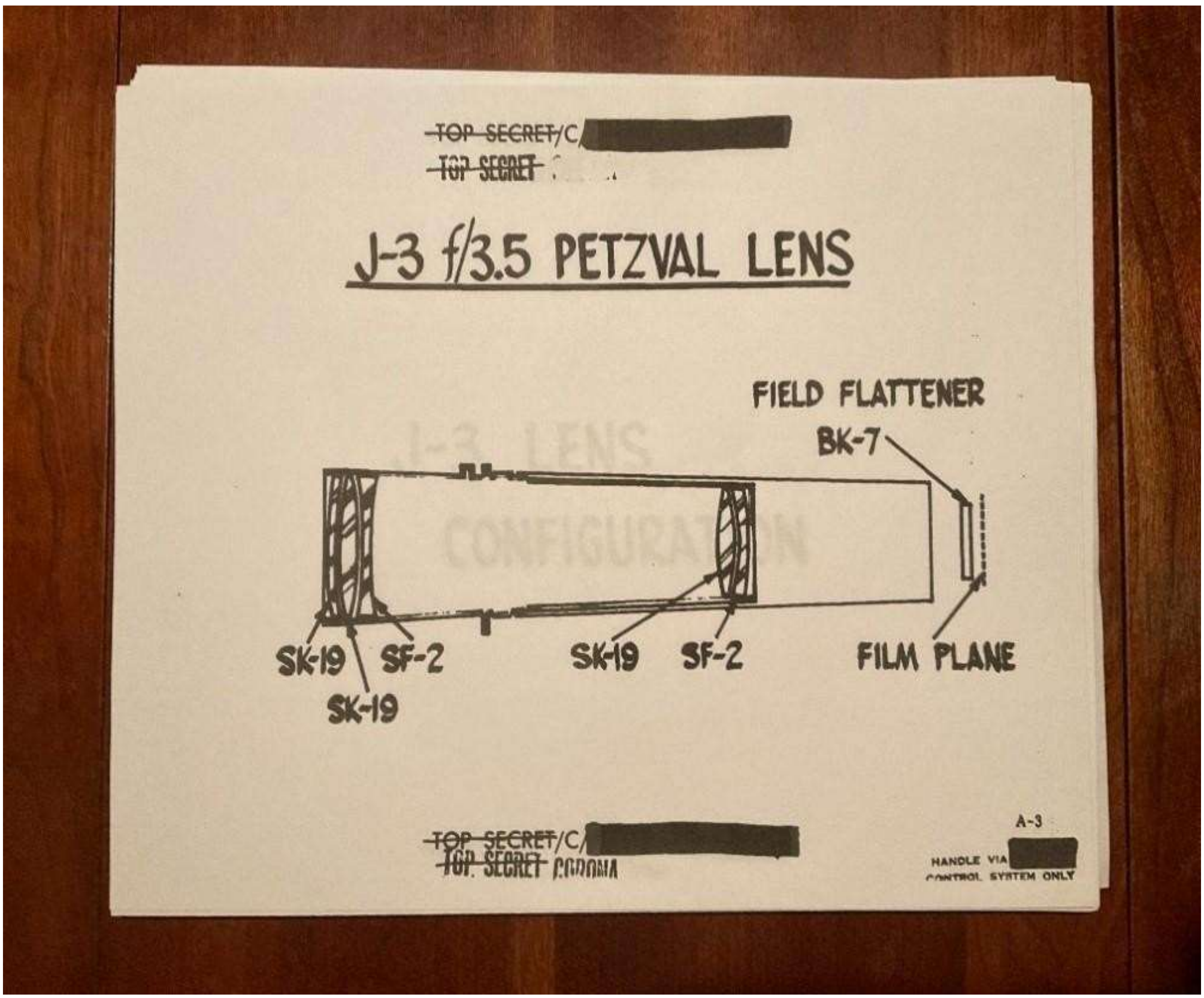
The ITEK Corporation and The University of Rochester conducted the day-to-day management of the various activities involved in producing the opto-mechanical subsystems for the classified customer, the Central Intelligence Agency. From left to right, top row, Dr. Robert Hopkins of the University of Rochester, and Frank Madden and Bob Shannon of Itek. Frank Madden was the mechanical lead while Bob Shannon and Bob Hopkins joined in to provide the original concept and generated the lens design parameters. During the production phase of the project, Madden and Shannon continued to lead the effort at ITEK. Assisting them in the optical shop were left to right, Sam Gardiner who managed the large optical shop; the co-author, Joe Houston, who was responsible for all test instrumentation and optical testing; and Robert Hilbert, who was deputy to Bob Shannon in the lens design department.

CORONA OPTICAL SYSTEM DESIGN, FAB & TEST

The manager for the small optics shop, Joe Appels, was responsible for state of the art, near-perfect Corona optical lenses. Joe, now 90 years old, is featured in the slide below, as he passes the baton at his company Tucson Optical Research Corporation (TORC) in Tucson, AZ, to the younger members of his family. He was trained at the University of Delft of the Netherlands and brought his expertise to the Boston area where he encouraged dozens of amateur telescope makers to achieve perfection in the optical shop.

The optical shops and testing labs at Itek operated 24/7. Three, 5-7 person teams, were organized for measurement and evaluation. The co-author was the overall manager for testing and the development of test instrumentation; John Buccini, was the chief designer and builder; Art Simpson, a former ATMer who grew up in Dallas, Texas, Lee Peters, and Walt Luban were team leaders. Most members were former ATMers from New England and New York, who had been working for other optical companies in Boston and in Connecticut.

Featured below is a copy of the original, highly classified, Petzval lens drawing:



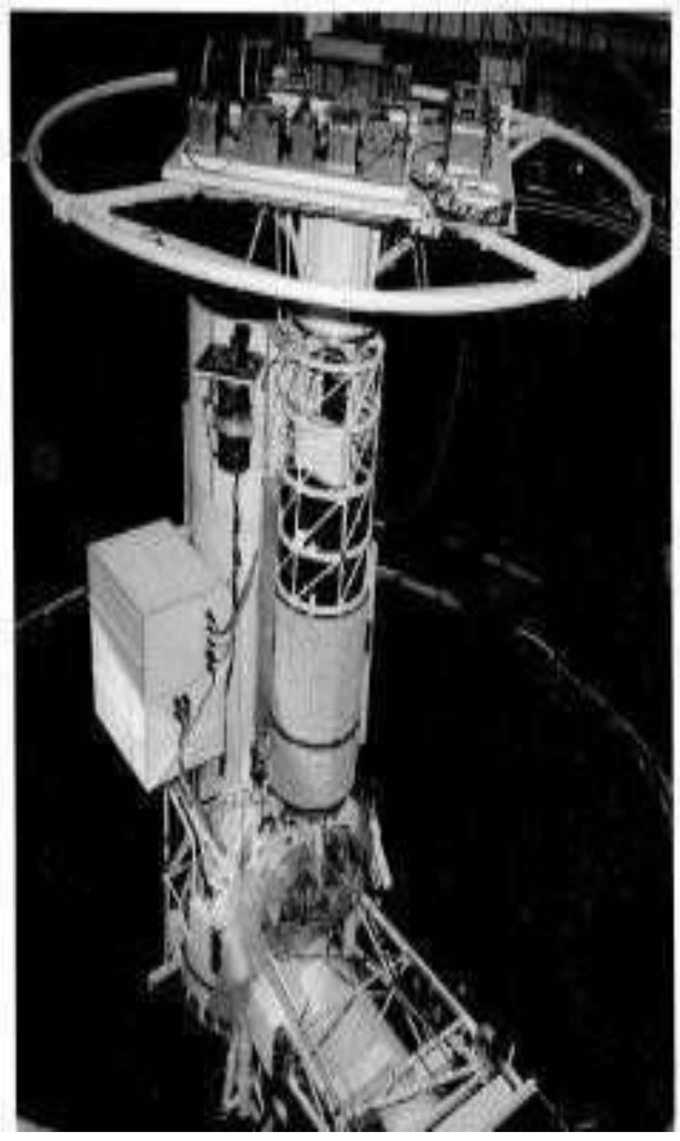
As the paragraph below makes it abundantly clear:

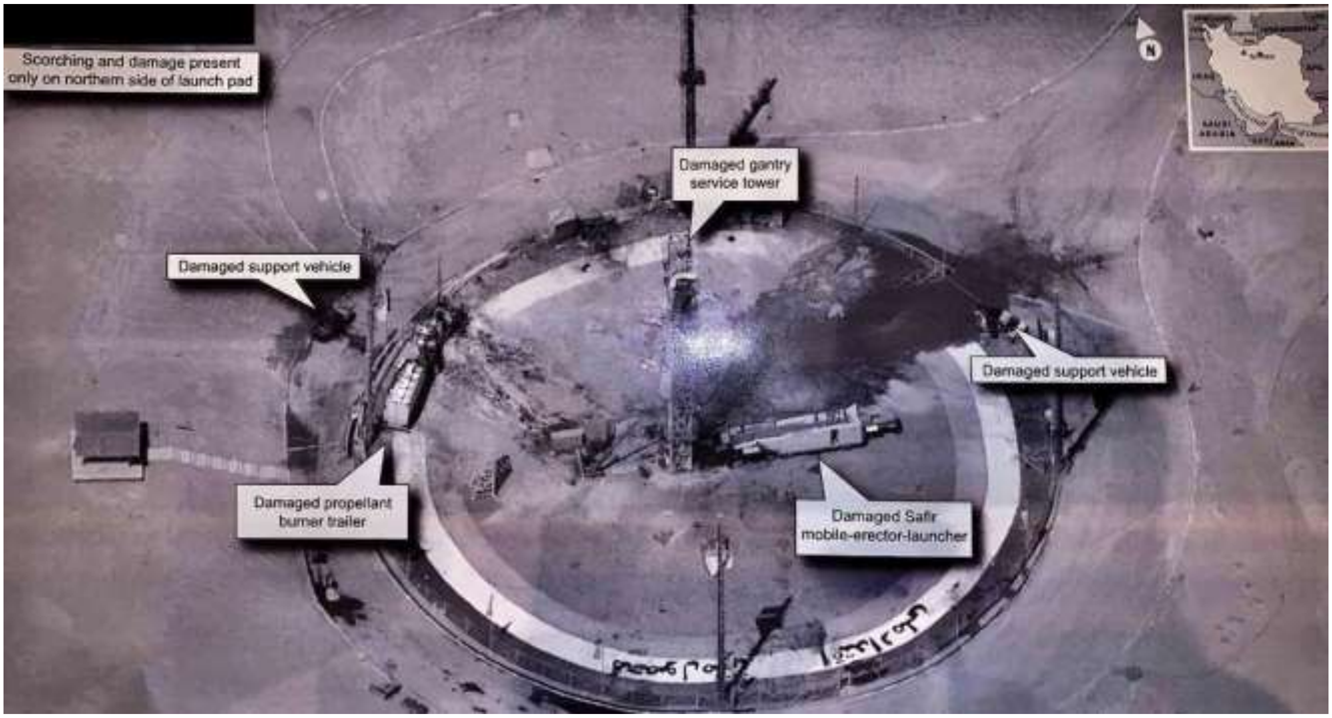
> "CORONA is a milestone in US history. Developers of this nation's first film-return photoreconnaissance satellite explored and conquered many technological unknowns of space, lifted the curtain of secrecy that screened military developments within the Soviet Union and Communist China, and opened the way for the even more sophisticated follow-on imaging satellite systems. The 145th and final CORONA launch took place on 25 May 1972 with the final recovery on 31 May 1972. Over its lifetime, CORONA provided photographic coverage totaling approximately 750,000,000 square miles of the earth's surface. This impressive capability was surpassed only by the quantity and quality of intelligence that it yielded. Without CORONA, the US may well have been misguidedly pressured into a World War III."

Follow-on spy satellite systems include the KH-9 "Hexagon" which was built by Perkin-Elmer and helped to win the Cold War.

Significantly, it only took a decade for the United States to put a man on the moon. During that same decade, the United States moved from Stratoscope II Balloon-borne Telescope which was designed to explore the potential for serious space-based astronomy to an intelligence gathering capability that far surpassed the capability of every other country on the planet. The technology and expertise that supported this dramatic revolution was based entirely on the first steps taken to create a perfect optical system for gleaning knowledge about our solar system and the universe we inhabit. The following illustration compares the two results:

STRATOSCOPE II versus KH-9 HEXAGON





A suspected KH-11 image of the Safir Launch Site disaster. If this is true, then the resolution can be estimated from public information about the diameter of the primary mirror, and the satellite's orbital altitude. The mirror for the first KH-11 was quite good and quite large - seven feet, eight inches wide. Assuming that a mirror is diffraction-limited, then its resolution is a function of its diameter, the wavelength of light to be detected, and the distance from the target:

resolution = 1.22 * wavelength * distance / diameter

The wavelength of visible light is about 5.5e-5 cm. The first KH-11 mirror was 234 cm in diameter. At perigee, a KH-11 is about 300 km above the Earth, or 3e7 cm. This formula yields 8.6 cm as a KH-11 resolution at 300 km, which is roughly 10 cm.

KH-9 Mapping Camera Image of Kubinka Airfield, near Moscow in the Former Soviet Union, 6 April 1979 (150X Magnification)

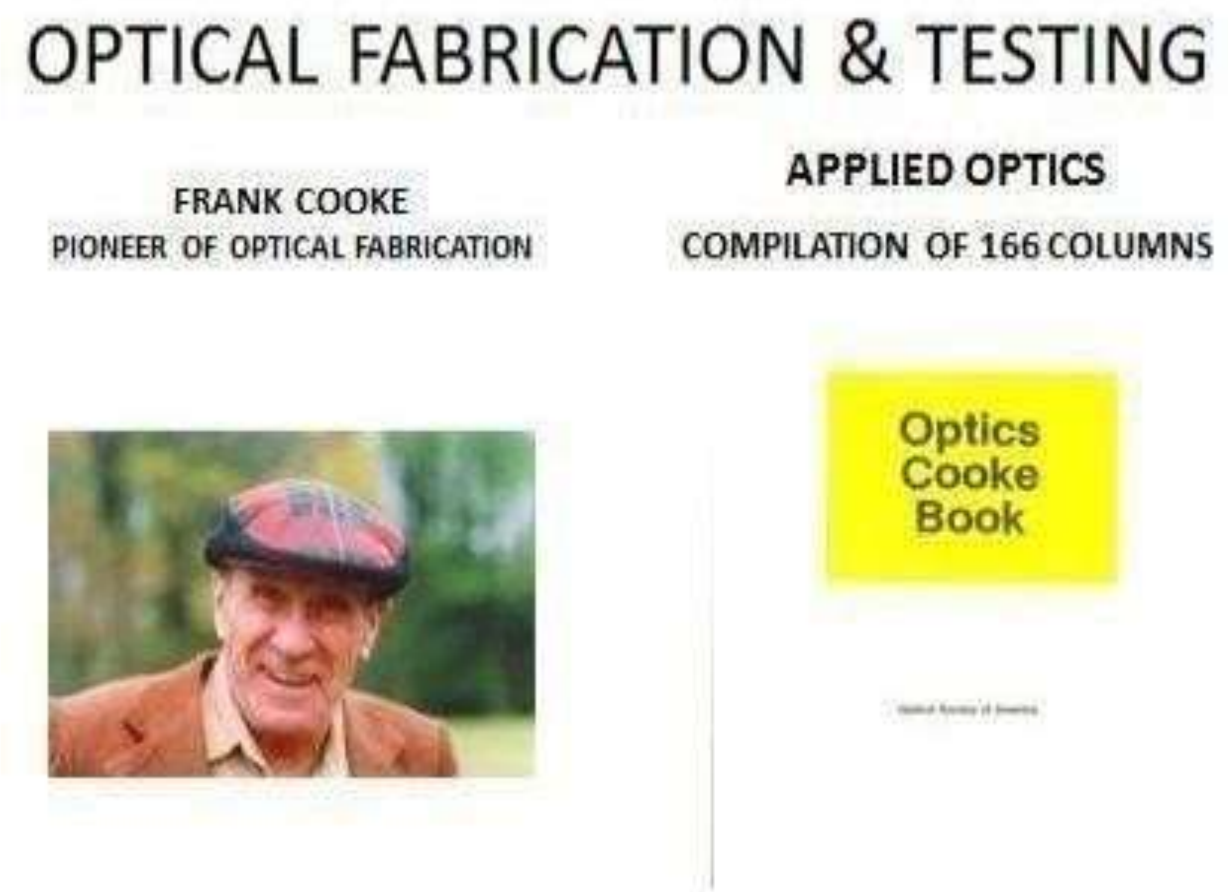
The KH-9 panoramic cameras, featured above, captured high resolution (2-4 feet) and moderate resolution (20-30 feet) terrain images. The KH-9 framing cameras produced 9 x 18-inch imagery at a resolution of 20-30 feet. The ground resolution varied within the scan and reached around 3m towards the 60∘ scan angle (for a 170 km satellite altitude).

OPTICAL FABRICATION AND TESTING

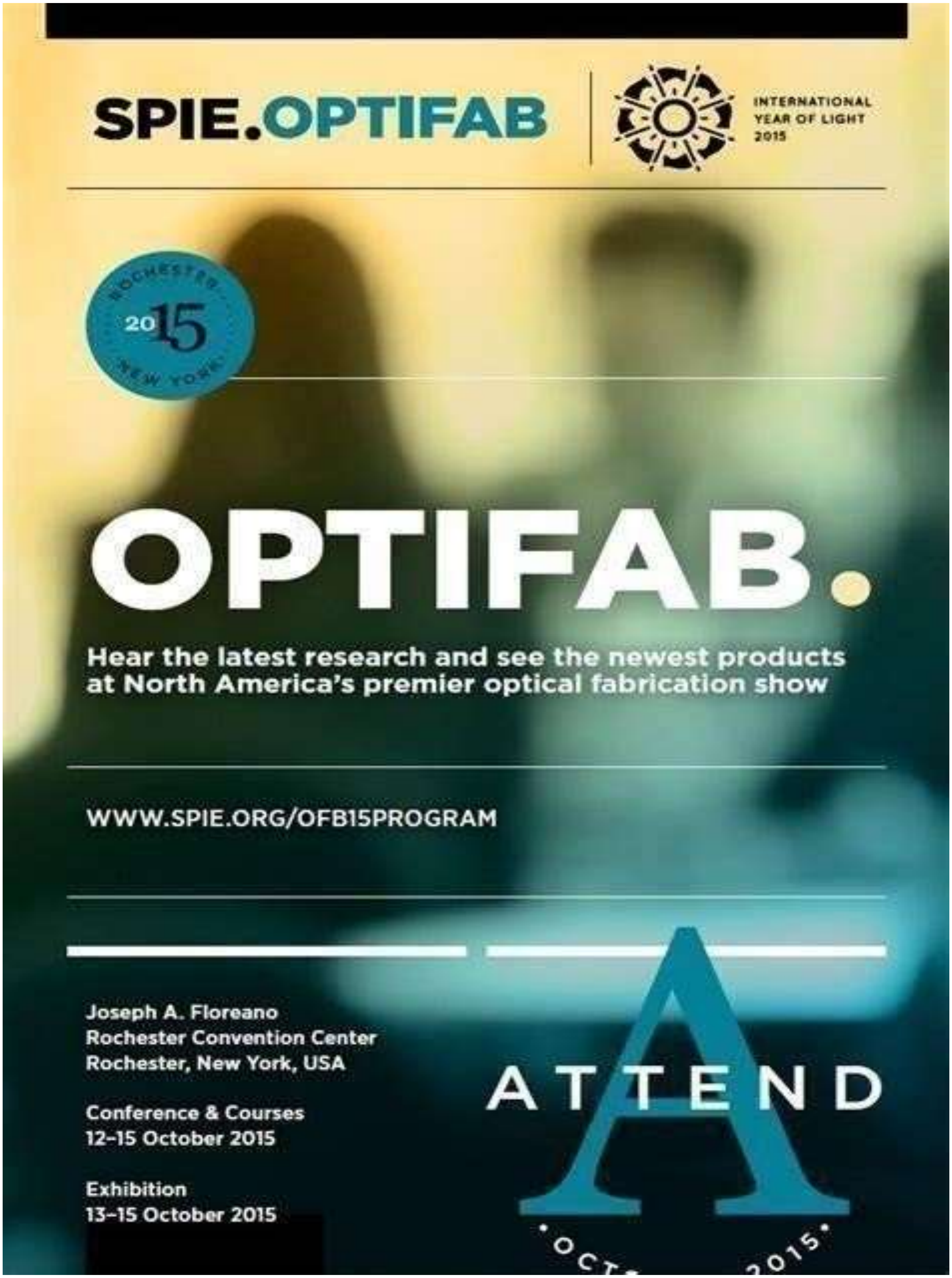
In 1975, the co-author asked Dr. Jarus Quinn, Executive Director of the OSA, now known as Optica, to use Society funds to underwrite an optical shop style “Road Show.” The stated purpose was to spread knowledge of new fabrication and testing methods and techniques to the optical community at large. Since it was costly for optical companies to send opticians to meetings and not only pay for travel and subsistence but also, lose valuable time on the job, the idea was to bring the technology to the shop by holding trade conferences in the locale of several of the top companies; and to hold them on weekends. (It was a simple matter to identify strategic locations such as Boston, Baltimore, and Rochester.)

Following several successful years on the road, the co-author asked Dr. Quinn to further grant the group official status within the

Optical Society of America by establishing an Optical Fabrication & Testing Technical Committee. The Board agreed and Frank Cooke was nominated and elected the Committee's first Chairperson.



The movement eventually evolved into OPTIFAB and enjoys a large and growing audience some 49 years later. Both Optica and SPIE worked together to make this happen.


SPIE.OPTIFAB
INTERNATIONAL YEAR OF LIGHT 2015
ROCHESTER 2015 NEW YORK
OPTIFAB.
Hear the latest research and see the newest products at North America's premier optical fabrication show
WWW.SPIE.ORG/OFB15PROGRAM
Joseph A. Floreano
Rochester Convention Center
Rochester, New York, USA
Conference & Courses
12–15 October 2015
Exhibition
13–15 October 2015
ATTEND

DMZ TELESCOPE, USAINSCOM, AND SKY&TELESCOPE

From February 1982 through February 1987, the co-author served as a part-time Consultant, GS-15E, to Electro-Optical Systems Division of the United States Army Intelligence & Security Command, Arlington Hall, VA. The Division Chief was Al Murdock, a veteran of the Army Security Agency and expert in the field of Electronic Intelligence and related activities such as Communications Intelligence, Signals Intelligence and Laser Intelligence. Headquarters and Mr. Murdock are shown below:

U. S. ARMY INTELLIGENCE & SECURITY COMMAND

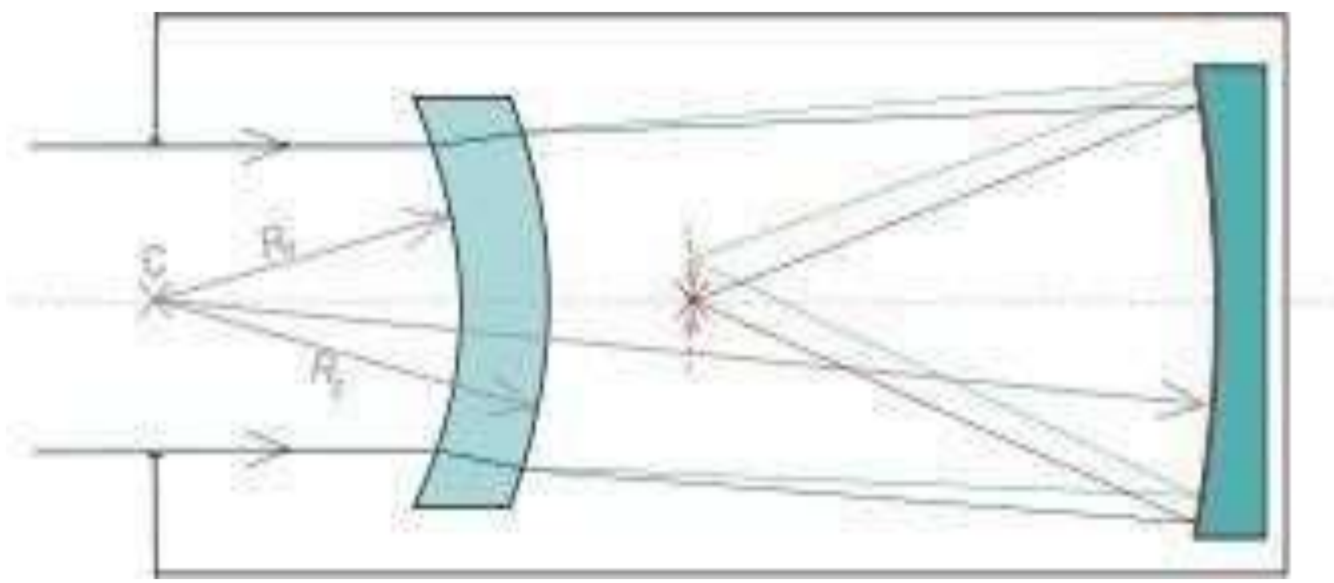
HEADQUARTERS, USAINSCOM
ARLINGTON HALL STATION, VA

AL MURDOCK & MLM/LARKSPUR
TEMPELHOF AIRPORT, BERLIN

Operational and technical liaison was maintained between USAINSCOM and the U. S. Army's Night Vision and Electro-Optics Laboratory at Fort Belvoir, VA, through its Director, Dr. Rudolf G. Buser, an internationally recognized scientist who was responsible in large part for the development of the Army's laser range finder, night vision goggles and other fielded electro-optical systems. Dr. Buser also visited Army field sites and interacted with DARPA, government and civilian laboratories, academe, as well as the intelligence community, to rapidly advance the state-of-the art during the Cold War.

Dr. Rudolf G. Buser
BRANDENBERG GATE

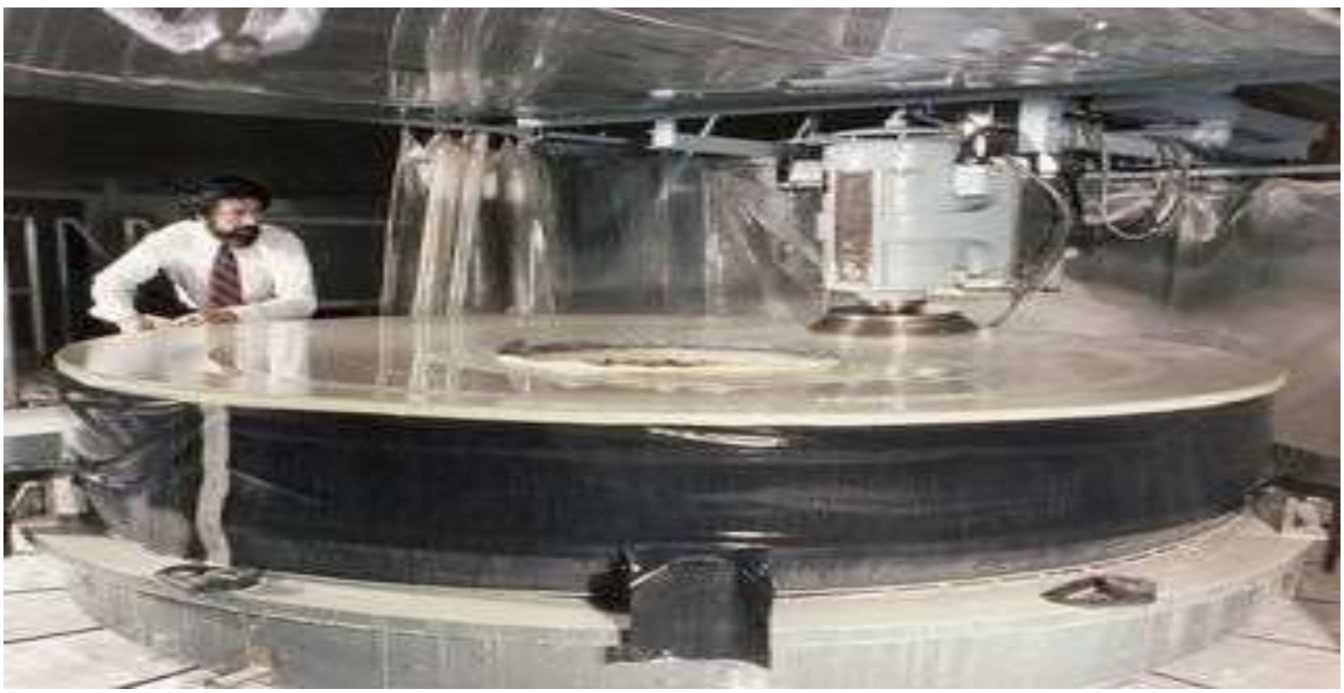
In the mid-1980s, the co-author was given the task of designing and building three moderately-sized, electro-optical, day-night telescopes, capable of being deployed with a control and monitoring unit, to strategic points along the Demilitarized Zone, in South Korea. Their purpose was to provide border surveillance and early warning. During that same period, an article appeared in Sky & Telescope describing catadioptric systems. A system invented in 1940 by the Dutch lens designer, Albert Bouwers, is illustrated below:



This configuration had several advantages as a baseline design. It allowed for a large field of view, was simple to align, easy to fabricate and test the optical components, and provided an optical path for attaching two video cameras to the outside of the telescope housing: one for daytime viewing and one for nighttime viewing. With a single, rotating fold mirror, switching between modes could be accomplished in seconds. Three optically perfect windows were manufactured by Meade Corporation and installed on the front of each instrument to prevent debris and dust from entering the optical chamber. Minor changes were made to the optical prescription to allow the operational configuration to be realized. Appropriate coatings were applied to all surfaces. Featured below is a map of the Korean Peninsula and a picture of the fielded product.

THE IRONY OF IRONIES: The Hubble Telescope troubles

Shortly after its launch in 1990, NASA reported a problem with the Hubble Space Telescope. It had taken years and millions of dollars to fabricate and test the primary mirror, build, and launch this national treasure. The process closely followed the protocols established by Martin Schwarzchild and Rod Scott in the early 1960s and provided the basis for Perkin-Elmer's award of the HST contract. See previous section on the contributions of Scott and Schwarzchild to the optical shop.



Immediately, a Blue-Ribbon Panel chaired by Dr. Lew Allen and staffed by experts in the field, including Bob Shannon, was assembled, and charged with studying the problem and seeking a solution. At the same time, Brant Houston, a Pulitzer Prize winning, investigative journalist working at the Hartford (Connecticut) Courant newspaper, contacted the co-author and suggested that Dr. Scott, who had recently and suddenly resigned from Perkin- Elmer as its Vice President and Chief Scientist, might agree to an interview with the Courant. He stated that the purpose of his telephone call was to obtain Dr. Scott's personal, unlisted, telephone number and to solicit Dr. Scott's cooperation in exposing the source of the problems at Perkin-Elmer. Following an in-depth discussion with Dr. Scott about the "fiasco" and armed with some amazing facts regarding the reason for his surprise "retirement", the co-author informed Brant that Dr. Scott would be pleased to "go public" and meet with the two, officially sanctioned journalists, Robert Capers and Erik Lipton.

The ensuing interview led to a four-part series of blockbuster-style articles published in the Hartford Courant during March 31 and April 3, 1991. These articles fully exposed the errors that had occurred and further, the negligence (and arrogance) of the fabrication and testing team who had ignored all rational planning and the protocols they had been directed to follow. It further exposed the attitude of the personnel who were assigned to the task and their total disregard for any "outside" help from Perkin- Elmer's most senior staff. Note: This disregard and abusive behavior had been allowed by Perkin-Elmer's new management and led to Dr. Scott's resignation.

The Courant reporters' four-part series won a Pulitzer Prize in Explanatory Journalism in 1992.

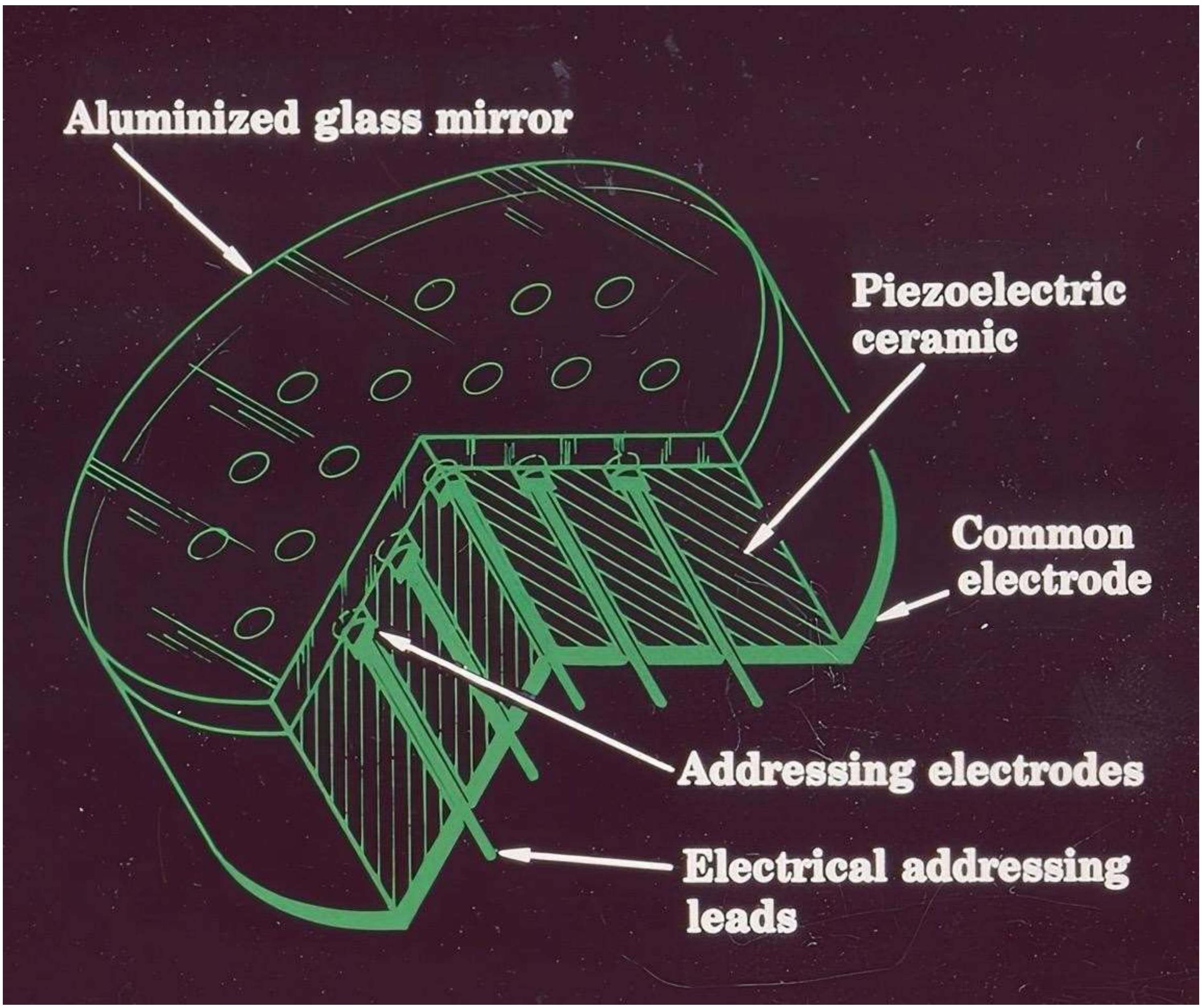
During that same period, Mark Kahan and Bob Parks, were engaged in generating a full report on the HST's troubled shop history. Their incredibly detailed analysis is recommended reading for any optician or optical engineer who is interested in learning lessons from the past. Bob Parks is with the University of Arizona and Mark Kahan is the SPIE's Conference Chair for its annual Lessons Learned Symposium. Mark is also a former lens designer at Itek, during his years supporting CIA and USAF projects, and is currently Chief Engineer of Electro-Optical Systems at Synopsys.

THE STORY OF LASER GUIDE STAR ADAPTIVE OPTICS: The Roles of Horace Babcock, Julius Feinlieb, and Robert Fugate, in Bringing this Concept to Fruition

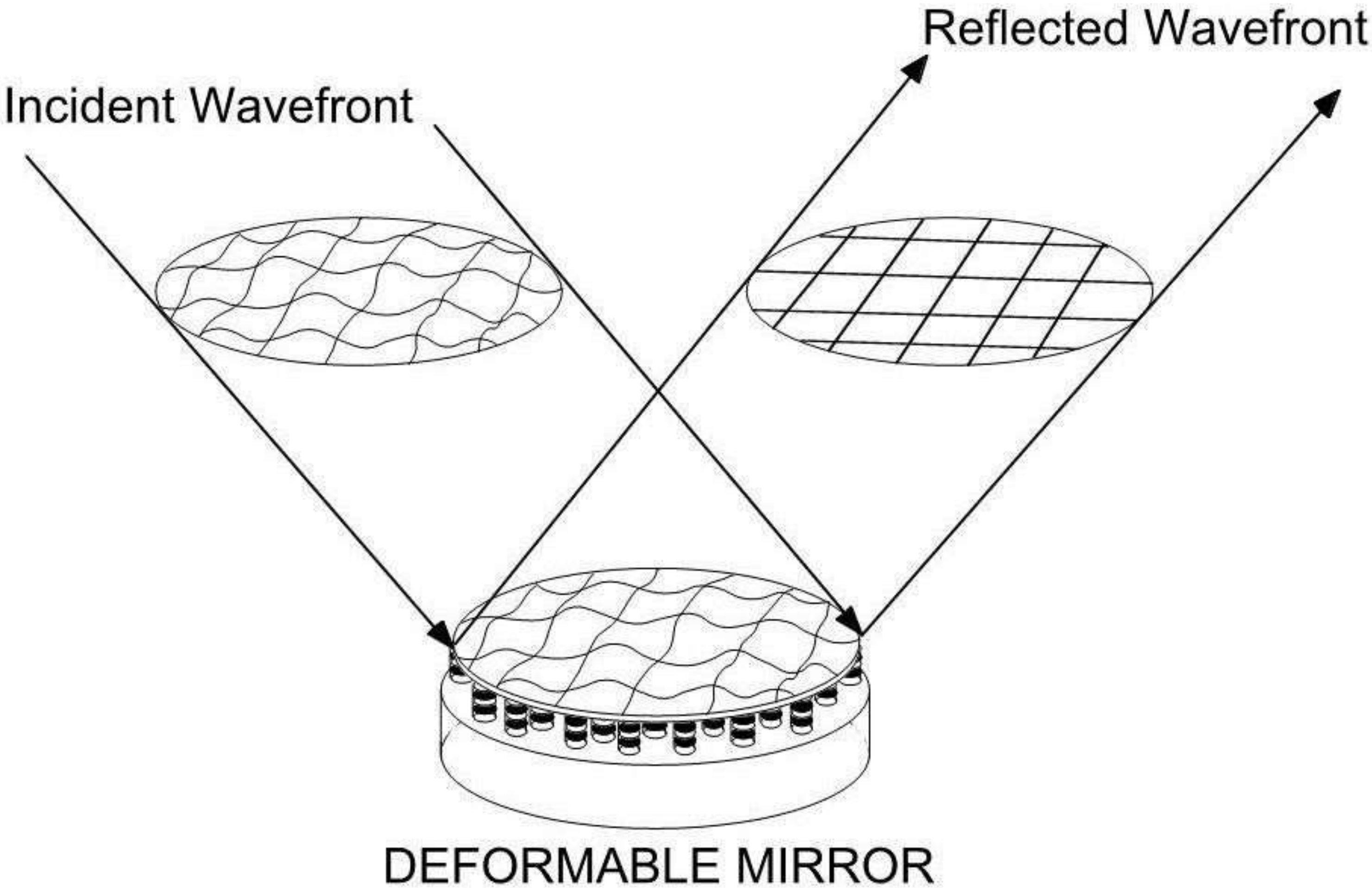
In the late 1960's and into the early 1970's, Julius Feinleib and Ralph Aldrich, researchers with Itek Corporation in Lexington, MA, led the manufacture of a device they referred to as a "rubber mirror." This term was used at the time to describe what was originally Horace W. Babcock's 1953 concept of an electro-optical device which would help compensate for atmospheric turbulence; the phenomenon that causes stars to twinkle. See Babcock, H.W. (1953) "The possibility of compensating atmospheric seeing," ASP, 65 (386):229-236.

Success was achieved and details were reported at an OSA conference held in Boulder, Colorado, about Optical Propagation through Turbulence, by Julius Feinleib, John W. Hardy and James C. Wyant.

Here is a baseline concept drawing of the first device produced in Itek's special instrumentation optical shop in Lexington, MA.



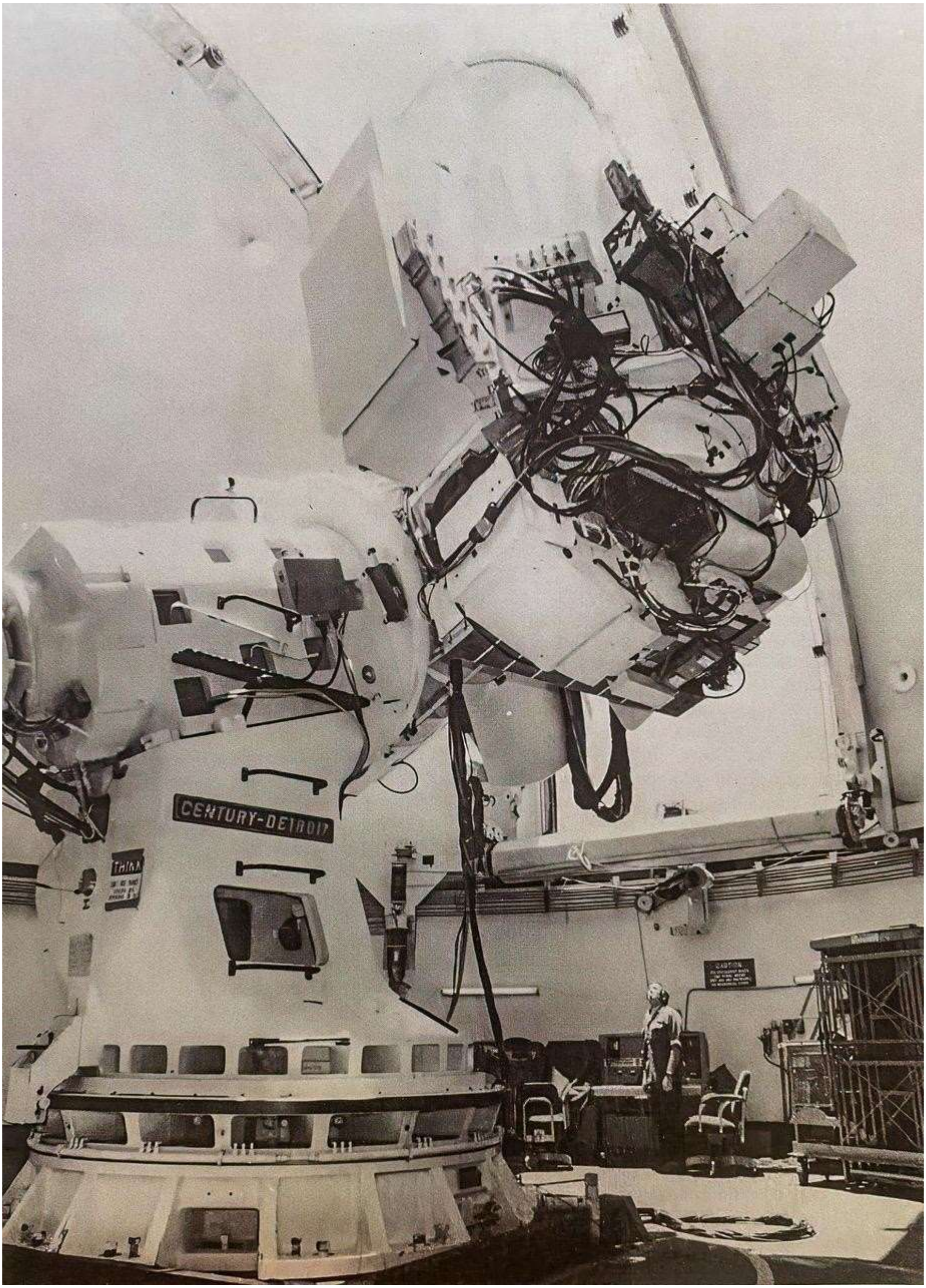
……and this is the way it works:



The Defense Advanced Research Projects Agency (DARPA) was extremely interested in advancing the state-of-the-art of adaptive optics and strongly supported the work at Itek. DARPA funded the Compensated Imaging System (CIS) which was built by Itek and installed on the University of Michigan 1.6-m telescope at the ARPA Midcourse Optical Station atop (AMOS), atop Mt. Haleakala on Maui in 1980. Pictured below, this system was a Herculean effort to demonstrate adaptive optics in an operational space surveillance environment. It weighed nearly 2,000 pounds (900 kg), had a 168-actuator deformable mirror, sampled the turbulence at 10 kHz with a radial shearing interferometer (designed by James C. Wyant), used 340 photomultiplier tubes for wavefront sensing, a resistor network for wavefront reconstruction, and demonstrated a 1 kHz closed loop control bandwidth. The CIS's performance was limited to bright targets because the wavefront sensor needed a lot of light to work well. A bright beacon or guide star that was independent of the target was needed for good compensation and imaging of dim targets of interest.

For more information see DARPA TECHNICAL ACCOMPLISHMENTS – AN HISTORICAL REVIEW OF SELECTED DARPA PROJECTS, Volume 1, dated February 1990 (Formally produced as IDA Paper P-2192 and archived under AD-A239-925. Note that AD refers to Defense Technical Information Center materials.

This document is unclassified and available to the public.


CENTURY-DETROIT

During the initial operation of the CIS AO system on Maui, Julius Feinleib was watching the pulsed argon laser used as a LIDAR for transmittance measurements and got the idea of using laser light reflected from the atmosphere by Rayleigh scattering as a beacon for adaptive optics. This would solve CIS's problem with dim targets. He subsequently proposed the idea to DARPA, and after review by the Jasons, who introduced the additional concept of exciting mesospheric sodium at 90 km above the Earth, DARPA funded experiments to test the concepts. DARPA also classified the work under the nickname LODESTAR, and limited access to those with strict need-to-know. Later, under Air Force direction, the program was called HAVE REACH. The technology was declassified in May, 1991.

Dr. Robert Q. Fugate of the Air Force Weapons Laboratory (now part of Air Force Research Laboratory) at Kirtland Air Force Base in New Mexico in collaboration with Dr. David L. Fried conducted the first on sky experiments in 1983 that demonstrated laser guide stars could indeed be used as guide star beacons for adaptive optics and quantitatively validated Fried's theory of how well the concept would work to measure the wavefront distortions induced by atmospheric turbulence. After a successful experimental campaign proving Fried's theory, Dr. Fugate expanded the program to demonstrate continuous, real-time compensation on a 1.5-m telescope using a pulsed copper-vapor laser, fast wavefront sensors, and 241 actuator deformable mirror, all before the program was declassified in 1991.

Dr. Fugate became the principal driver of the USAF's Laser Guide Star Adaptive Optics effort. He and his team at the Starfire Optical Range at Kirtland AFB, NM advanced the state of the art in laser guide star adaptive optics further by developing a 3.5-m telescope capable of tracking low earth orbit satellites, with a laser guide star AO system employing a 50-watt CW narrow-line guide star laser to excite mesospheric sodium coupled with a high speed 941 channel adaptive optics system resulting in world-class performance for a large aperture ground-based telescope.

During the decade following declassification in 1991, Dr. Fugate was the DoD's strongest advocate for transferring this technology to the astronomy community, including the use of the systems at the SOR by astronomers through grants from the National Science Foundation.

1983 Kirtland AFB, New Mexico. The first experiment demonstrating laser guide stars were feasible.

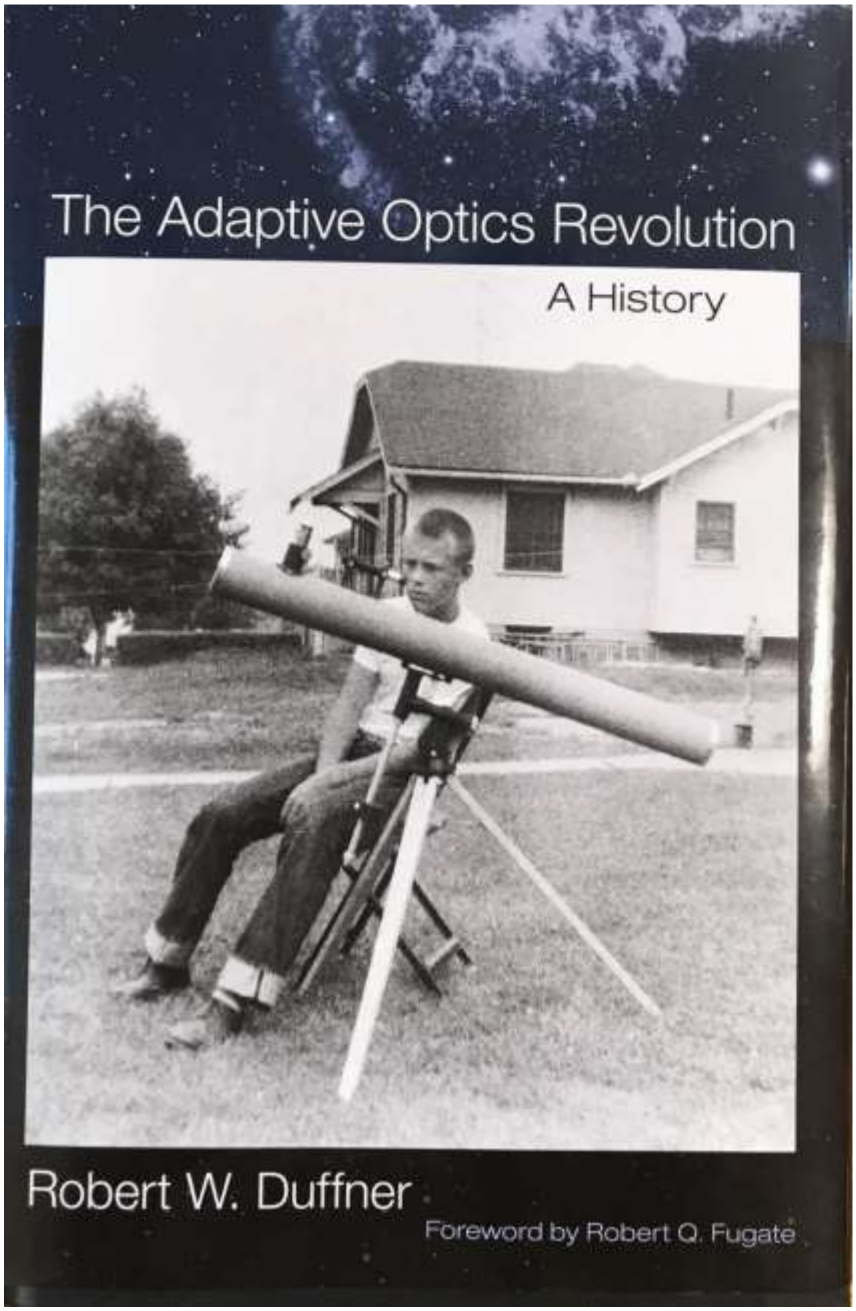
1989, 1.5-m telescope, Starfire Optical Range, Kirtland AFB, New Mexico. First demonstration of continuous closed loop operation of laser guide star adaptive optics.

2004, 3.5-m telescope, Starfire Optical Range, Kirtland AFB, New Mexico. First operation of 50W CW sodium wavelength laser for laser guide star adaptive optics. The following video links help describe the history of this revolution:

https://www.youtube.com/watch?v=mm8wFRRGvLc

https://www.youtube.com/watch?v=dIRG2J7nrxw

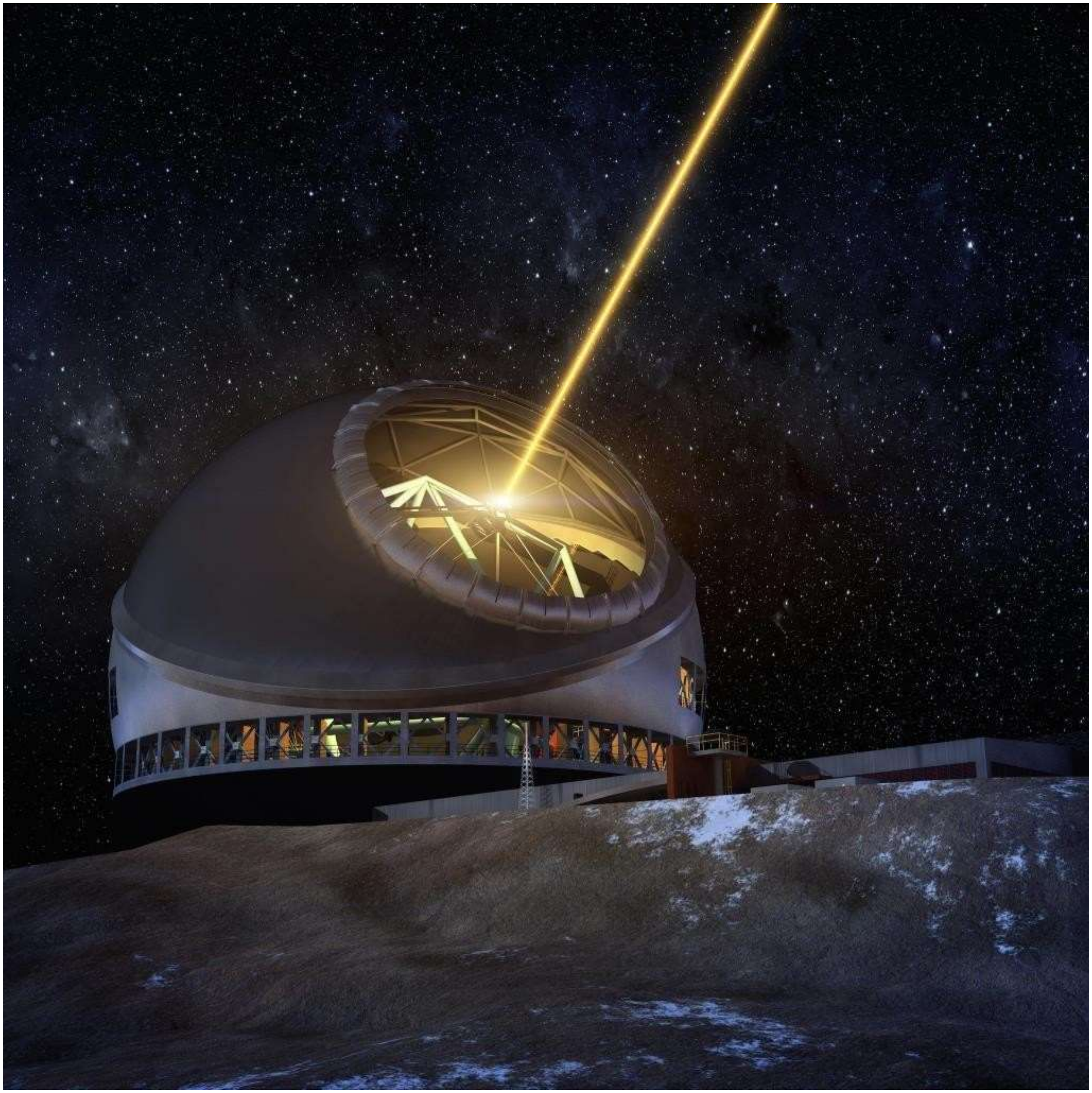
For a considerable wealth of engineering, political and military mission details regarding this activity of turning ploughshares into swords, read the book authored by Robert Duffner, with foreword by Robert Fugate, shown on the front cover at age 13, with his first telescope.



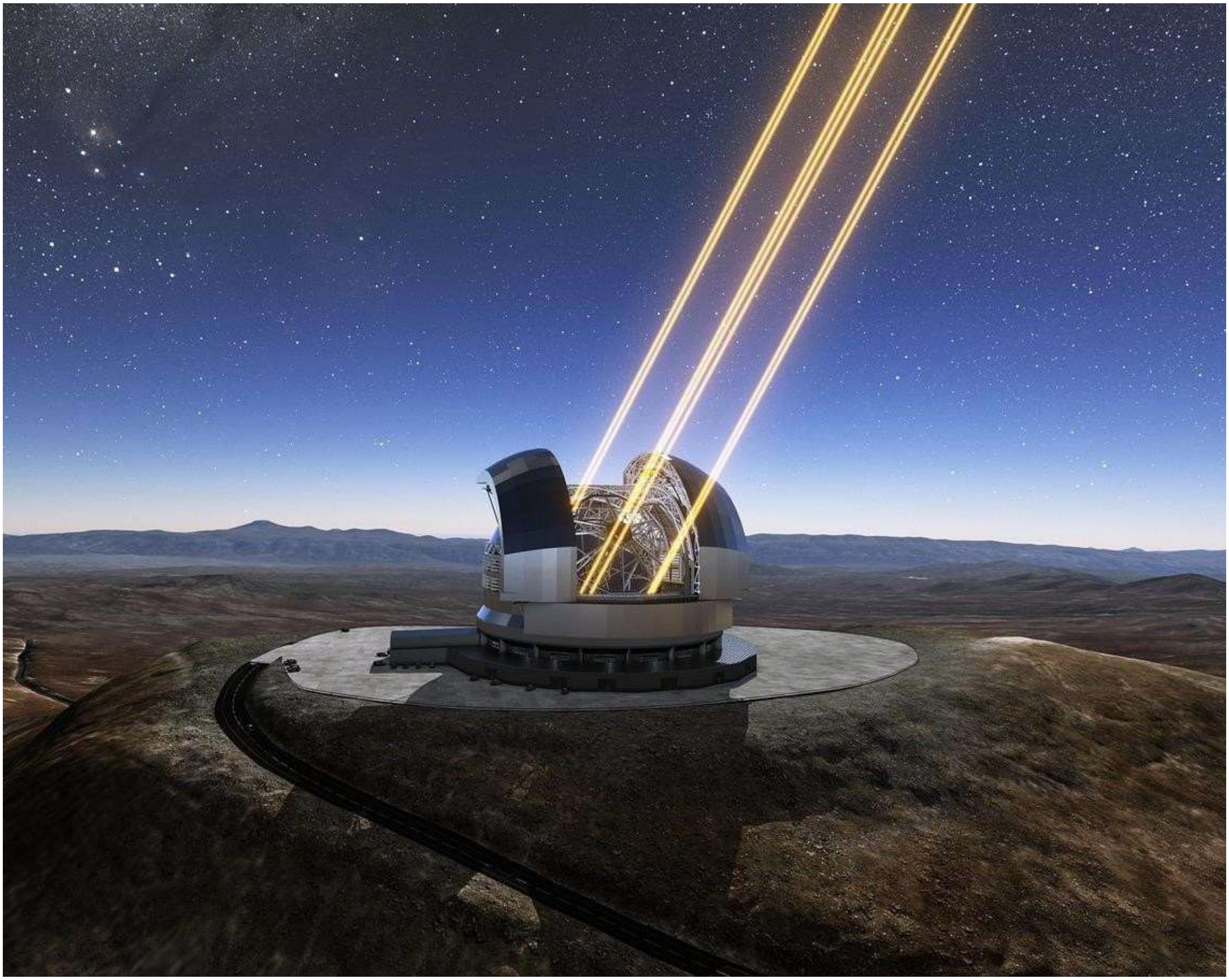
Footnote: For classical celestial images by Dr.Fugate, see https://www.rqfphoto.com/Astrophtography

Today the ground-based astronomy community has strongly endorsed laser guide star adaptive optics (LGSAO) technology as THE enabling factor for making Extremely Large Telescopes (ELT) feasible. LGSAO has been retro-fitted on nearly every existing telescope larger than 4 meters and is an integral part of the design of the 3 ELTs – the Giant Magellan Telescope (24-m), the Thirty Meter Telescope (30-m) and the European Extremely Large Telescope (39-m).

Giant Magellan Telescope (GMT): 7x 8.4-m primary mirrors and 7 adaptive secondary mirrors plus 6 sodium wavelength laser guide star beacons. Sponsored by Smithsonian Institution and under construction in northern Chile.

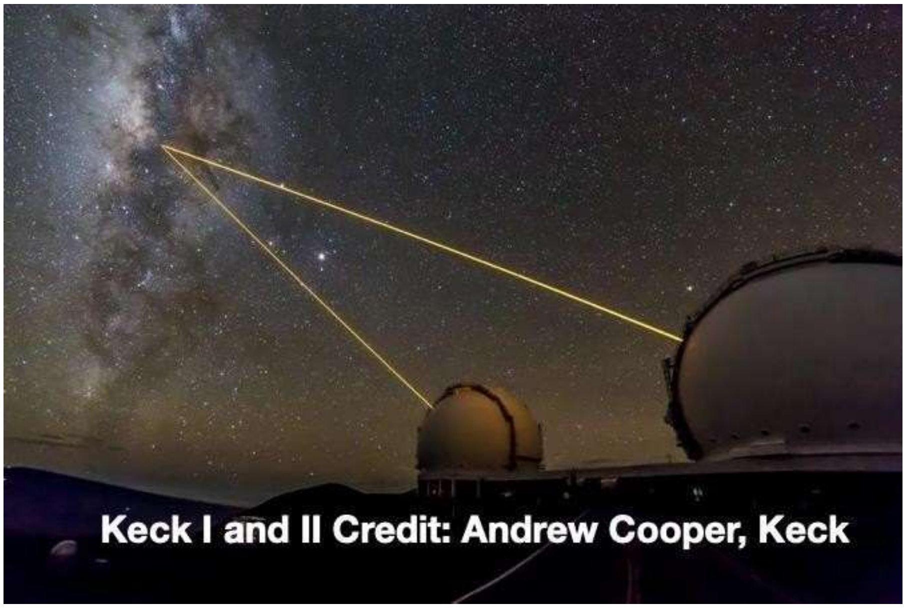


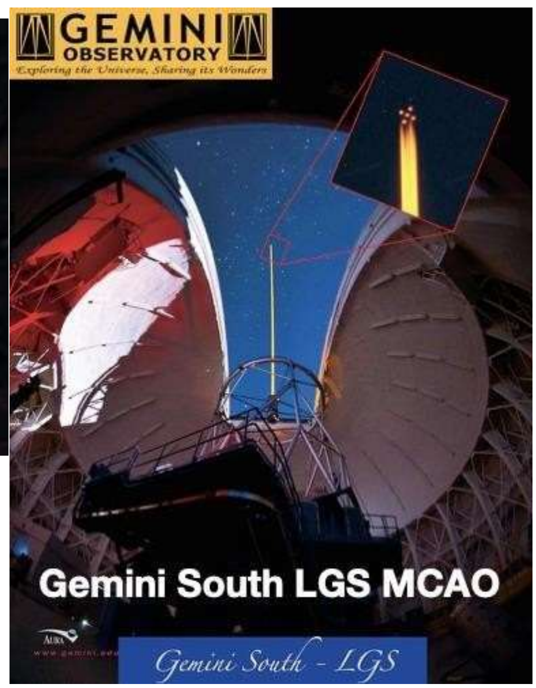
Thirty Meter Telescope (TMT): 30-m segmented filled aperture slated for Mauna Kea on the big island in Hawaii. Multi-conjugate adaptive optics with cooled optics and multiple laser guide star asterisms projected from the center of the aperture.

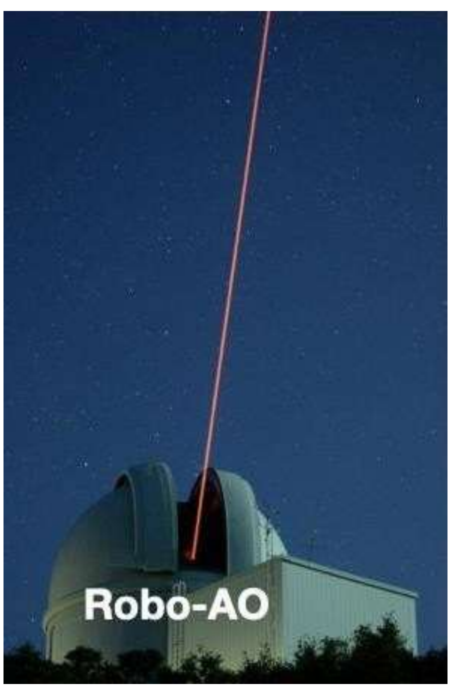


European Extremely Large Telescope (EELT): 39-meter segmented filled aperture with multiple laser guide stars. Sponsored by European Southern Observatory and being built in northern Chile.

Existing observatories using Laser Guide Star Adaptive Optics







THE STRATEGIC DEFENSE INITIATIVE OGANIZATION (STAR WARS)

The Cold War heated up in 1981. During that year with the support of Hollywood movie actor, Charlton Heston, and the Father of the Hydrogen Bomb, Dr. Edward Teller, President Ronald Reagan established the Strategic Defense Initiative Organization (SDIO).

STAR WARS

SDIO LOGO

LT. GEN. JAMES ABRAHAMSON

The research arm of the organization was managed by an Astrophysicist, Dr. James Ionson.

STAR WARS SCIENCE & TECHNOLOGY

DR. JAMES A. IONSON, SDIO

ACADEMIC INSTITUTIONS

UNIVERSITY OF DAYTON RESEARCH INSTITUTE :
OPTICAL COMPUTING CONSORTIUM

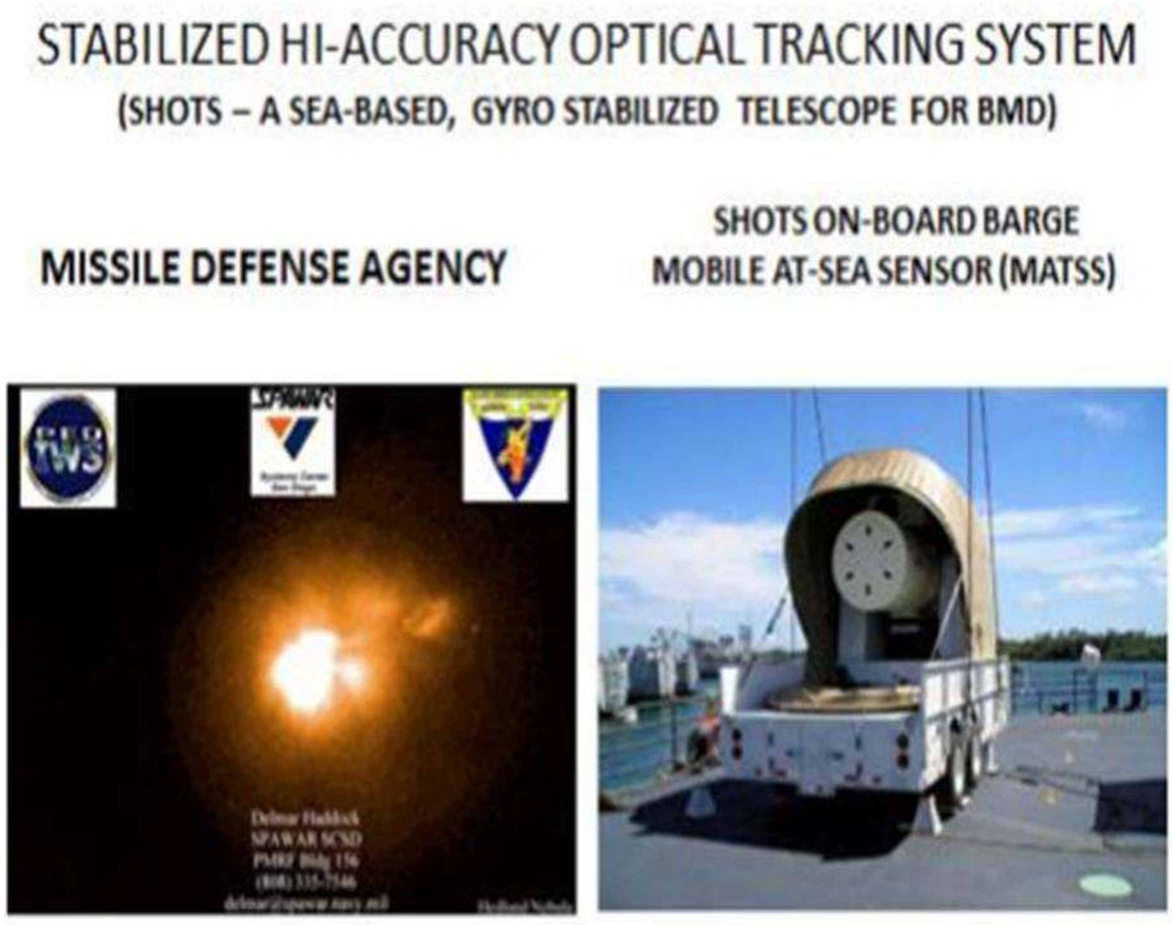
UNIVERSITY OF ALABAMA AT HUNTSVILLE:
OPTICAL COMPUTING & SUPERCONDUCTING MATERIALS

UNIVERSITY OF CENTRAL FLORIDA:
ISTEF AND SPECIAL TELESCOPES

It was known as The Office of Innovative Science & Technology.

In 1993, President Clinton renamed it the Ballistic Missile Defense Organization (BMDO); it was much later renamed the Missile Defense Agency (MDA); it also changed its mission to Theater Defense.

Among the developments pursued by MDA was the design, build and deployment of a unique barge-based tracking telescope.



The above slide illustrates the application of optical shop expertise to the creation of an extremely sophisticated optical system capable of recording a seemingly impossible task; that of capturing the moment when a simulated, nuclear warhead headed for the U.S. mainland gets intercepted and destroyed in space, by a defensive ballistic missile; a bullet seeking out and destroying a bullet!

The contract to build SHOTS was awarded to Space Optics Research Labs in Chelmsford, MA. The customer was the U.S. Navy’s Space & Naval Warfare Systems Command (SPAWAR) located in San Diego, CA. The engineer in charge of this project at

SORL was Jim Sterritt, who has built a vast array of telescopes during his career of designing, fabricating, and testing optical systems. Jim was trained in optical sciences at the University of Rochester.

The Project Manager at SPAWAR was Delmar Haddock, who was an inspirational innovator within the Range Commanders Council. He was instrumental in both developing as well as upgrading range assets, not only at SPAWAR, but also at White Sands Missile Range, the ISTEF at Cape Kennedy, both Vandenberg and Patrick Air Force Bases, and at Barking Sands, the Pacific Missile Range Facility (PMRF), in Kauai County, HI.

Important Footnote: The gifted master machinist at the Public Works Facility in San Diego who helped design and who turned out the critical components for the many MDA projects pursued by each of the above-named organizations, was Hal Malinski. Hal hosts an ATMers Club in San Diego and trains young telescope makers for the future.

Sadly, Delmar Haddock passed away in 2019.

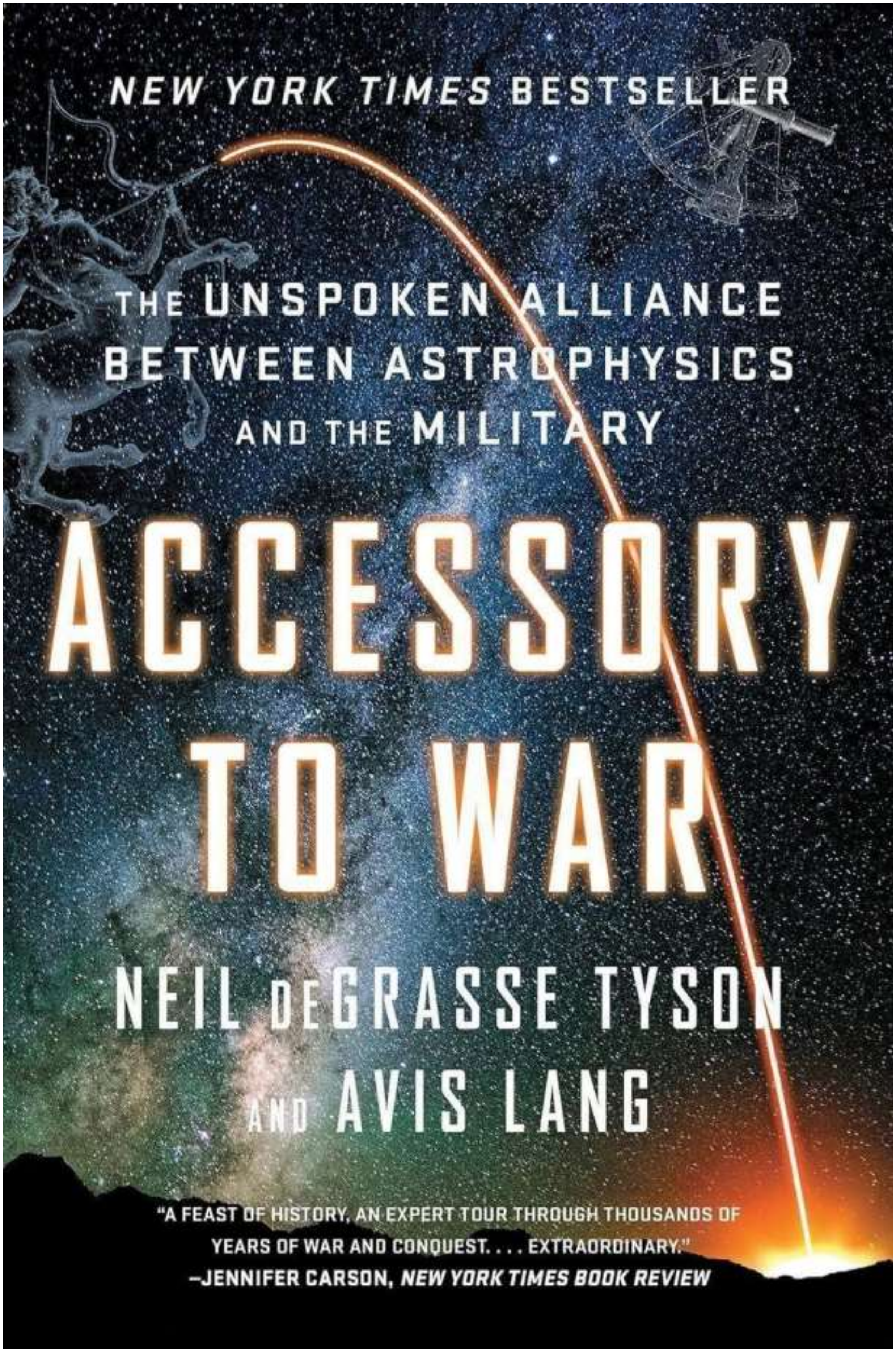
This last illustration represents a fitting conclusion to this presentation. ALOHA!

CONCLUSION

In summary, the fact that there were experienced telescope makers available to turn their talents and passions to staffing special optical shops, where they worked on the most highly classified programs in the nation's history, speaks volumes about Stellafane, the importance of the ATM community and the field of Astronomy. Meanwhile, this monograph will not be the last method used to describe the relevance of astronomers and telescope makers to the success enjoyed by the United States in winning the Cold War. Already there are efforts underway, e.g., book sales and documentaries, to educate the public on the opportunities and advantages of having these disciplines engaged in National Security.

Always, as decades of closely held information is declassified and becomes a part of our history, we will begin to see and therefore understand the need to protect our nation's secrets and continue to pursue research and development on a grand scale. In other words, it is not always easy to distinguish between a potentially "good" application of a breakthrough invention and a "bad" application since much of science is by its very nature DUAL USE. The important fact to keep in mind is that we must continue to explore, invent, innovate, and pursue research and development where it "most likely" benefits the human race as a whole.

The following illustration is a very recent example of this latest effort to examine the process of turning Ploughshares into Swords and then reversing the process in times of peace.


NEW YORK TIMES BESTSELLER
THE UNSPOKEN ALLIANCE BETWEEN ASTROPHYSICS AND THE MILITARY
ACCESSORY TO WAR
NEIL DEGRASSE TYSON
AND AVIS LANG
"A FEAST OF HISTORY, AN EXPERT TOUR THROUGH THOUSANDS OF YEARS OF WAR AND CONQUEST. . . . EXTRAORDINARY."
—JENNIFER CARSON, NEW YORK TIMES BOOK REVIEW

The impact of the ATMers' contribution is still being felt in the 21st Century as those Swords forged during the Cold war are once again being turned into Ploughshares through projects such as the James Webb Space Telescope, the Giant Magellan Telescope, and many others.

The photograph shown below was taken by a 16-inch Ritchey-Chrétien telescope, suspended from a balloon, flying at 80,000 feet MSL over the desert in Southwestern U.S. in the mid-1960s; it illustrates the capabilities and potential of spy cameras operating from space-based platforms. Several researchers were interested in establishing the theory to support this type of photoreconnaissance including Robert Shannon et al, Robert Hufnagel et al, Robert Fugate, and David Fried* among others.

*See addendum

in space is a huge advantage because we

spy satellite with a 10 cm resolution, you can discern a soft-ball sized object from several hundred miles away. Using the satellite, you would be able to see the home run that causes the Yankees to win the World Series.

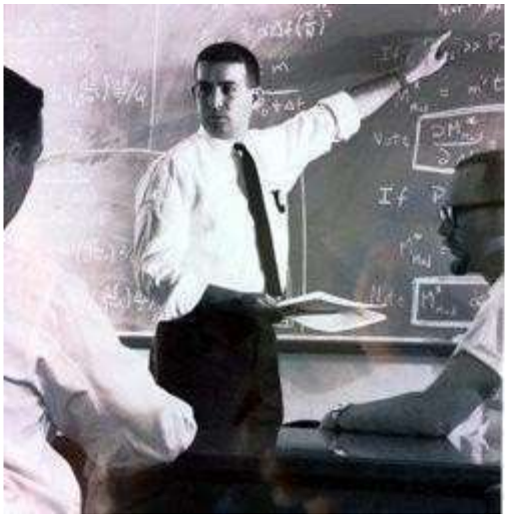
GO YANKEES!

Jeannelle Louis -- 2001

*Addendum - David L. Fried

TOO GOOD TO BE TRUE

David was an exceptional optical scientist who is best remembered for his “parameter” known as r-naught. R-naught or r0 is a measure of the turbulence in the earth’s atmosphere, the phenomenon that limits the optical resolution of ground-based telescopes…..of any size! Details in the image of an object such as a crater on the lunar surface begin to degrade as the aperture of a telescope gets larger. For example, in perfect “seeing”, an ATMers 8-inch telescope will outperform a 48-inch telescope in terms of image resolution or image quality. David’s contribution to astronomy was to determine mathematically “ “the smallest diameter of a telescope aperture at which the fidelity starts to suffer significantly from turbulent airflows in the atmosphere of the earth” and that r0 may change rapidly on a time scale of minutes or less; opening the pathway to Laser Guide Star Adaptive Optics technology and applications and making it cost-effective to build larger ground-based telescopes. It turns out that r0 = 20cm (about 8-inches) for visible starlight is “good seeing” at the best astronomical observing sites. For instance, sites like Chews Ridge, Carmel Valley, CA, the Canary Islands, the Hawaiian Islands, Chile, Anderson Peak, CA, and Merritt Island, Florida. Note the presence of a large body of water nearby and an extremely stable atmosphere.



David passed away on May 5, 2022, in Monterey, CA. He was 89.

For those interested in more detail, an invited paper was published in *Applied Optics* this year:

Robert Q. Fugate, Jeffrey D. Barchers, and Brent L. Ellerbroeks, *"David L. Fried: bringing vision to atmospheric optics,"* G112-G127, Vol. 62, No. 23, 10 August 2023 (Applied Optics)