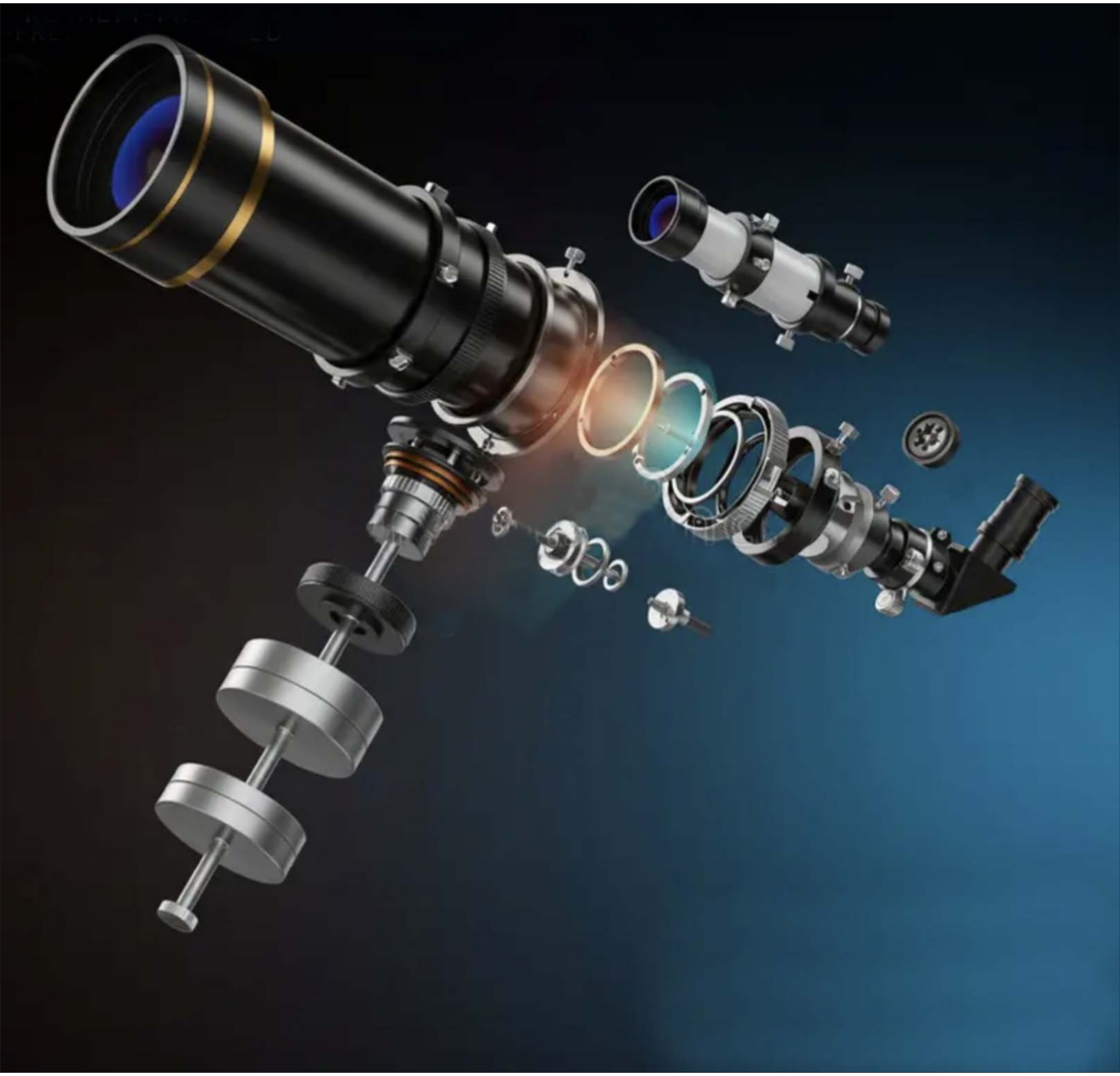
Optomechanix

Brief History of Telescope
Celestron 8 SE Design
Celestron C90
Celestron Advanced GT
Mirror Testing Interferometry
Hasselblad Design
God’s Hope

Telescope Design Explored

Jan - Mar 2026



Technical journal of OMiD, Opto-Mechanical Institute of Design

The Single-fork azimuth mount in SE is optimized to deliver both accurate pointing accuracy, while dimentionally reducing their traditional double-fork support. The result is a highly compact/reliable design that is easy to carry, and operate. Thanks to its NextStar control software, this azimuth design is capable of finding/tracking stars as its more complex, hard to carry equatorial counterpart. We'll discuss how SE mount is as easy to lift, and carry as a vintage telephone.

Contents

Page

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Prophet Mohammed in his youth (570-632 CE)

This issue Dedicated to:

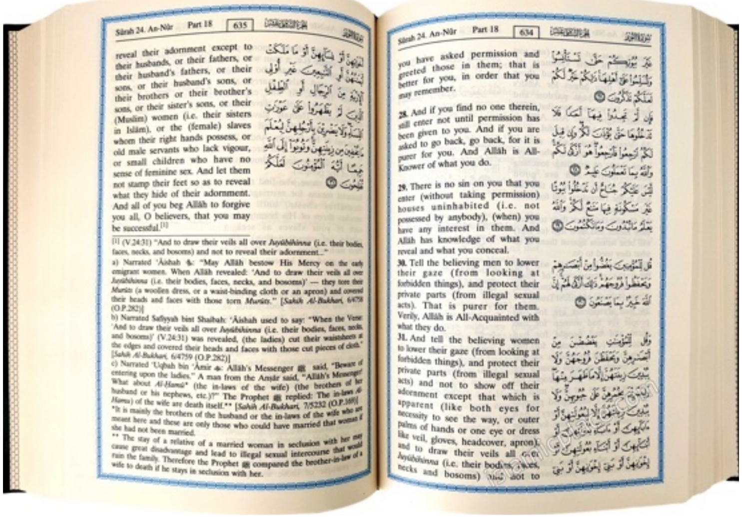
Prophet Mohammed (570-632 CE) Was born in Arabia, the revelation of Holy Quran was at age 40. In his early teens, Muhammad worked in a camel caravan, following in the footsteps of many people his age, born of meager wealth. Working for his uncle, he gained experience in commercial trade traveling to Syria and eventually from the Mediterranean Sea to the Indian Ocean. In time, Muhammad earned a reputation as honest and sincere, acquiring the nickname “al-Amin” meaning faithful or trustworthy.

In his early 20s, Muhammad began working for a wealthy merchant woman named Khadijah, 15 years his senior. She soon became attracted to this young, accomplished man and proposed marriage. He accepted and over the years the happy union brought several children. Not all lived to adulthood, but one, Fatima, would marry Muhammad’s cousin, Ali ibn Abi Talib, whom Shi’ite Muslims regard as Muhammad’s successor in Sunnah.

Holy Quran at a Glance: The Quran is the central religious text in Islam. Muslims believe the Quran was verbally revealed by God, through the angel Gabriel, to the Prophet Muhammad over the course of 23 years.

The Quran assumes the reader's familiarity with major narratives recounted in the Biblical and apocryphal texts. It summarizes some, dwells at length on others and, in some cases, presents alternative accounts and interpretations of events. The Quran describes itself as a book of guidance for humankind (2:185). It sometimes offers detailed accounts of specific historical events, and it often emphasizes the moral significance of an event over its narrative sequence.

Source: Wikipedia



Sūrah 24. An-Nūr Part 18 634

you have asked permission and greeted those in them; that is better for you, in order that you may remember.

28. And if you find no one therein, still enter not until permission has been given to you. And if you are asked to go back, go back, for it is purer for you. And Allāh is All-Knower of what you do.

29. There is no sin on you that you enter (without taking permission) houses uninhabited (i.e. not possessed by anybody), (when) you have any interest in them. And Allāh has knowledge of what you reveal and what you conceal.

30. Tell the believing men to lower their gaze (from looking at forbidden things), and protect their private parts (from illegal sexual acts). That is purer for them. Verily, Allāh is All-Acquainted with what they do.

31. And tell the believing women to lower their gaze (from looking at forbidden things), and protect their private parts (from illegal sexual acts) and not to show off their adornment except that which is apparent (like both eyes for necessity to see the way, or outer palms of hands or one eye or dress like veil, gloves, headcover, apron), and to draw their veils all over *Juyūbihinna* (i.e. their bodies, faces, necks and bosoms) and not to

Sūrah 24. An-Nūr Part 18 635

reveal their adornment except to their husbands, or their fathers, or their husband's fathers, or their sons, or their husband's sons, or their brothers or their brother's sons, or their sister's sons, or their (Muslim) women (i.e. their sisters in Islām), or the (female) slaves whom their right hands possess, or old male servants who lack vigour, or small children who have no sense of feminine sex. And let them not stamp their feet so as to reveal what they hide of their adornment. And all of you beg Allāh to forgive you all, O believers, that you may be successful.[1]

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[1] (V.24:31) "And to draw their veils all over *Juyūbihinna* (i.e. their bodies, faces, necks, and bosoms) and not to reveal their adornment..."

a) Narrated 'Āishah: "May Allāh bestow His Mercy on the early emigrant women. When Allāh revealed: 'And to draw their veils all over *Juyūbihinna* (i.e. their bodies, faces, necks, and bosoms)' — they tore their *Murūts* (a woollen dress, or a waist-binding cloth or an apron) and covered their heads and faces with those torn *Murūts*." [*Sahih Al-Bukhari*, 6/4758 (O.P.282)]

b) Narrated Safiyyah bint Shaibah: 'Āishah used to say: "When the Verse 'And to draw their veils all over *Juyūbihinna* (i.e. their bodies, faces, necks, and bosoms)' (V.24:31) was revealed, (the ladies) cut their waistsheets at the edges and covered their heads and faces with those cut pieces of cloth." [*Sahih Al-Bukhari*, 6/4759 (O.P.282)]

c) Narrated 'Uqbah bin 'Āmir: Allāh's Messenger ﷺ said, "Beware of entering upon the ladies." A man from the Anṣār said, "Allāh's Messenger! What about *Al-Hamū** (the in-laws of the wife) (the brothers of her husband or his nephews, etc.)?" The Prophet ﷺ replied: The in-laws (*Al-Hamu*) of the wife are death itself.** [*Sahih Al-Bukhari*, 7/5232 (O.P.159)]

*It is mainly the brothers of the husband or the in-laws of the wife who are meant here and these are only those who could have married that woman if she had not been married.

** The stay of a relative of a married woman in seclusion with her may cause great disadvantage and lead to illegal sexual intercourse that would ruin the family. Therefore the Prophet ﷺ compared the brother-in-law of a wife to death if he stays in seclusion with her.

Holly Quran: 114 Capters, 6236 Verses, 604 Pages

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Optomechanix is a quarterly journal of Opto-Mechanical Institute of Design (OMiD), with technical articles for practical, hands-on opto-mechanical engineers. This magazine is privately founded.

Cover page photo: A refractive telescope drawn by AI
Front back: Celestron 8SE single fork mount

In This Issue ...

One of the most exciting advancements in optomechanics has been the design and continual evolution of telescopes. Like many opto-mechanical engineers, I have been fascinated with telescopes since early childhood. The telescope has a 400-year history, and countless innovators have contributed to its development — among them, George Ellery Hale, who devoted his life to persuading wealthy patrons to fund ever-larger instruments. His final and most ambitious achievement was the 200-inch Hale Telescope at Palomar Observatory.

I often visited Palomar while holding a JPL badge. I met Jim Westphal—perhaps the humblest scientist I have ever known. He utilized the Hale Telescope's prime focus for testing Hubble's early imaging CCDs, which at the time were being developed by Jim Janesick. Both Jims worked at JPL, but the politics of their positions shaped them in very different ways—one for the worse, the other for the better. I mention this because science is not merely a matter of knowledge; becoming a good scientist demands much more than intellect.

All this is somewhat connected to what I'd like to discuss in this issue, which concerns industrial design. Celestron's official page describes the 8SE as featuring a "single-fork arm design and sturdy steel tripod ... transportable, quick assembly." Despite being described as "award-winning," I could find no verifiable record of a specific design competition, year, or award body recognizing the 8SE in particular. Most of Celestron's award mentions refer to other products such as the StarSense line or the EdgeHD optical tubes.

When asked about my background, I often mention the Hubble Space Telescope. Reading astronomical journals might give most people the impression that the most important work happens at Keck, Palomar, Mount Wilson, or Magellan. On the contrary, I believe the designers working on consumer instruments often demonstrate greater ingenuity. Take the Celestron NexStar 8SE, for example: it is, in my view, one of the most remarkable consumer telescope designs ever produced. I disassembled, and drew both Alt Azimuth, and Equatorial designs to explain their inner workings.

Ali Afshari
Editor in chief
Optomechanix

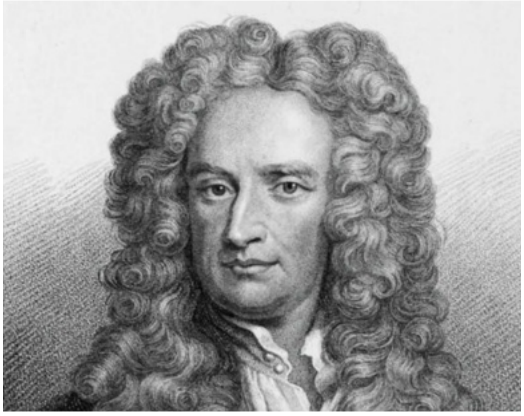
Gene, and Carolyn-Shoemaker at 18 inch Schmidt Cassegrain telescope at Palomar in 1994. In her hand is a 6" round film carrier that was placed at the primary focus of Schmidt Optics to capture images to detect asteroids.

Brief History of Telescope

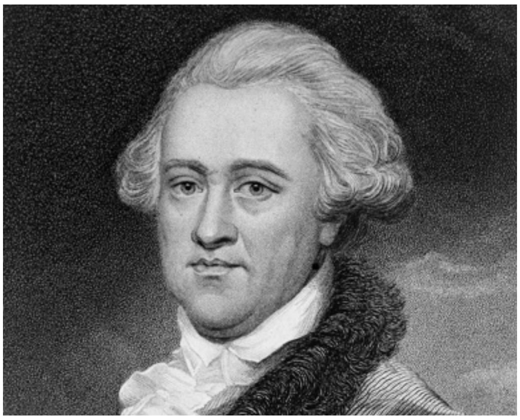
Era	Milestone	Key Figures
10th–14th c.	Optics foundations	**Ibn al-Haytham**
1609	First astronomical telescope	**Galileo Galilei**
1668	Reflecting telescope	**Isaac Newton**
1789	Giant reflector	**William Herschel**
1897	Largest refractor	Yerkes Observatory
1917–1948	Giant reflectors	**George Hale** Telescopes
1990	Space telescope era	Hubble
2021–Today	Infrared & mega-telescopes	James Webb, E-ELT, GMT

Ibn al-Haitham (965-1049) made experiments with the curved polished glass. He is credited to make the first telescope.

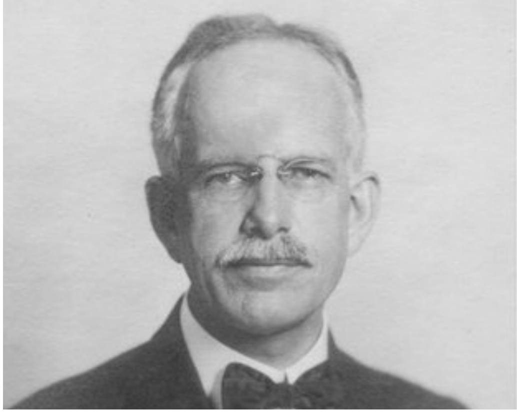
Galileo Galilei (1564-1642) made the first use of telescope for astronomy. He hands drew his observation of the craters of the moon, and the position of Jupiter's moons.



Issac Newton (1643-1727) invented the first reflector telescope.
William Herschel (1738-1822) built the largest telescope of his time made of polished brass. His massive elescope was a challenge to point at the skies. He recorded his first observation of the M56 nebula but couldn't resolve its individual stars.



James Lick (1796-1876) built the 65" telescope atmount Hamilton.
George Ellery Hale (1868-1938) was instrumental in building larger, and larger telescopes in America. It began with the 60" telescope in Chicago, then 100" telescope at Mount willson, and finally the 200" telescope at Mount Palomar.



1. Islamic Foundations (8th–14th centuries)

Before telescopes existed, Islamic scholars laid the groundwork for optical science.
Ibn al-Haytham (Alhazen, 965–1040 CE) — wrote Kitab al-Manazir (Book of Optics).
Explained how vision works: light travels into the eye, not out.
Described reflection, refraction, lenses, and pinhole cameras.
His ideas directly influenced European scientists like Kepler and Newton centuries later.
These optical theories were crucial for inventing lenses — and eventually, telescopes.

2. The Birth of the Telescope (1608–1610)

Hans Lippershey (Netherlands, 1608): built the first refracting telescope.
Galileo Galilei (Italy, 1609): improved it for astronomy — discovering Jupiter's moons, Venus's phases, and lunar craters.
Johannes Kepler (1611): redesigned it with two convex lenses, improving magnification and field of view.

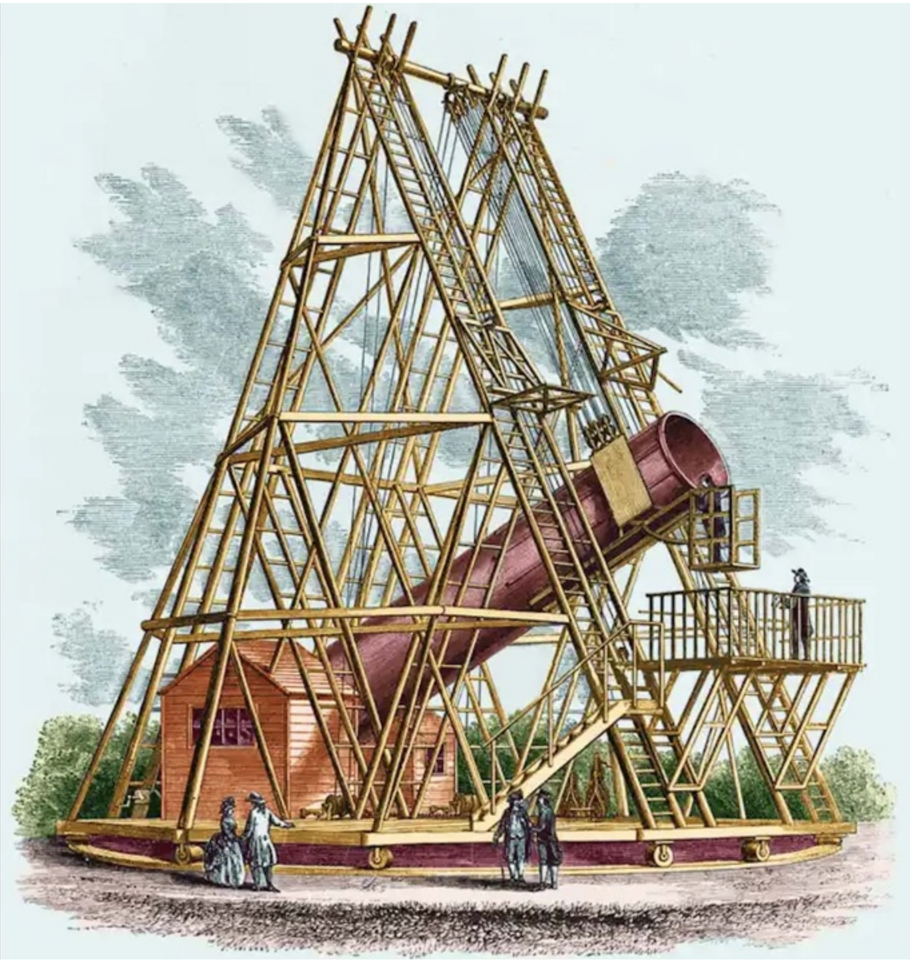
3. Reflecting Telescopes (17th–18th centuries)

Isaac Newton (1668): invented the reflecting telescope, using a curved mirror to avoid color distortion.
William Herschel (1789): built a massive 40-foot reflector, discovering Uranus and studying nebulae.

4. The Era of Giant Refractors (19th century)

Advances in glassmaking led to large refracting telescopes, like:

Great Refractor at Harvard (1847)
Yerkes Observatory (1897) world's largest refractor (40 inches).
These dominated astronomy until mirrors became more practical.



1m William Herschel reflector telescope was completed in 1775

12 Inch refractor at Lick observatory looks like a classic Zeiss telescope

5. The Reflector Revolution (20th century)

George Ellery Hale led the creation of huge telescopes:

60-inch (1908) in Chicago, and **100-inch** (1917) at Mount Wilson. In 1925, Edwin Hubble (1889-1953) used it to discover the expanding unverse by resolving Cepheid star on Andrameda galaxy, based on findings of Henrietta Leavitt (1868-1921).

200-inch Hale Telescope (1948) at Palomar — used for major discoveries, including galaxy formation and quasars.

6. Space Telescopes and Modern Technology

Hubble Space Telescope (1990):

94.5-inch (2.4 m) primary mirror, polished to 1/60 λ, freed from Earth's atmosphere, provided unmatched clarity of deep space.

Keck Telescopes (1993, Hawaii): Utilized 1 meter segmented mirrors (10 meters total).

Adaptive optics developed — allowing ground-based telescopes to correct for atmospheric distortion.

James Webb Space Telescope (2021):

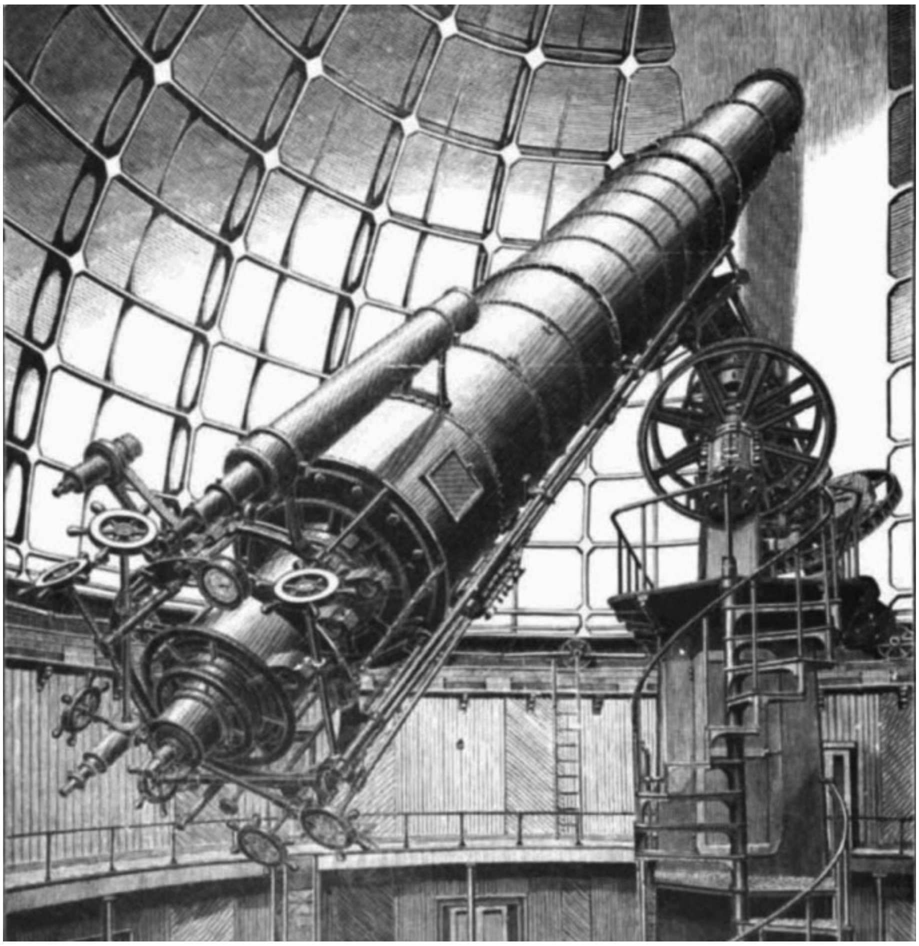
255 inch (6.5 m) with 0.6 ~ 5 µm wave length infrared sensor, largest and most powerful ever launched, observing the early universe in infrared light.

Extremely Large Telescopes (under construction):

25 m Giant Magellan Telescope (**GMT**) still under construction, will be finished in early 2030's.

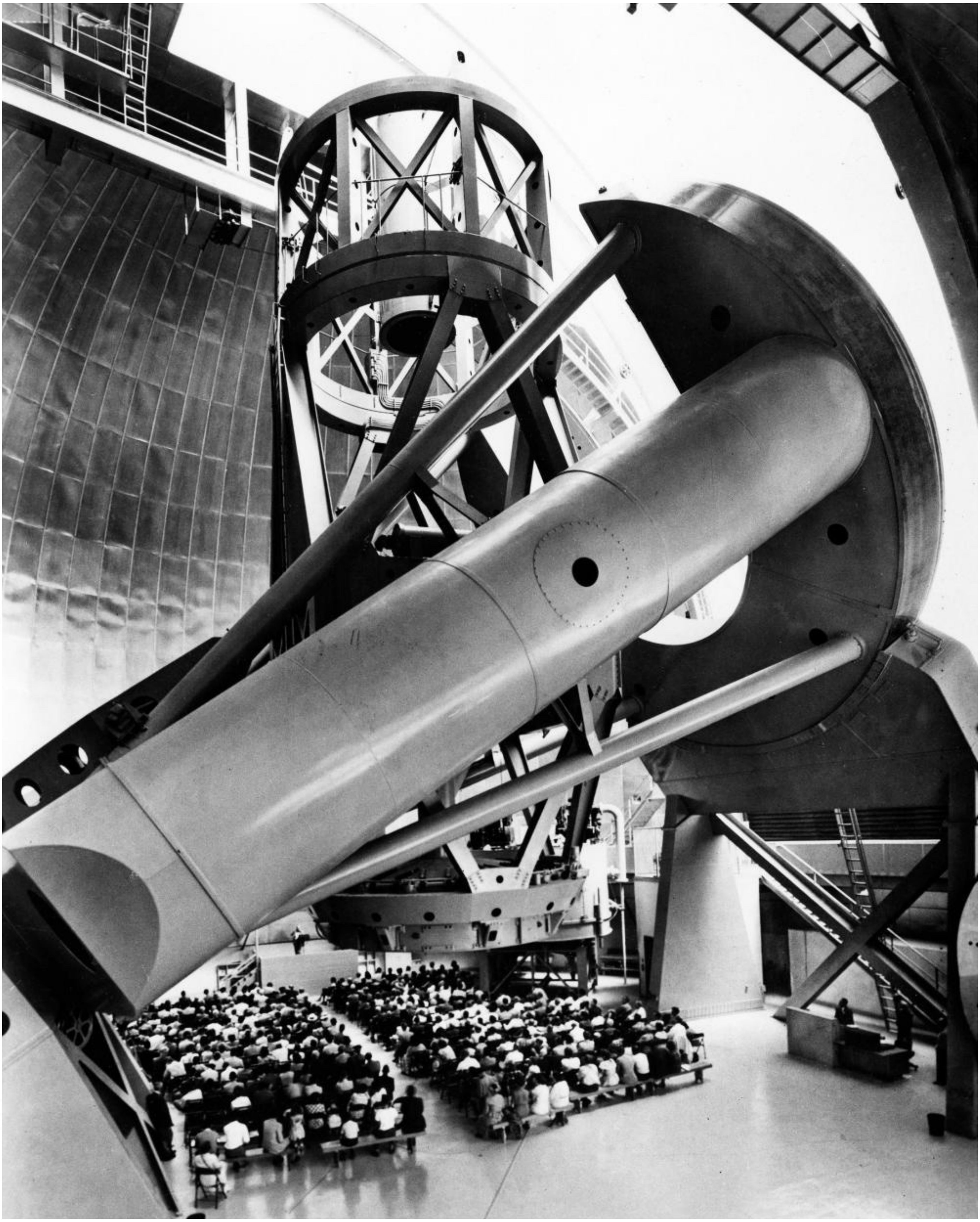
30 m Thirty Meter Telescope (**TMT**) still under development. It has an uncertain finished date, still has legal disputes to start its proposed construction on Mana Kea site in Hawaii.

39 m European Extremely Large Telescope (**E-ELT**) still under construction, expected to have its first light on March 2029.

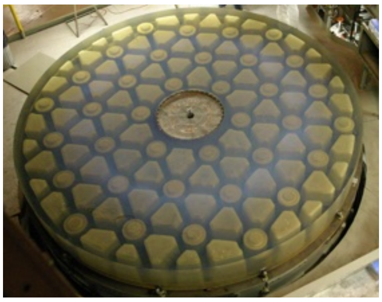


36 inch refractor telescope at Lick observatorey at mount Hamilton was completed in 1888, was founded by James lick, 57 feet long, 4 feet in diam.

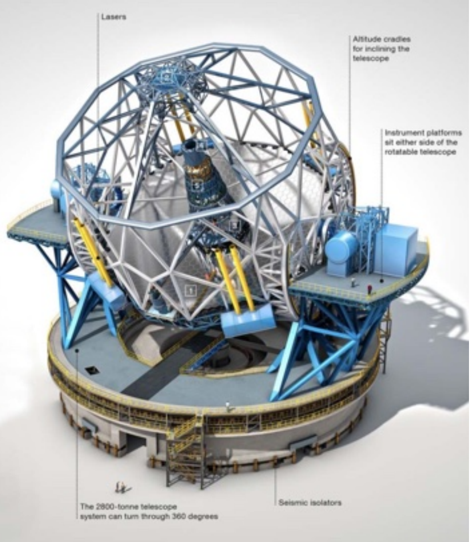
100 Inch reflective telescope at mount Wilson was completed in 1925, was founded by Andrew Carnegie (1835-1919). Helped Hubble to discover Big Bang.



200 inch Palomar observatory was completed in 1935, the six Billion dollar telescope was founded by Rockefeller Foundation. Far right, the first image taken through the telescope by Edwin Hubble. Right, the 14.5 Ton, 600 mm-thick honey-combed design was the last large telescope with parabolic primary mirror. Other telescopes that followed, use the Ritchi-Chretien optical design, whose primary, and secondary are both aspherical to provide sharper images over a larger usable field of view.



Eleanor Helin at Schmidt Cassegrain telescope at Palomar that I had the pleasure of working with. With only a crew of 2, she discovered 2,500 asteroids by photographing them on 6” negatives, and comparing them through a stereo microscope. I designed the automatic image capture camera for her telescope.



European Extremely Large Telescope

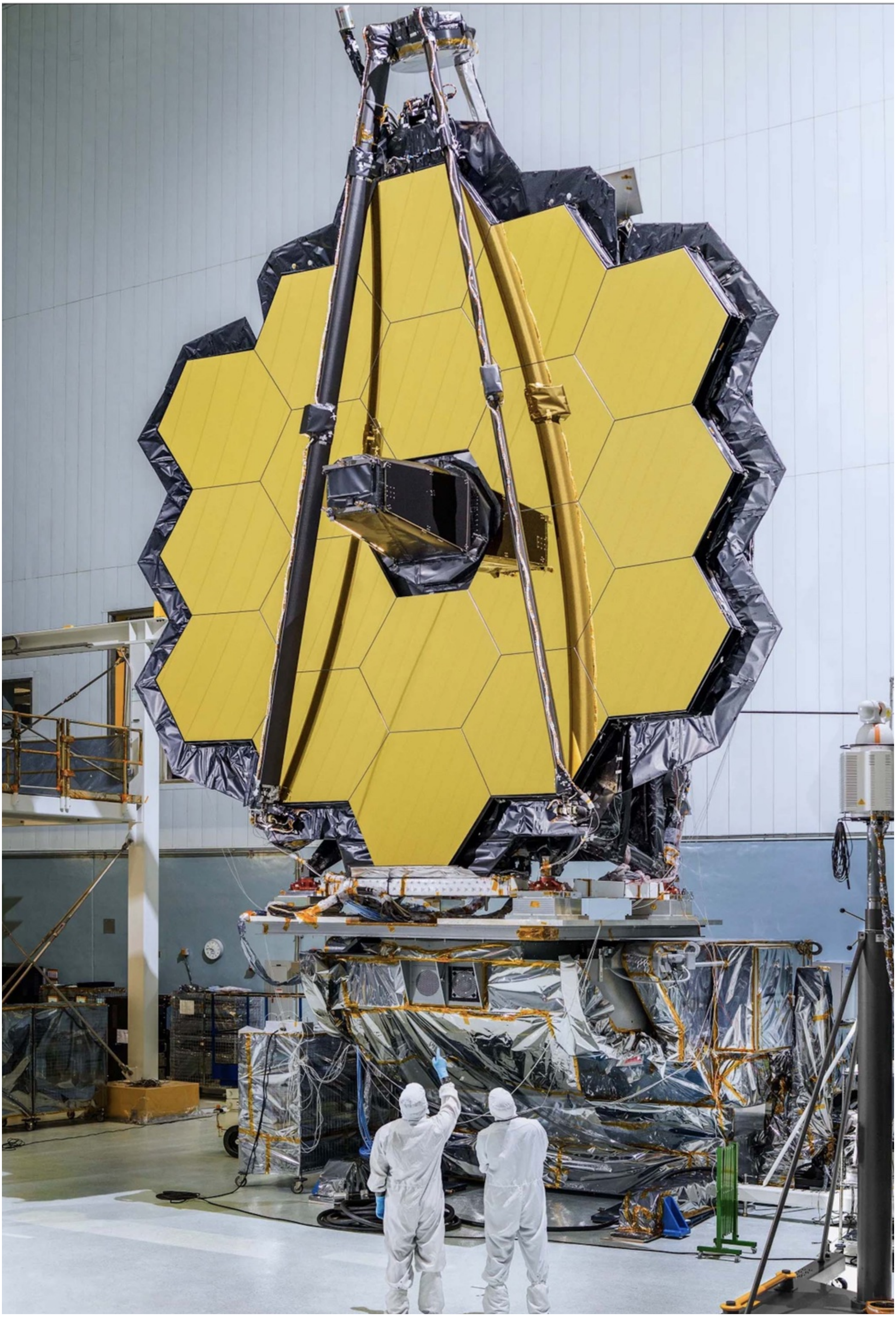
Thirty Meter Telescope (TMT)

One of the first images released from JWST was an image of the galaxy cluster SMACS 0723. There are thousands of galaxies in this small patch of sky that is approximately the size of a grain of sand held at arm’s length. This is one ten-millionth of the full sky. The JWST image alternates with the same area of sky imaged by HST. The JWST image is the sum of 12.5 hours of exposures whereas HST needed to integrate for nearly two weeks.

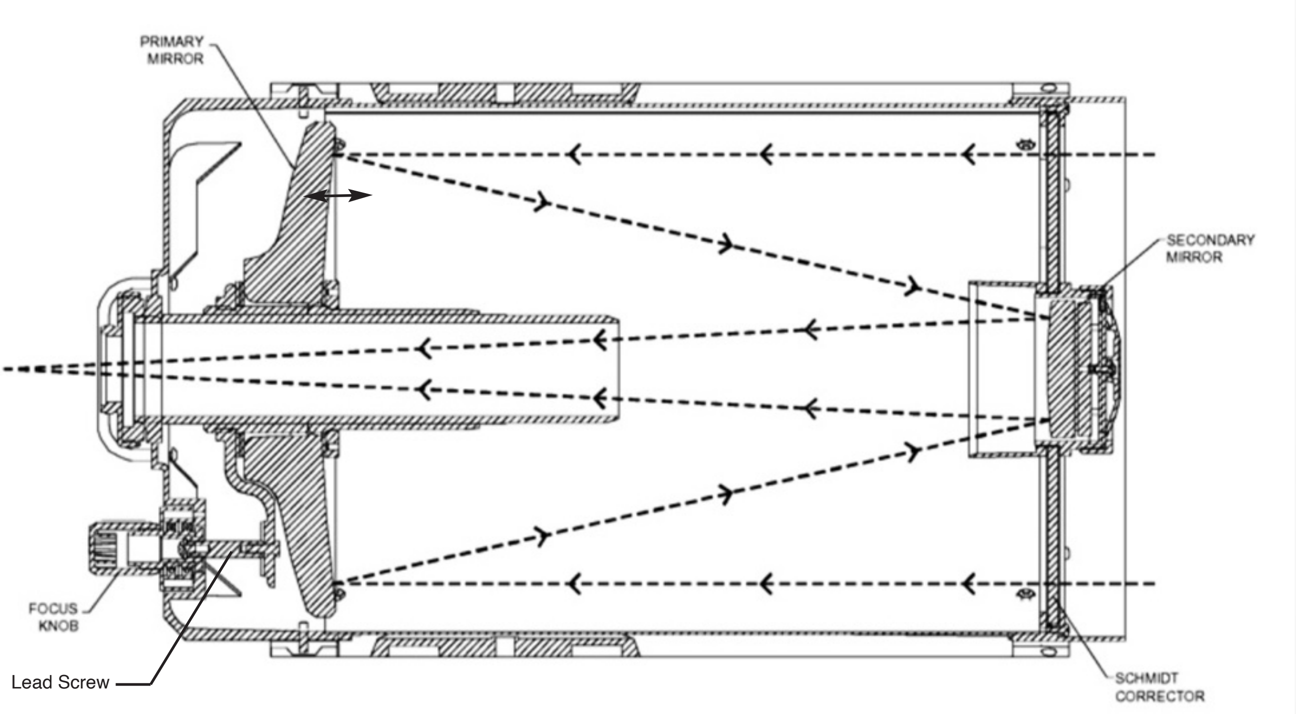
Giant Magellan Telescope has a 25.4 meter aperture. It is expected to have a resolving power approximately 4-10 times greater than the Hubble Space Telescope and four times greater than the James Webb Space Telescope. However, it will not be able to observe in the same infrared frequencies as space-based telescopes.

It consists of seven 8.4 meter mirrors, each weighs 16-metric tons and is supported by a highly specialized pneumatic support system which is housed in a steel weldment, or “cell.” This highly sophisticated system — containing three times the number of parts of a typical car — is vital to the telescope’s optical performance and precision control.

Opposite Page, Engineers at Goddard Space Flight Center inspect the 6.5-meter diameter JWST primary mirror after installation of the 18 hexagonal mirror segments. (NASA / Chris Gunn)

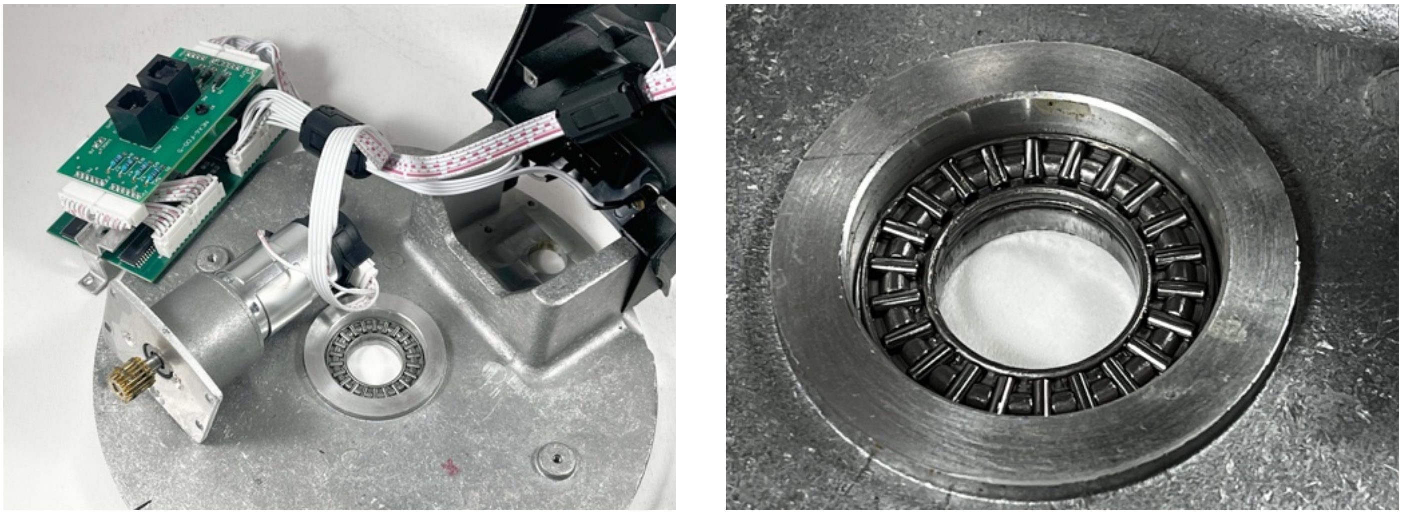


Celestron 8SE Single Fork Mount

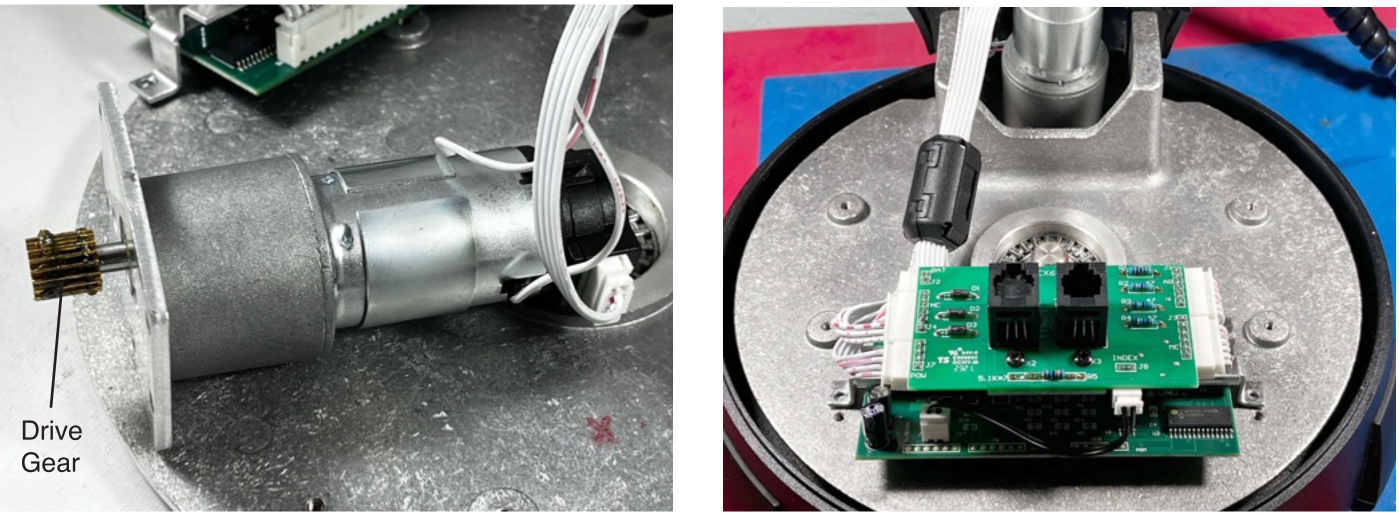


Celestron NexStar mount:

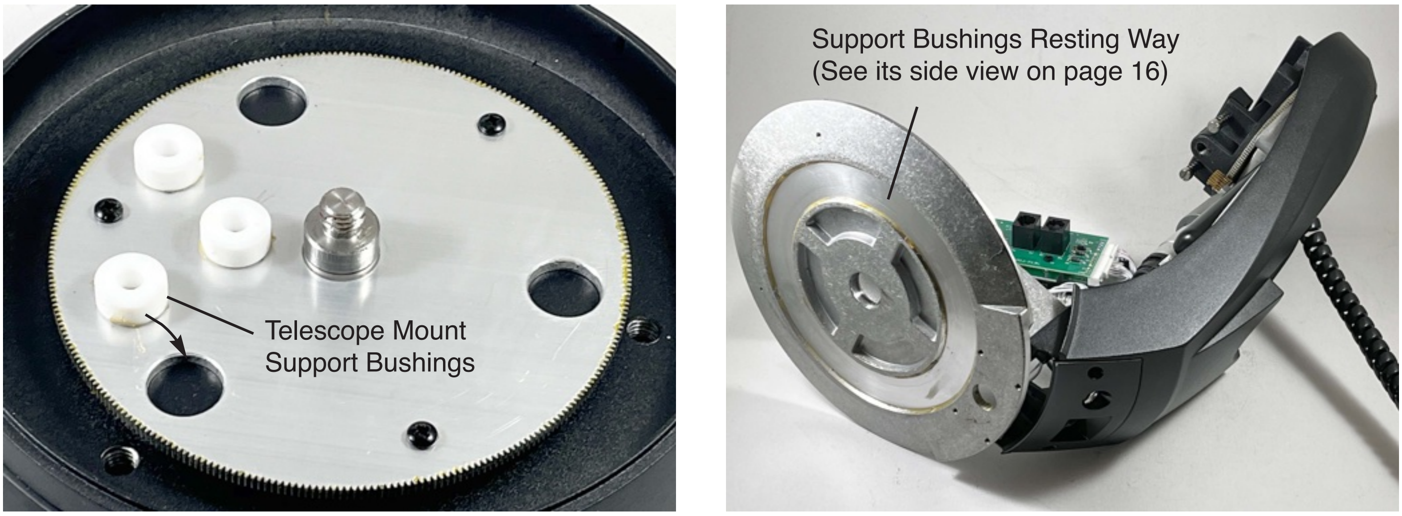
'Travel Pro' - the first variable-use fork mount from Celestron, with built-in stand, which can also be used without a tripod. A knob allows the OTA to be disconnected from the Celestron Travel Pro fork mount, allowing you to take the telescope on flights as hand luggage and to put the mount in a suitcase. Also other telescopes, used for other purposes, can be connected onto the same fork mount - such as a solar telescope or various cameras with a range of lenses, etc..



Drive motor (left), and close up view of roller bearing at the center of horizontal axis (right ascension). This type of roller bearing is utilized where heavy loads are to be supported by a compact, and relatively maintenance free design. Celestron supports it by a hardened flat washer on top, and three Teflon bushings on the bottom (see P16).

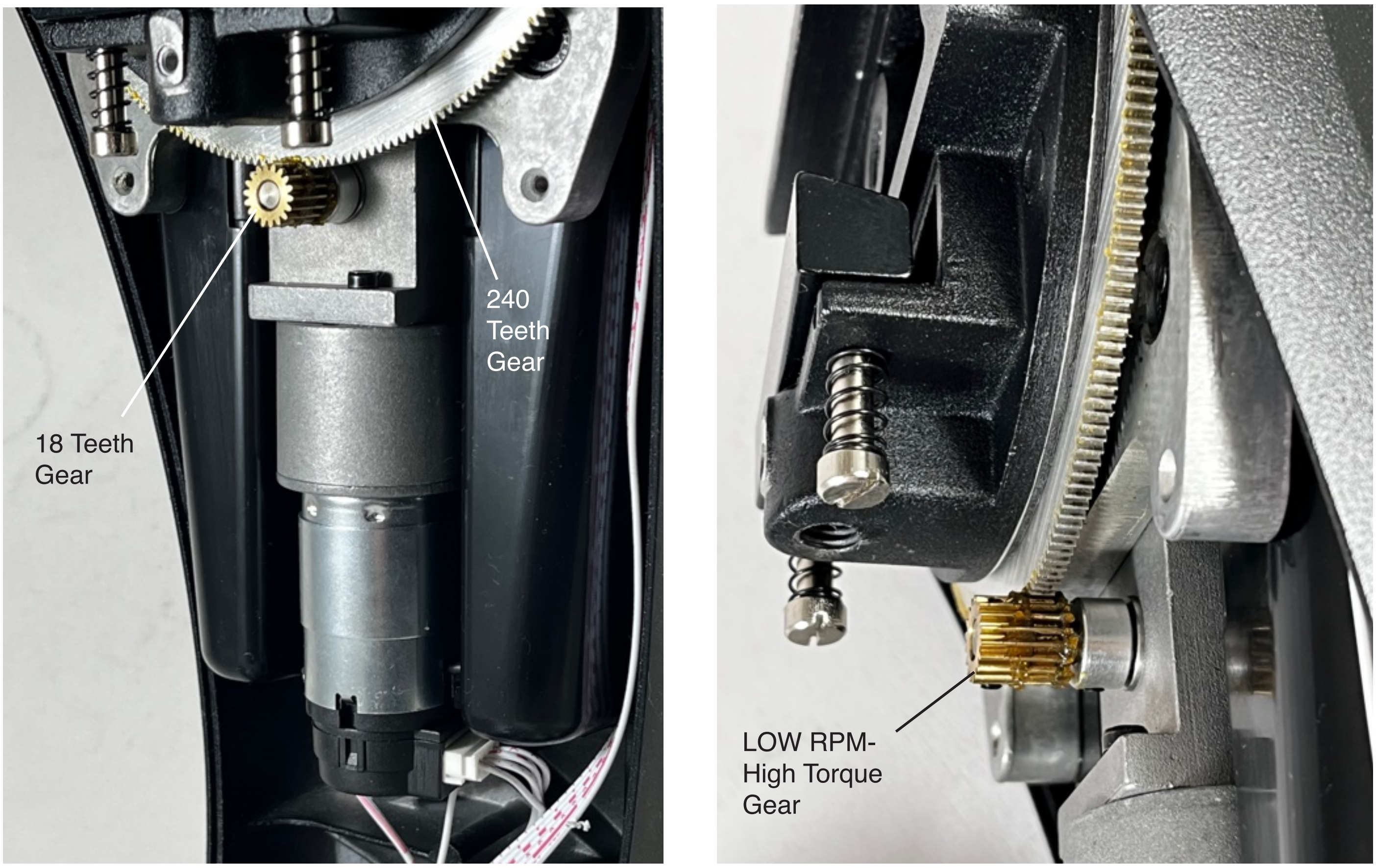


Motor drive with reduction gear housing (left), and drive electronics board (right) can be interfaced with laptop to position the telescope using Celestron's NexStar software. At the back of the motor, there is an encoder that generates pulses to tell the controller its whereabouts.

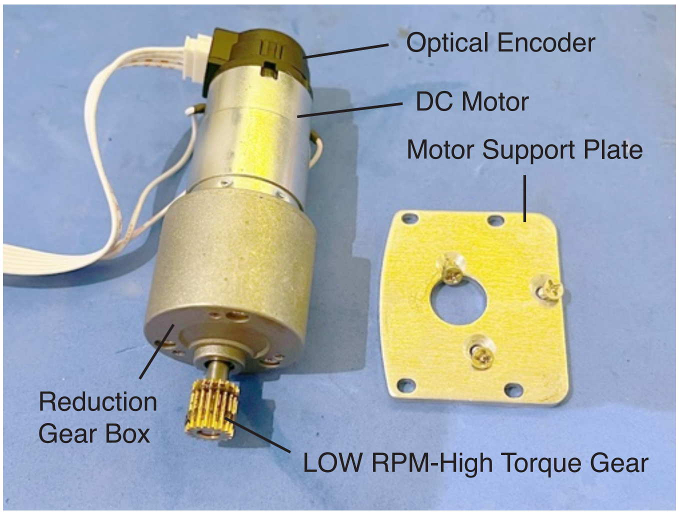


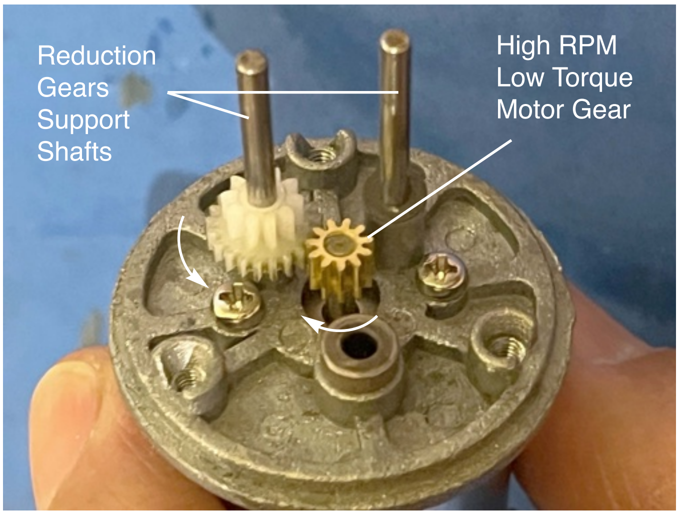
The entire weight of L-Shaped telescope mount (right) rides on three Teflon support bushings (left). This design avoids heavy/expensive bearings that large telescopes use. The large central 519-teeth gear fits in between three Teflon bushings (left) to provide a smooth — wobble free rotation. The gear ratio of this large gear to motor's drive gear is 1:28.8

Declination, and right ascension rotary axis drive motors (left) are controlled by electronics board, and key pad. Both axis utilize roller bearings and Teflon pads to deliver smooth rotary performance.

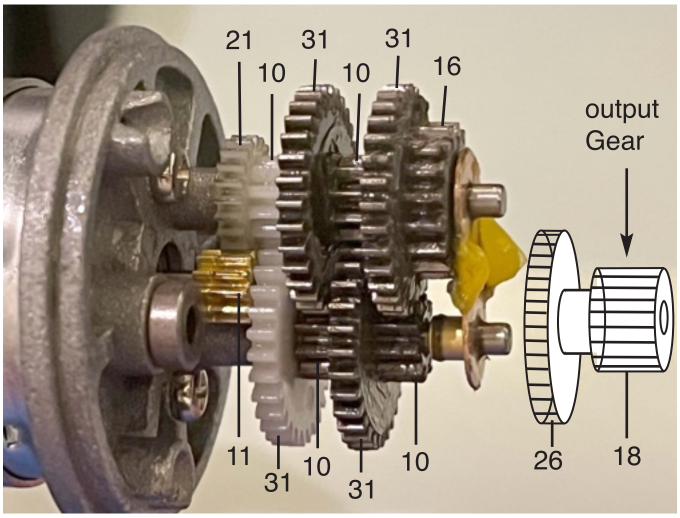


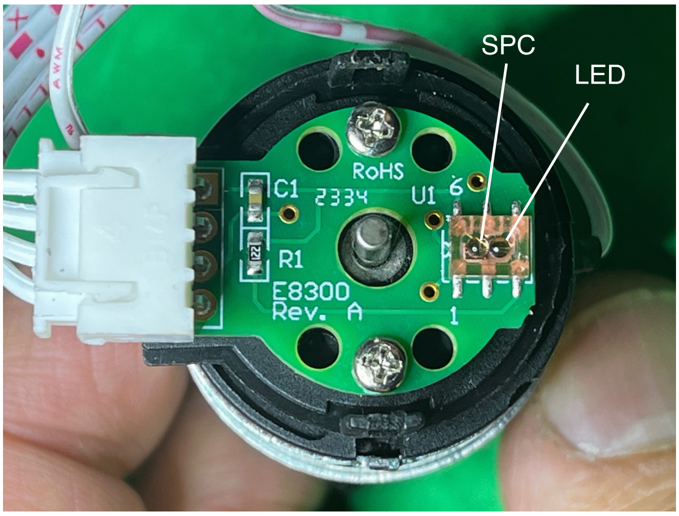
Two views of the large declination gear: A bevel gear is utilized to transfer the motor rotation at right angle.



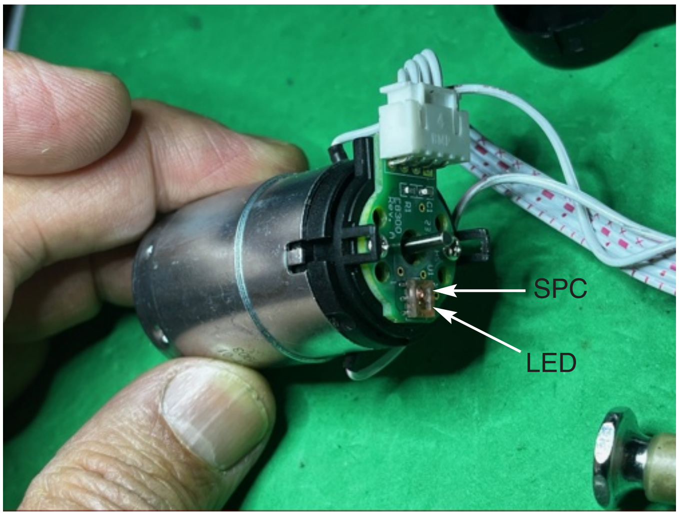


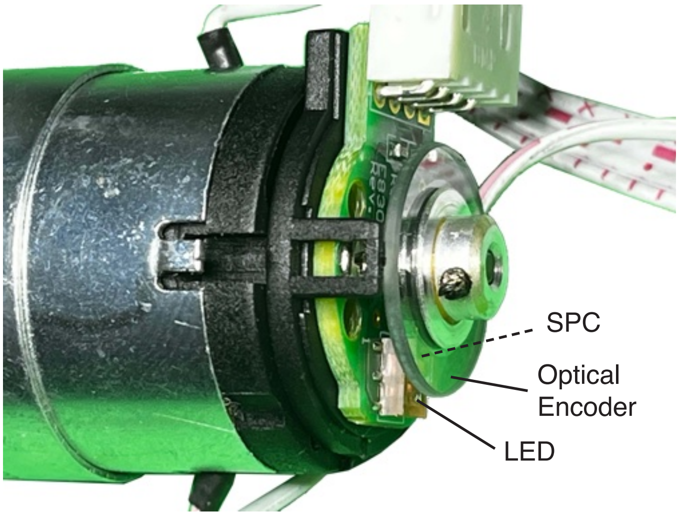
The drive gear motor consists of a reduction gear box (108:1) consisting two rows of gears riding on two support shafts.



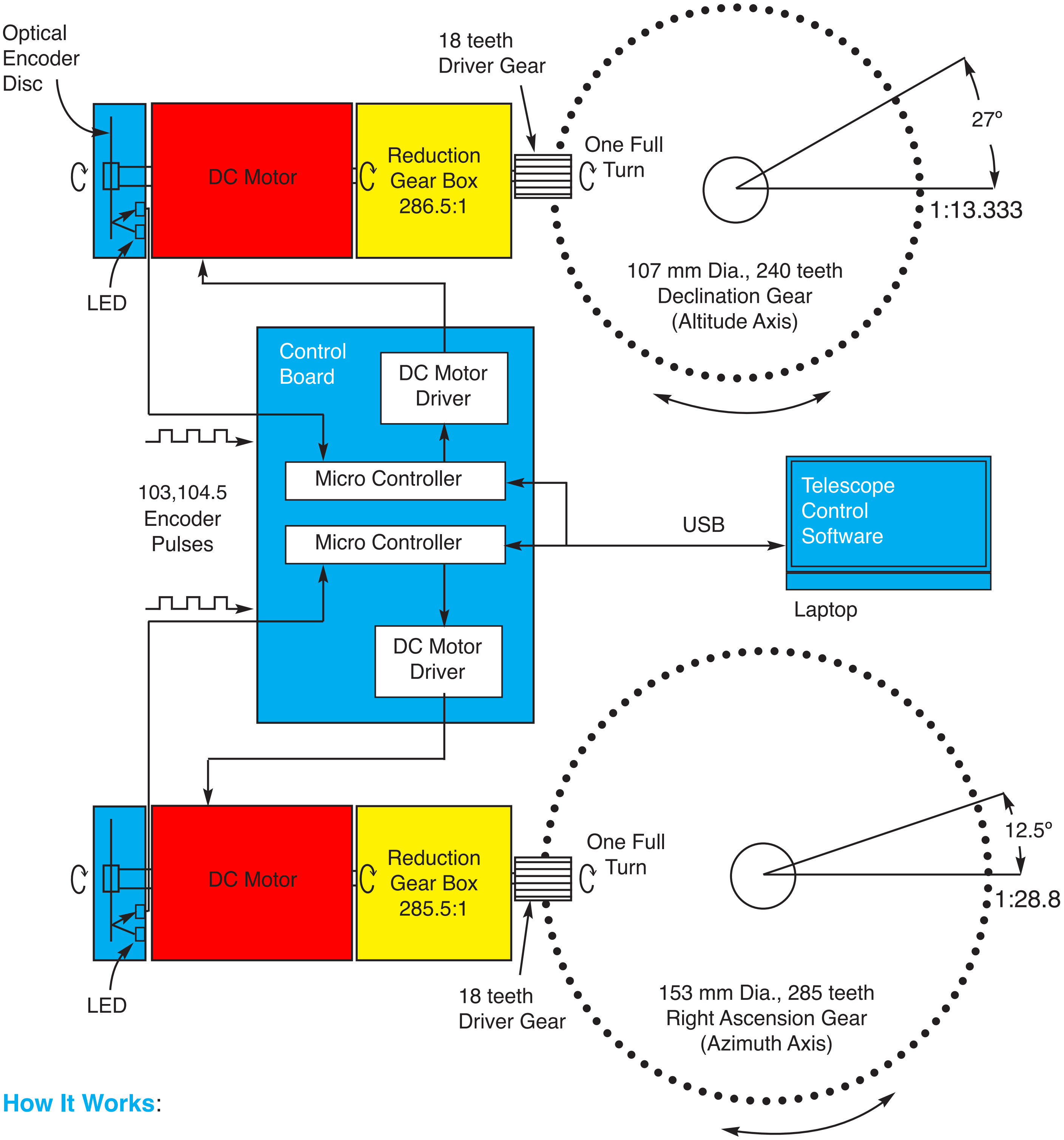


Reduction gear train ratio: 11/21x(10/31x10/31x10/31x10/31)x16/26 = 1,760,000/504,242,466 = 0.003,490,384,326. The optical encoder disc (below, right) generates 360 pulses per revolution. 286.501x360=103,104.504 pulses/revolution





Above, rear end shaft has an optical encoder (right). Electronic pulses are sent back to the control board to match the number of pulses necessary to point the telescope to the right location in the sky. The gear ratio from the motor to the declination axis is 286.501 to 1. Each rotation of the encoder generates 360 pulses. This translates to an angular resolution of 103,104.5 pulses per Drive Gear's full revolution. For declination axis, this is also multiplied by 240/18 or 12.5°. For right ascension, this is multiplied by 519/18 or 27°. The result is sub arc second resolutions for both axis with the right ascension having almost twice the resolution of declination. For an overview of this calculation, see full illustration on the next page.

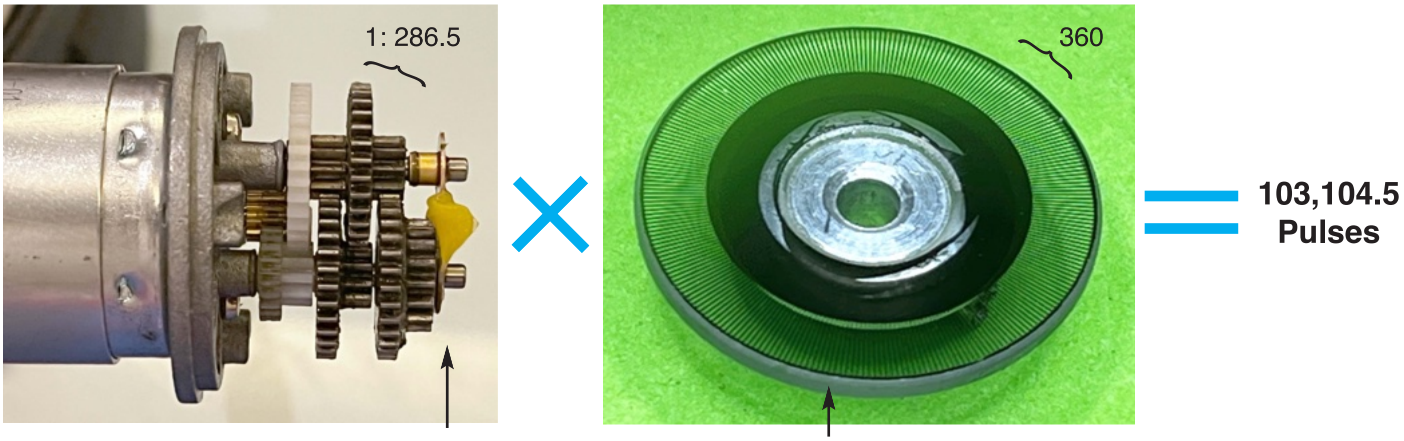


How It Works:

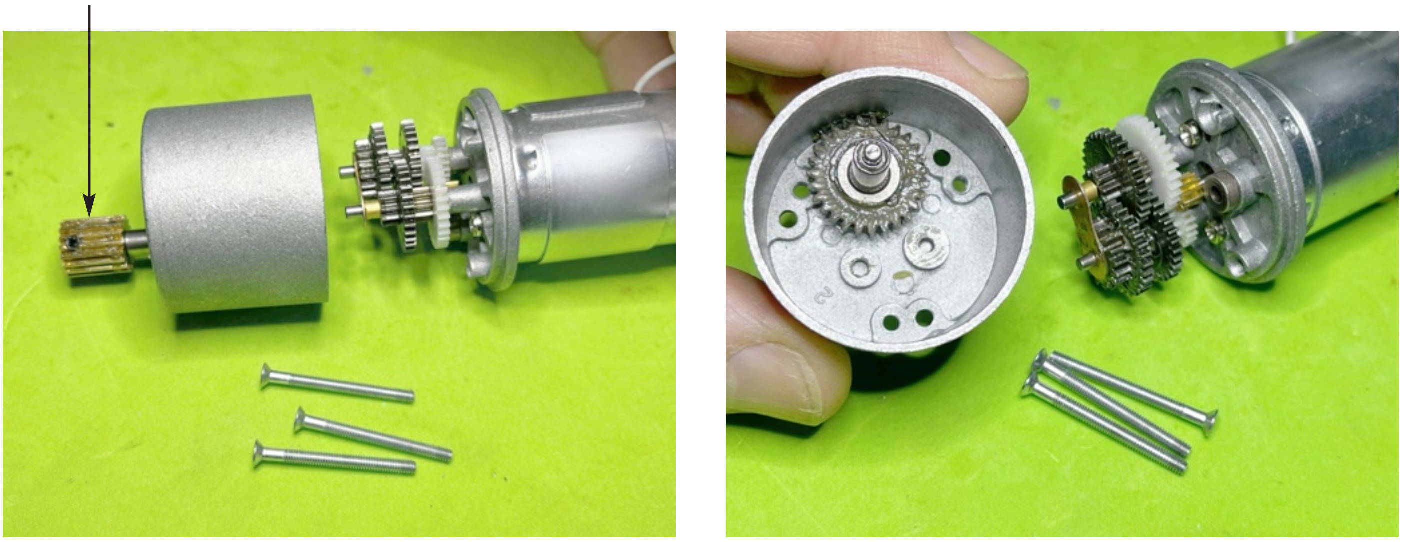
Schematic block diagram of how this motorized angular positioning in Celestron 8SE works. The computer sends positioning commands to the control board at the base of the telescope mount, and the motors are turned on to rotate the telescope towards the intended position in the sky. The feedback pulses from the encoder are sent back to the microcontroller to tell the processor when the position is reached.

To calculate the Declination resolution, we know for every 12.5°, there are 103,104.5 Pulses. So the number of pulses per each degree would be 103,104.5/12.5 = 8,248 pulses. Dived that by 3,600, we get **0.436 arcseconds** per pulse. To calculate the right ascension resolution, we know for every 27°, there are 103,104.5 Pulses. So, the number of pulses per each degree would be 103,104.5/27 = 3,818.7. Divide that by 3,600, we get **0.943 arcseconds** per each pulse.

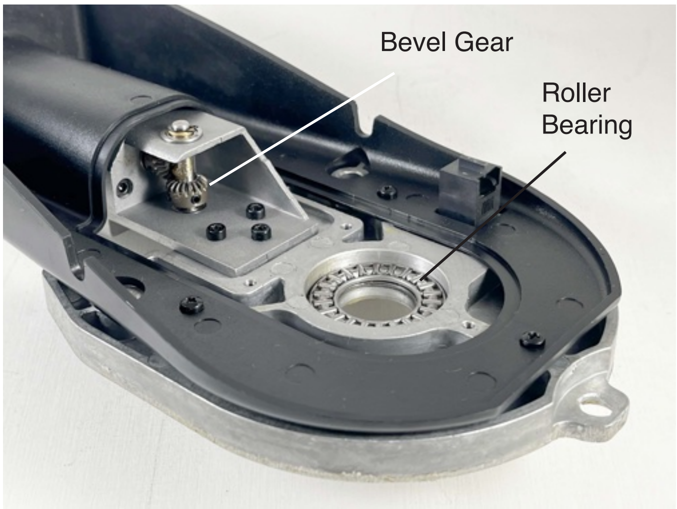
We could see both axis reach sub arcseconds resolution, but what is the backlash in this gear design? One way to find out is to turn the encoder by hand, then reverse the rotation to see the backlash. For Declination, I measured 3 1/2 turns, or 0.15 degrees. For right ascension, having an extra bevel gear, and smaller rotary gear, I expected much worse but it turned out to be the same 3 1/2 turns. The backlash measured was 0.33 degrees. To compensate for this NextStar software has a solution, explained next. We will see in case of the GT Equaterial mount, it is only 0.047 degrees (Page 26).

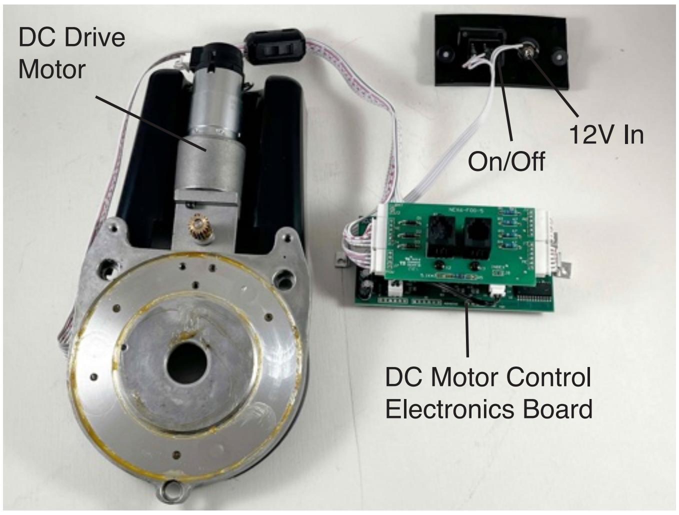


1 rotation of this gear has 1: 286.5 Gear Reduction, generating 360 Pulses/Revolution



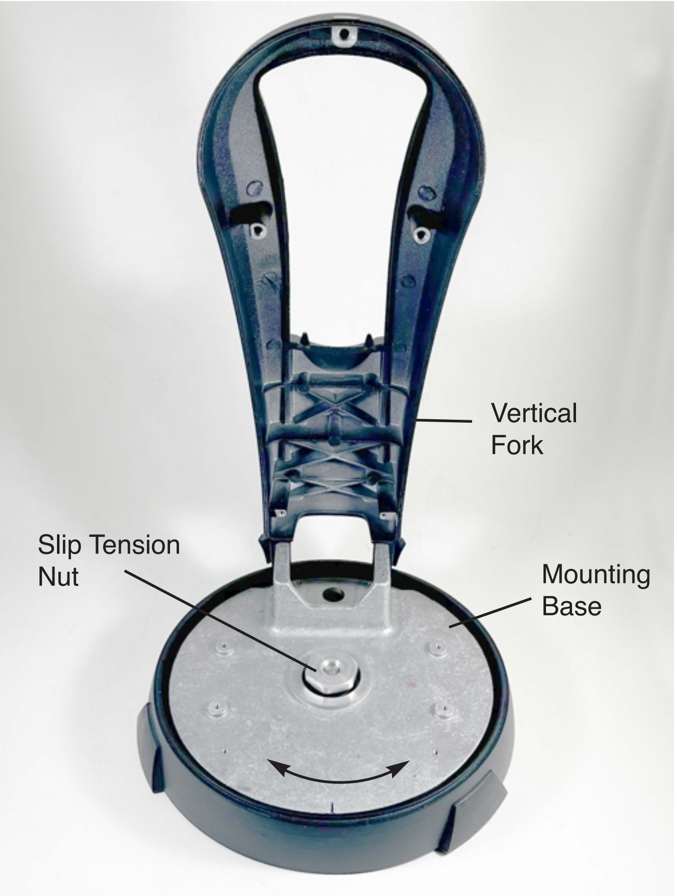
Inside the reduction gear box (left), and the straight 1:1 bevel gear (right) for right ascension assembly.



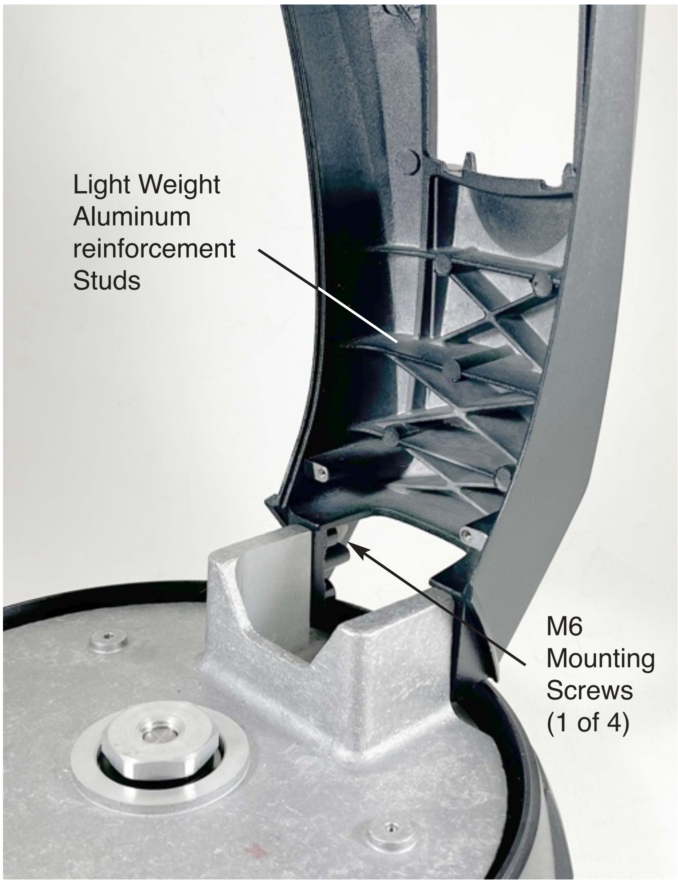


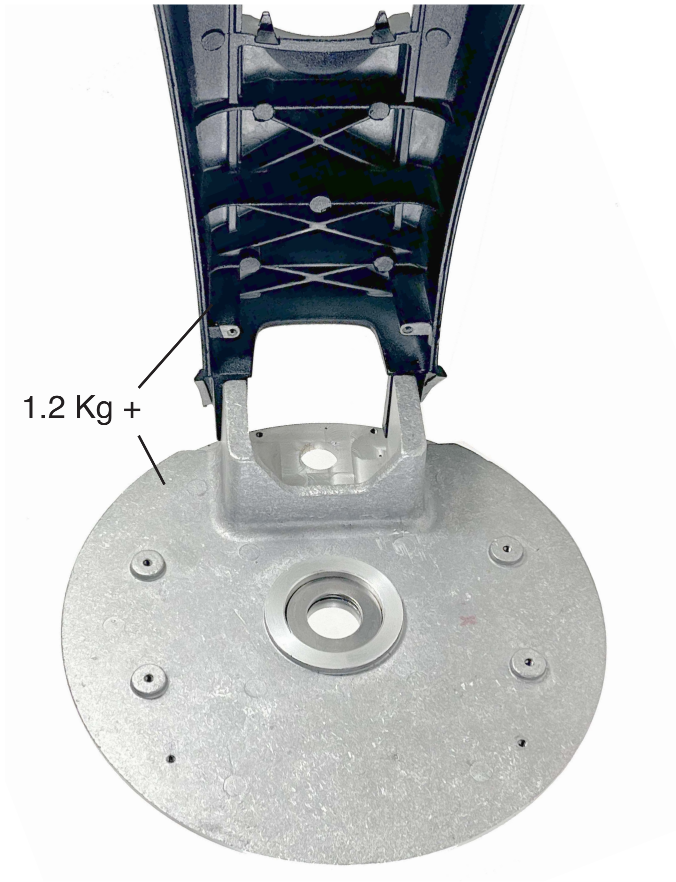
Above, Celestron utilizes roller bearings for both Declination, and right ascension axis, utilizing the same 12V DC motors (right). Below right, same computer control may be performed utilizing Celestron's hand held Key-Pad with NextStar software. The most intuitive button to use is the direction keys. The motor speed allows you to change the motor's speed while pressing direction keys.

To compensate for backlash: When the stellar object coordinates are fed to the motors, the motors will turn the telescope passed the point, then the motors are reversed to point to the star to make the system unidirectional.

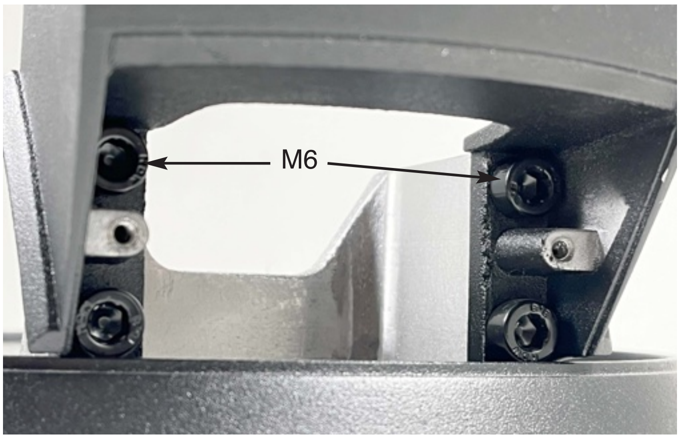


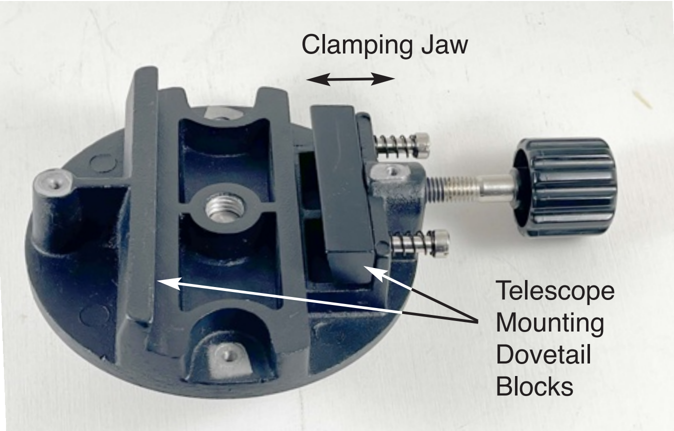
Right ascension rotary plate (above) with its drive motor removed to show the basic skeleton of the SE mount. the slip tension nut controls the friction of each axis. Without the control motors the telescope is manually operational.



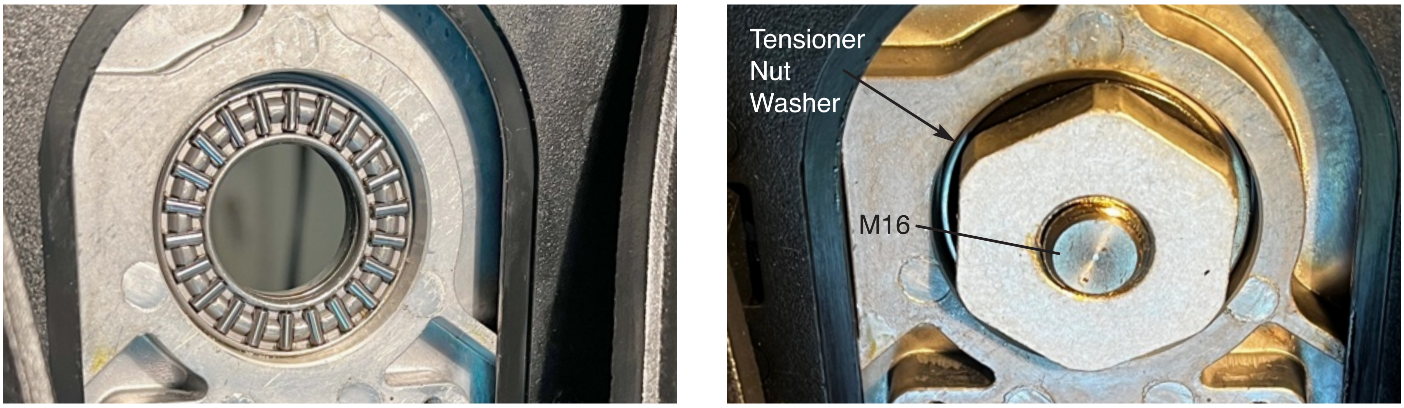


Light weight diecast Aluminum fork, and baseplate go together in a well-balanced — compact design. The baseplate and vertical fork (above) weigh only 1.2 Kilograms. This is the main support frame to secure everything including the motion control motors, drive electronics, keypad, and the telescope itself, with C8 SE being their largest aperture utilizing this design.

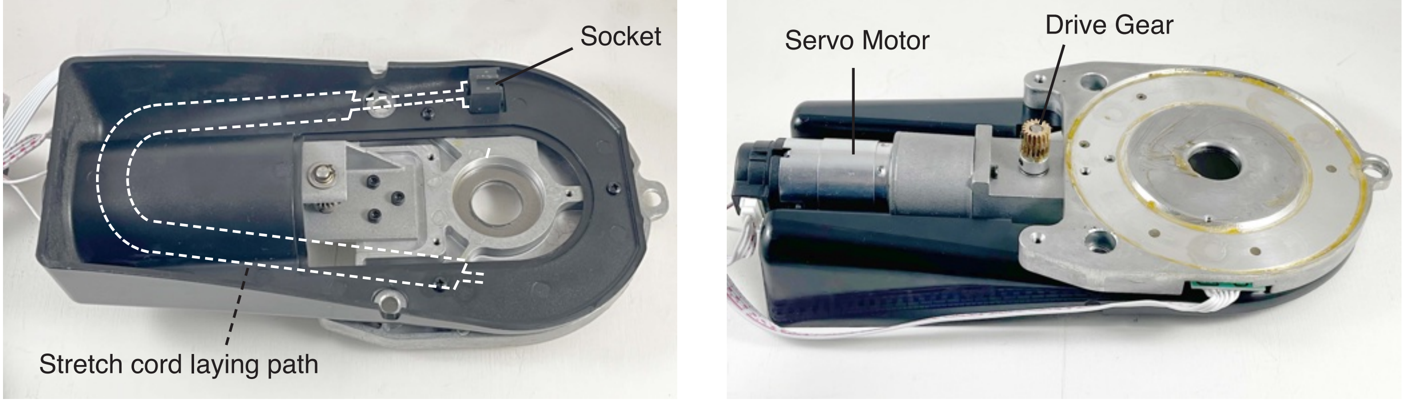




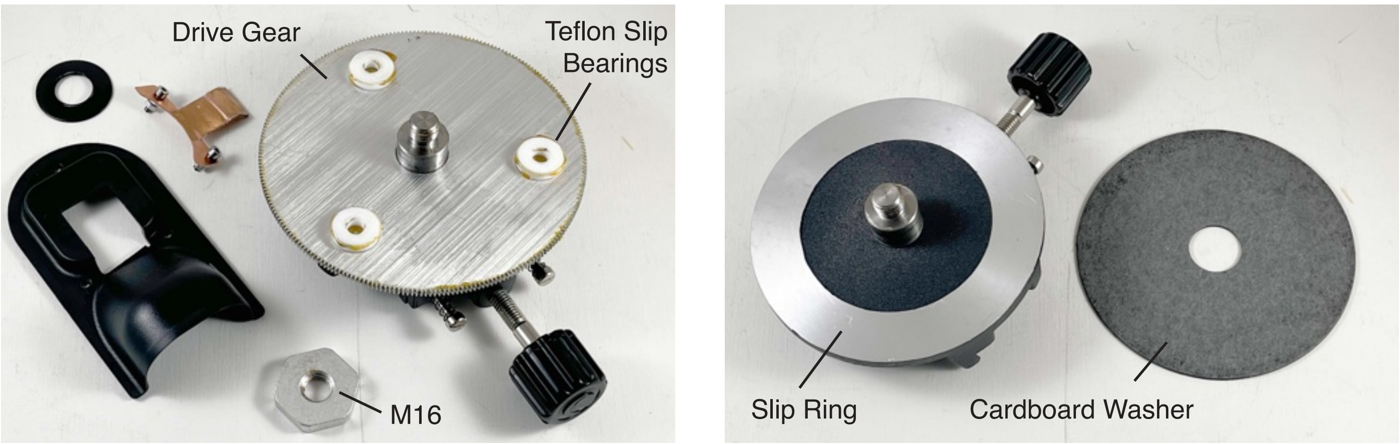
Vertical fork is secured to bottom rotary piece via four M6 screws. Right, telescope mounting dovetail Clamping Jaw.



The roller bearings of declination axis (left), and is fully assembled, and secured by Aluminum tension nut (right).



Two views of the large declination gear. Note brilliant use of plastic shell to provide inner space to house the keypad's telephone-type stretch cord (dotted line, left).



Declination (Altitude) 240-tooth gear (left) with Teflon slip bearings. Celestron utilizes a large diameter cardboard washer behind the slip ring. This material is apparently utilized to produce constant friction. The Altitude axis can be manually rotated by hand.

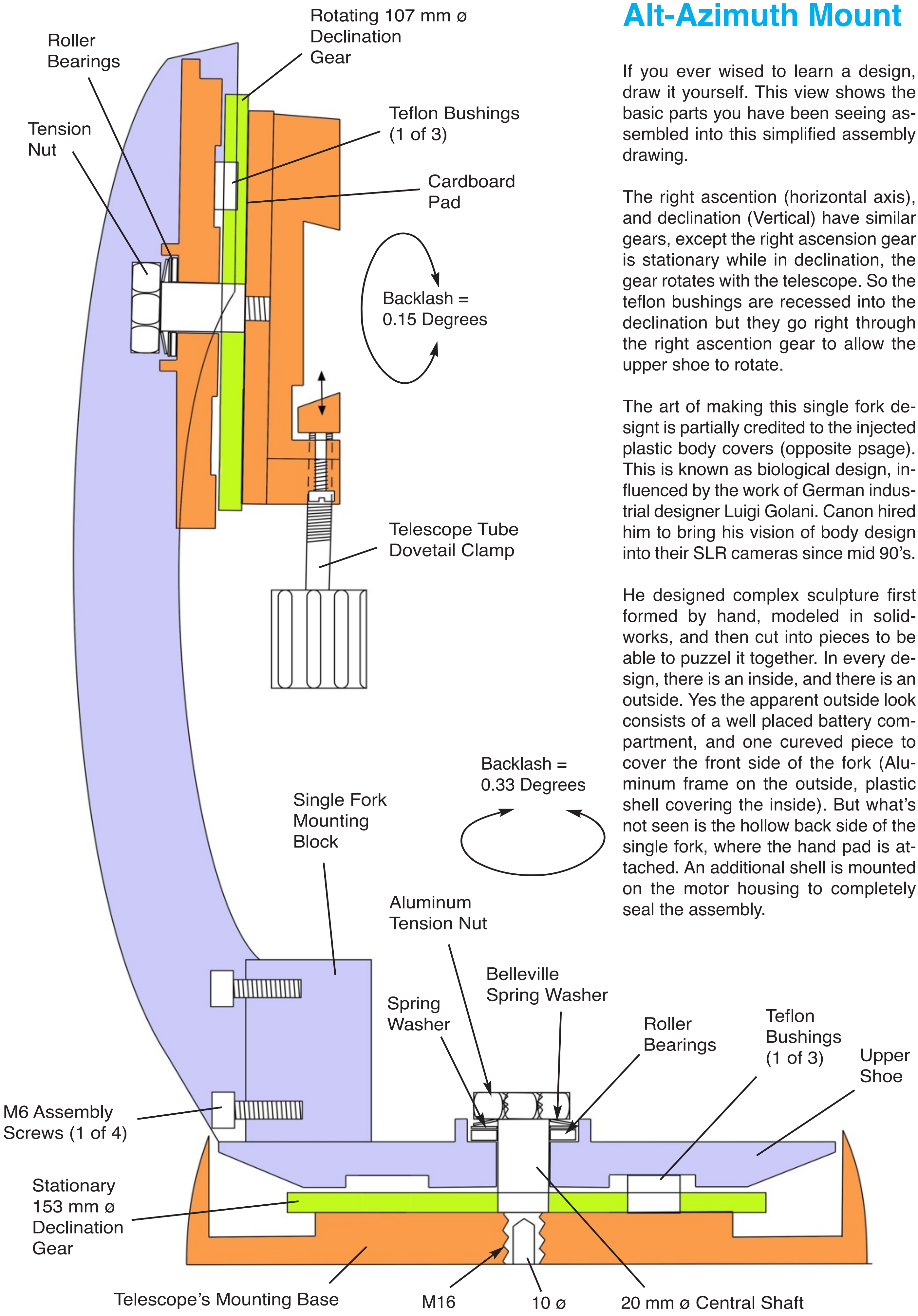
Alt-Azimuth Mount

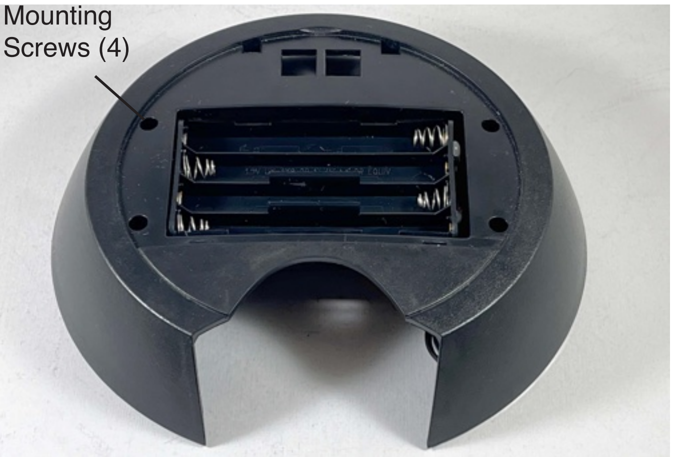
If you ever wised to learn a design, draw it yourself. This view shows the basic parts you have been seeing assembled into this simplified assembly drawing.

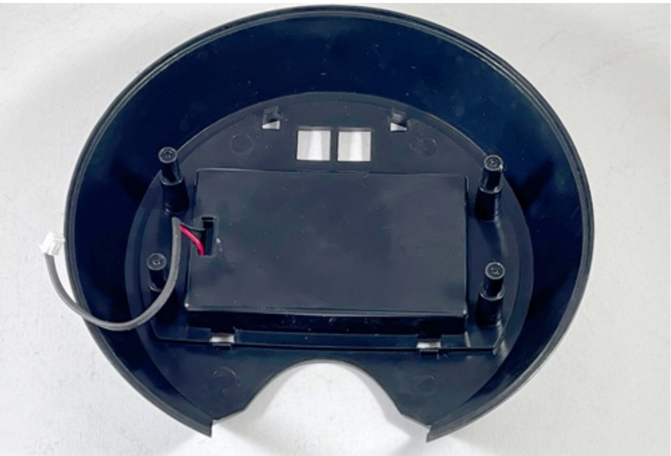
The right ascention (horizontal axis), and declination (Vertical) have similar gears, except the right ascension gear is stationary while in declination, the gear rotates with the telescope. So the teflon bushings are recessed into the declination but they go right through the right ascention gear to allow the upper shoe to rotate.

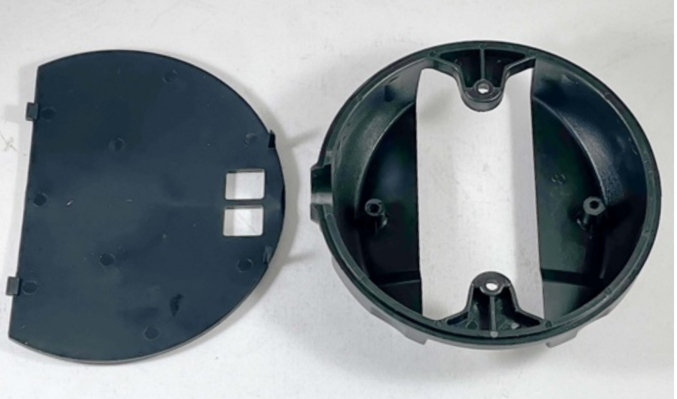
The art of making this single fork designt is partially credited to the injected plastic body covers (opposite psage). This is known as biological design, influenced by the work of German industrial designer Luigi Golani. Canon hired him to bring his vision of body design into their SLR cameras since mid 90’s.

He designed complex sculpture first formed by hand, modeled in solidworks, and then cut into pieces to be able to puzzel it together. In every design, there is an inside, and there is an outside. Yes the apparent outside look consists of a well placed battery compartment, and one cureved piece to cover the front side of the fork (Aluminum frame on the outside, plastic shell covering the inside). But what’s not seen is the hollow back side of the single fork, where the hand pad is attached. An additional shell is mounted on the motor housing to completely seal the assembly.

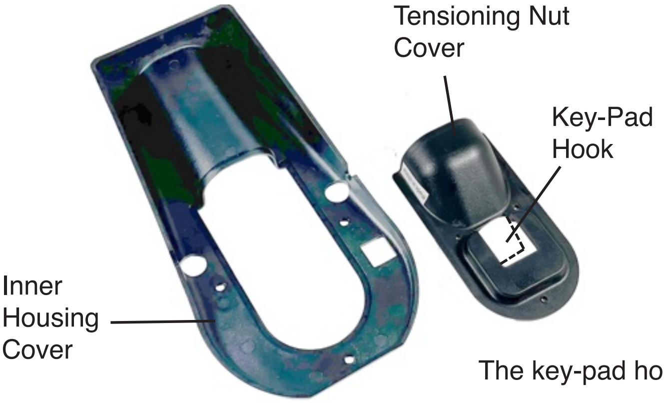


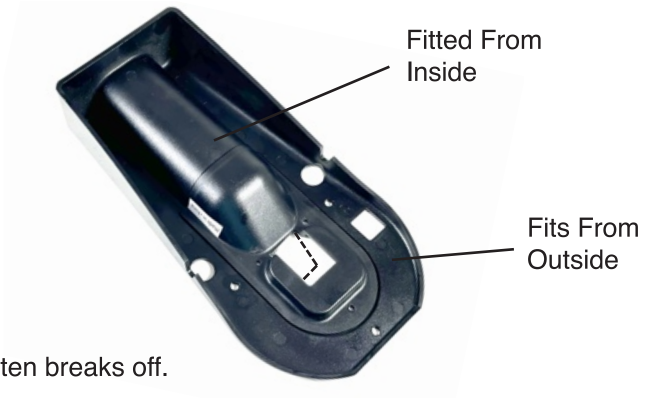




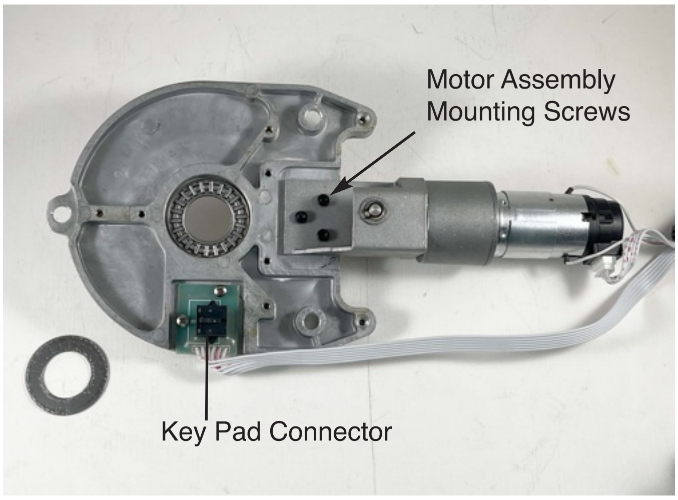


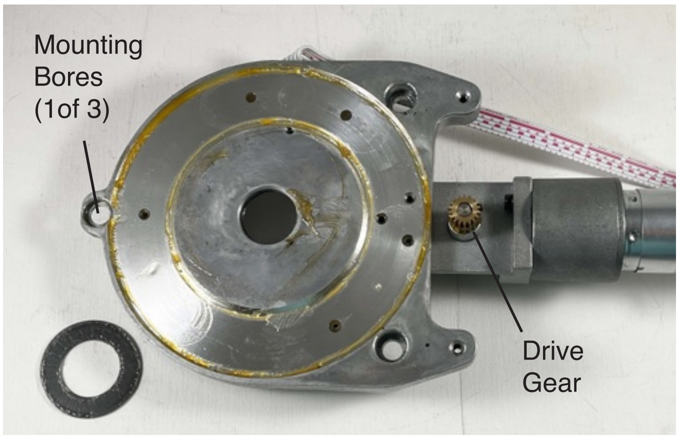
Plastic covers in Celestron blend so well with the rest of its Aluminum support assembly. There is much to learn from Celestron SE from its industrial design. The form of shells to fill the space inside, and around the body is brilliant, specially the way the hand held lighted key pad mounts to the side.

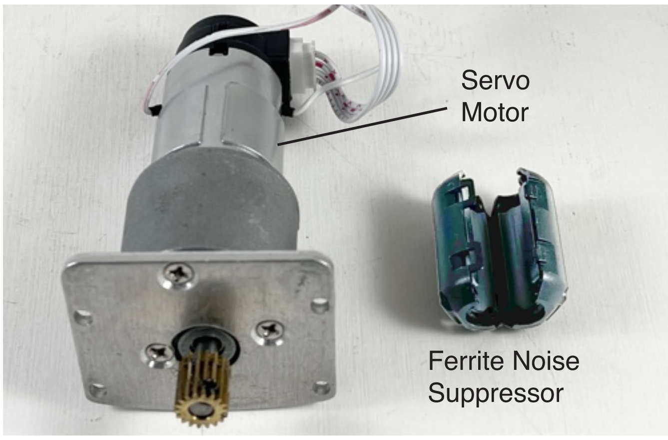




The key-pad hook often breaks off.







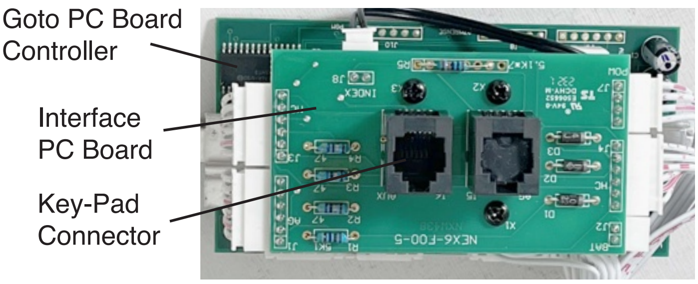
Above, further disassembly of the cover shells reveal how cleverly plastic covers are pieced together from inside, and from outside to seal, and protect the inner workings of the fork mount. There is a certain procedure how these are assembled together, some screws are not accessible at the end. The right ascension drive motor is further shown below.

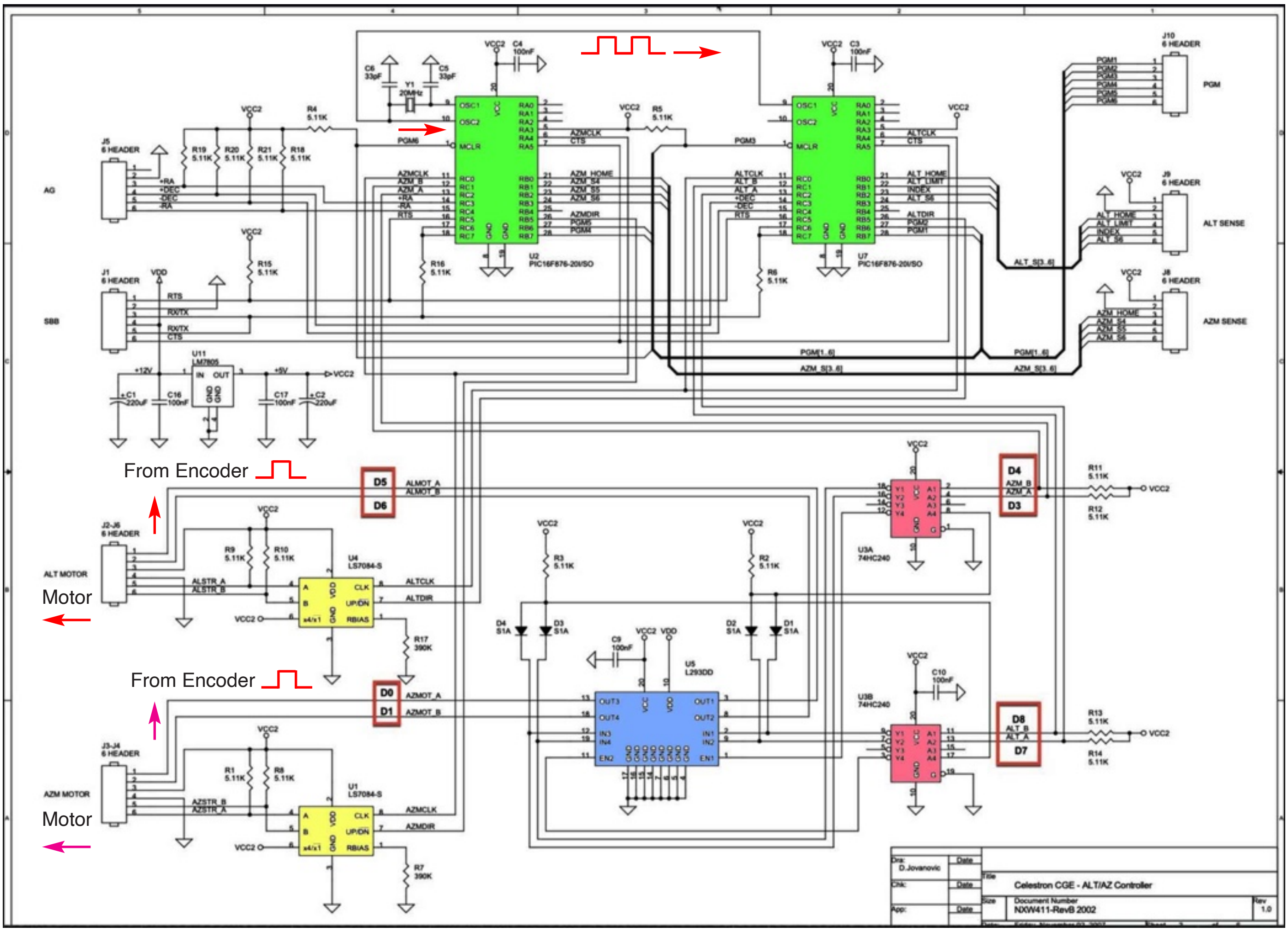
The industrial design of Celestron 8SE mount is a clever combination of ergonomics, aesthetics, up to date electronics, portability, user friendliness, self-contained battery power, illuminated/detachable hand pad to control the telescope, etc.

The single fork design allows well balanced portability, like lifting up an old telephone. The entire weight is less than 5Kg. I spent almost a week studying this design, and although the plastic key-pad hook is too thin to last very long, but the rest is so well designed that I'll give it a 10/10. Well done this design team.

Schematic Diagram

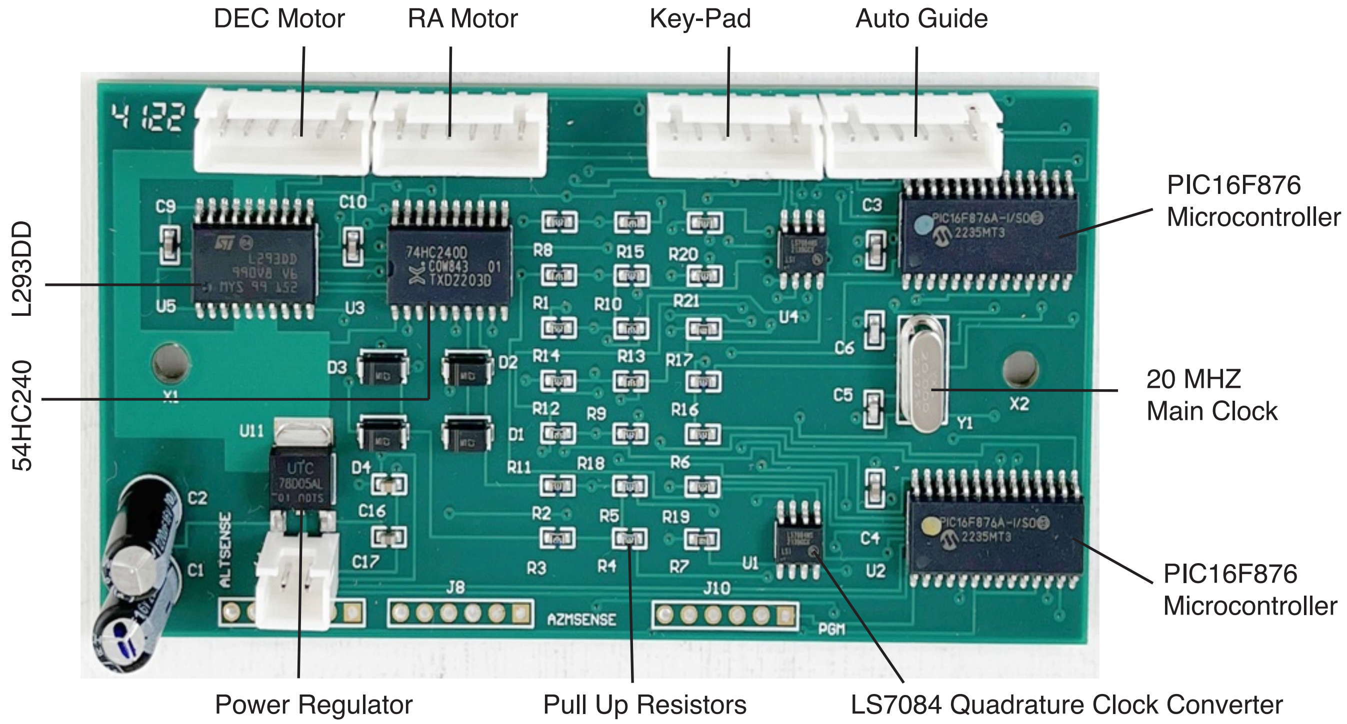
Unlike the telescope's mechanical drawings that I could not find anywhere to explain it, I was lucky to find its electronics diagram. Here's a brief description of it, concentrating on motor driver, and encoder signals to control it. A screen capture of the logic analyzer shows the encoder pulses, and the timing to turn on/off the RA/DEC motors:



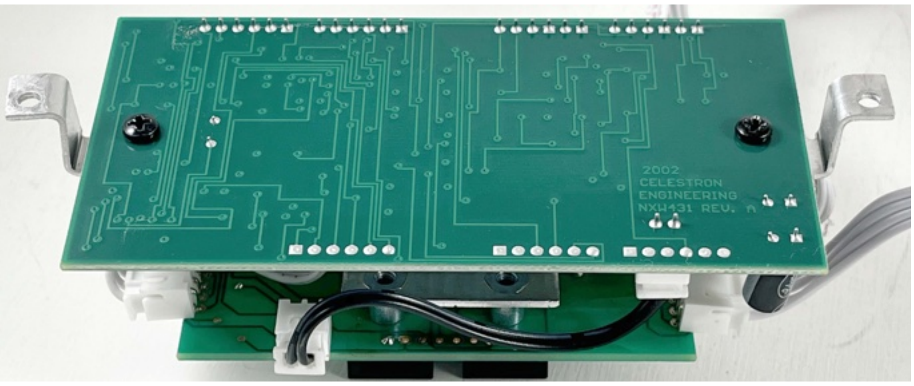


The schematic is courtesy, Cloudy Nights astronomical community, shows PIC16F876 microcontroller that drives the motors as well as the main buffered motor drivers that drive the actual motor inputs at the controller board.

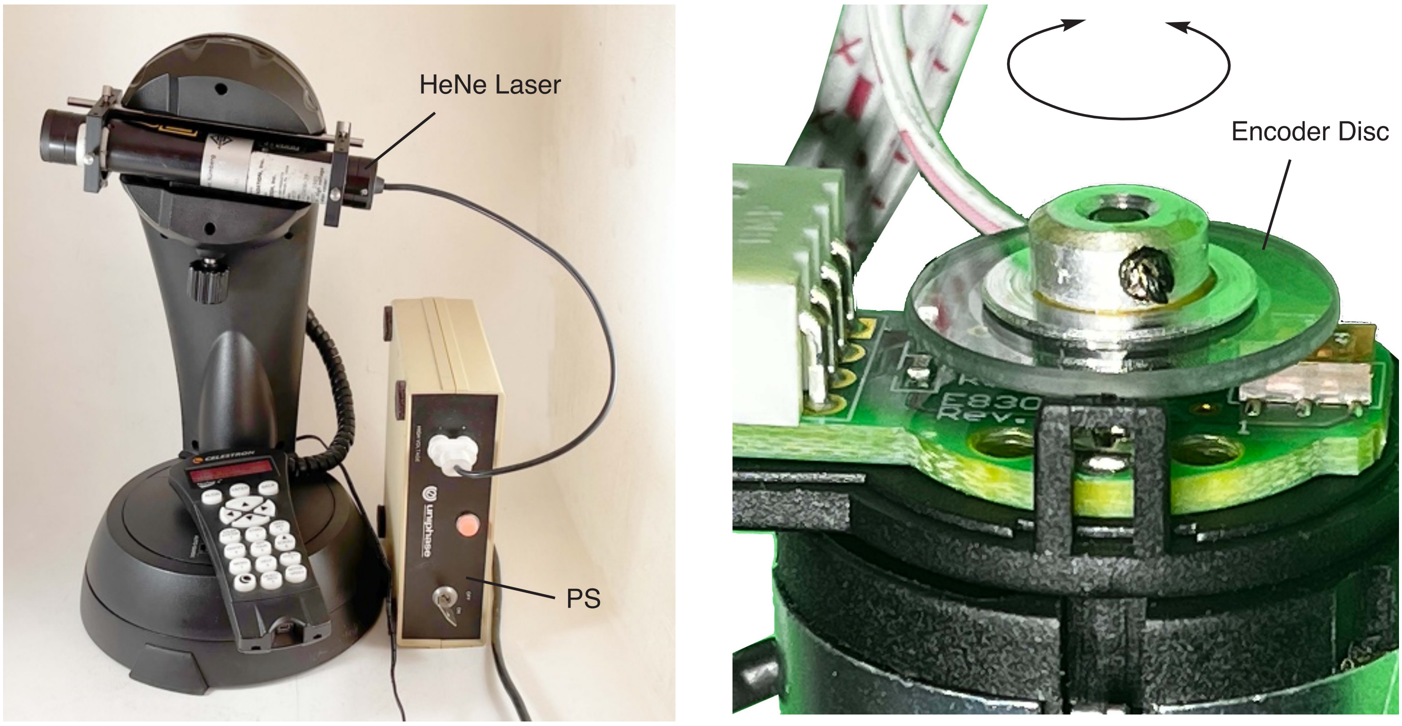
Logic analyzer output measured at points marked on the schematic shows the pulses generated by encoders, and motor switch on/off signals. Note the Declination motor reverses to the intended point in sky while the Right Ascension motor just goes one way. The RA motor has 360° range while DEC motor has a 90° range. It shows the microcontroller would only reverse the motors if necessary.



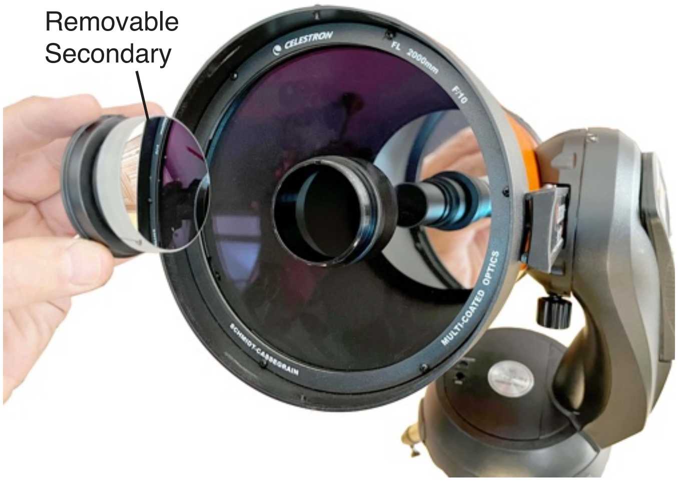
PIC16F876 is an 8-bit flash based programable Microcontroller, LSI Computer Systems **LS7084**: Quadrature clock converter, STMicroelectronics **L293DD**: Push-pull 4 channel drivers with diodes, Texas Instruments **54HC240**: High speed CMOS logic inverting octal buffer/line drivers, Cystek **LM78D05A**: 3-terminal positive voltage regulator.



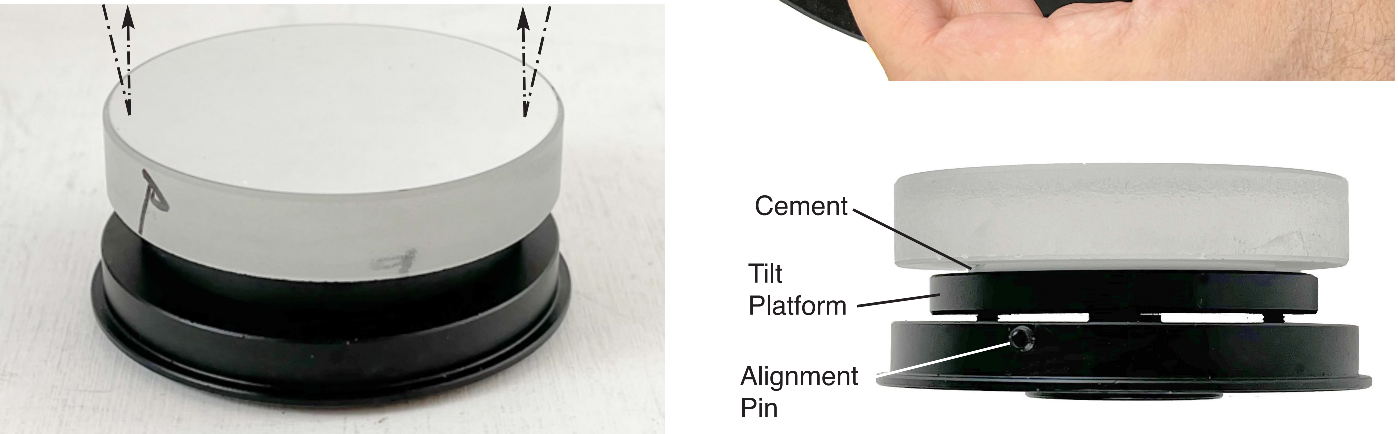
Nexstar Software Began in 2006: An easy to setup telescope control software with 120,000 stars, more than 200 star clusters, nebula, galaxies, and dozens of asteroids, comets, and satellites—including the International Space Station.



Mounting a HeNe laser in place of the telescope (left) to measure its backlash: By turning the encoder behind the motors in one direction, and then in reverse direction, the backlash is measured to be 2.5 turns. Celestron compensates for this by always passing a point of interest by a few degrees, then returning to the intended point to compensate for backlash.



Removable secondary mirror allows mounting SLR cameras at the focal plane of the primary mirror.

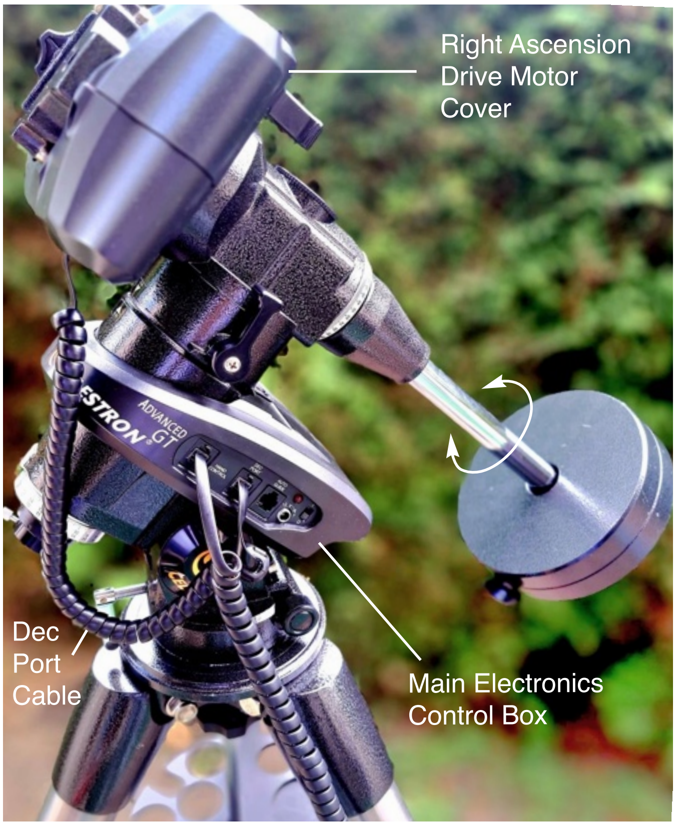


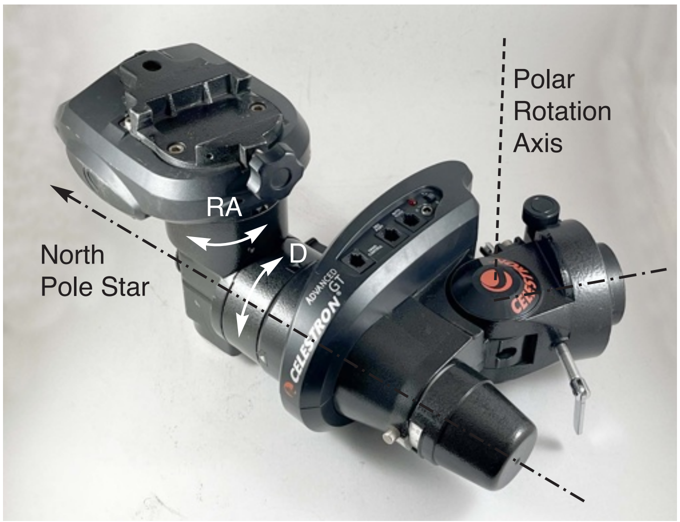
The secondary mirror is mounted on a tilt platform. Alignment pin ensures correct orientation of mirror to preserve its alignment with primary mirror.

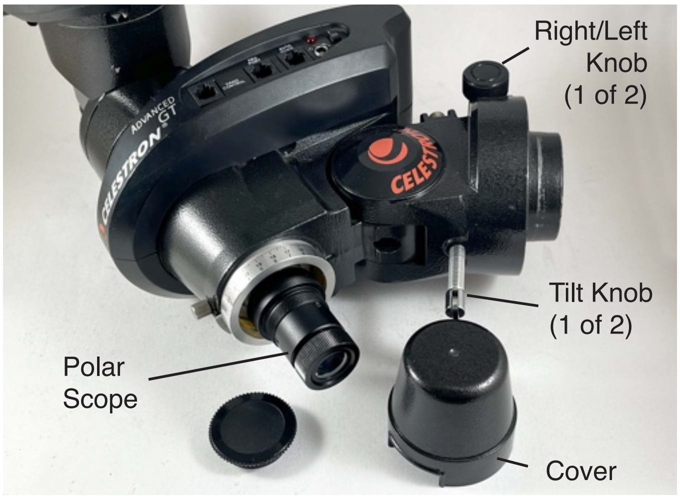
Celestron Advanced GT Equatorial Mount

This is one of Celestron's earlier designs that is capable of handling their larger size telescopes up to 14". We will disassemble it to examine its inner mechanics, and overall product design. At first glance, the use of plastics is inferior to the SE we discussed earlier. In SE, the plastic covers are so strongly supported that it is almost undistinguishable from the rest of its Aluminum diecast body.

In GT, however, the plastic covers have 360º coverage around its bare bone rotary joints, without having much support from its Aluminum diecast. It is as if they already had the barebone design, and decided to add the plastic covers later. This doesn't seem to work so well for a telescope mount because the user grabs the same plastic cover to lift it up, to mount on a tripod.





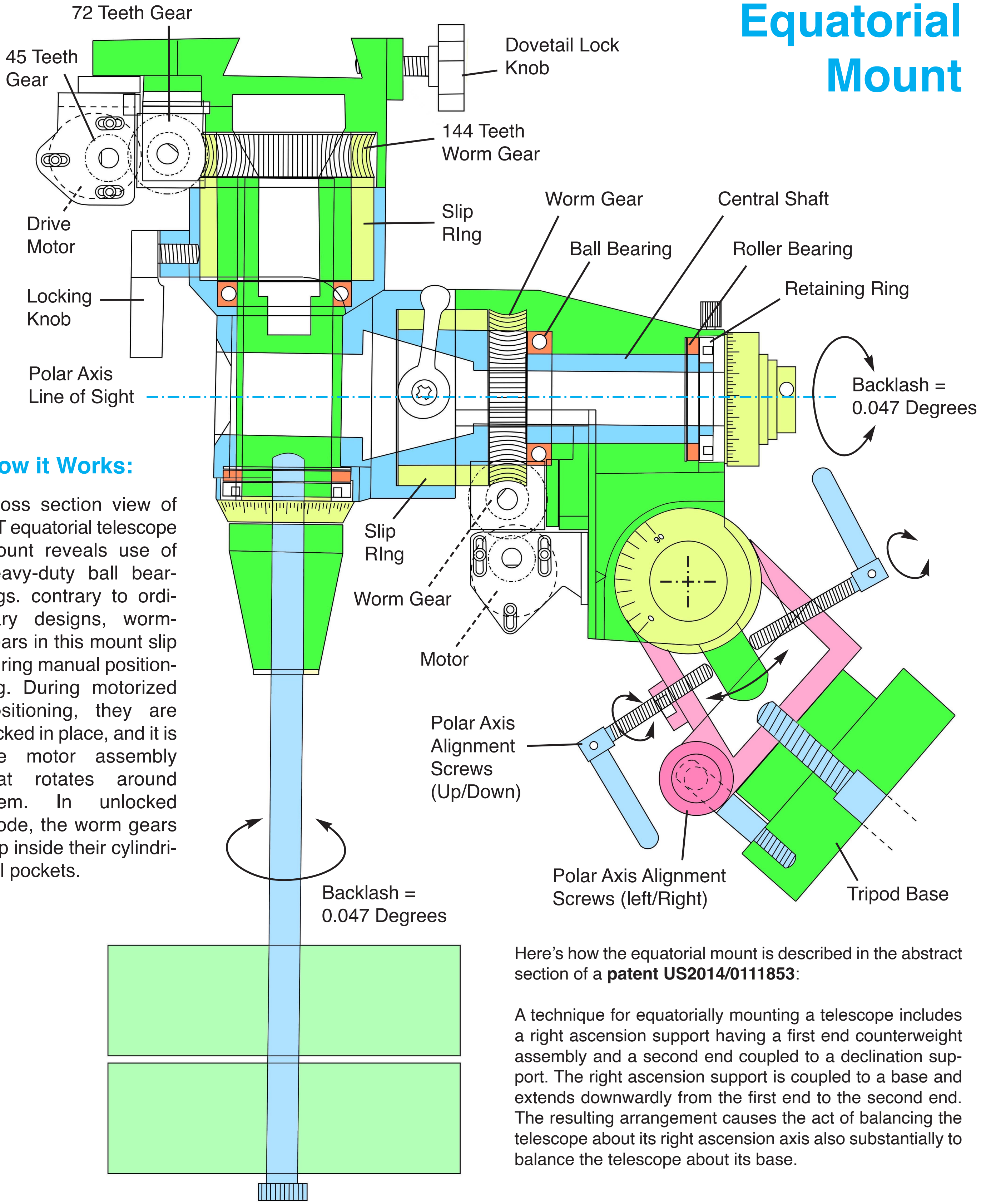


A bit confusing which is RA, and which is Declination. Just know the counter weight is always put on right ascension.

Equatorial Mount

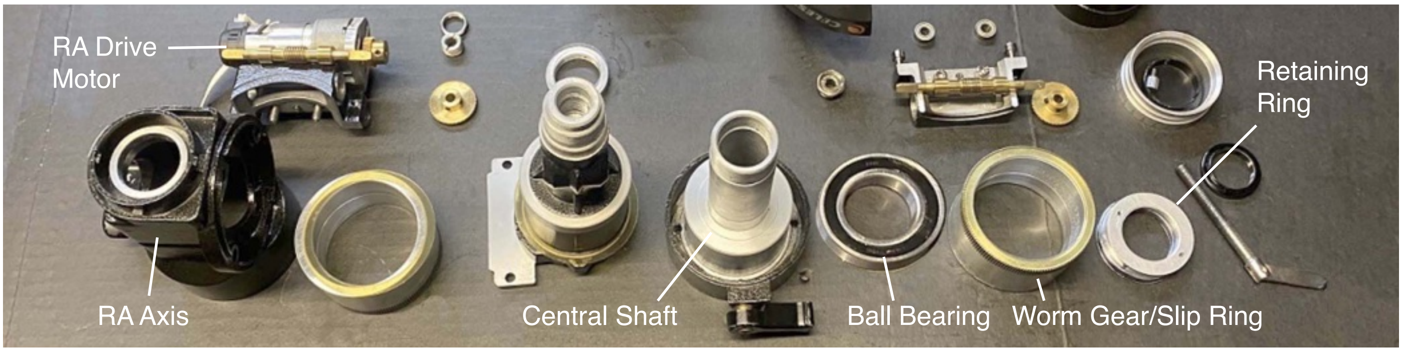
How it Works:

Cross section view of GT equatorial telescope mount reveals use of heavy-duty ball bearings. contrary to ordinary designs, worm-gears in this mount slip during manual positioning. During motorized positioning, they are locked in place, and it is the motor assembly that rotates around them. In unlocked mode, the worm gears slip inside their cylindrical pockets.



Here’s how the equatorial mount is described in the abstract section of a **patent US2014/0111853**:

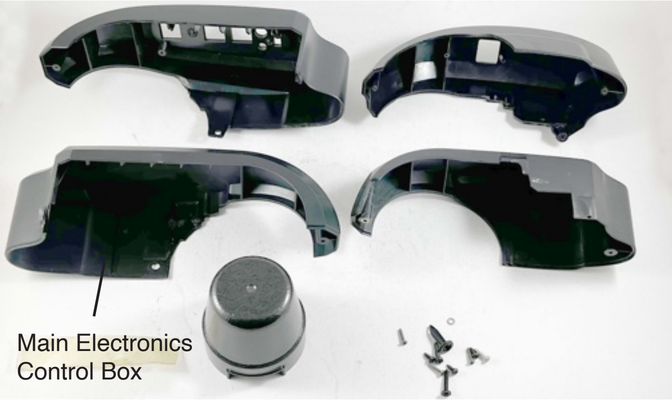
A technique for equatorially mounting a telescope includes a right ascension support having a first end counterweight assembly and a second end coupled to a declination support. The right ascension support is coupled to a base and extends downwardly from the first end to the second end. The resulting arrangement causes the act of balancing the telescope about its right ascension axis also substantially to balance the telescope about its base.



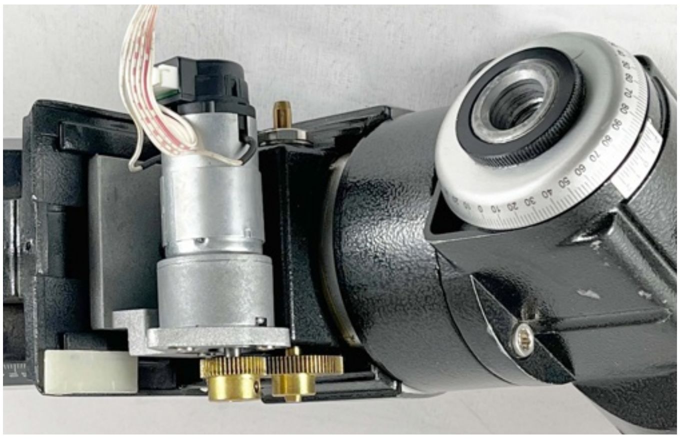
The gear train in GT seems to have much more play and backlash than SE. The methos I use to measure it is to rotate the encoder disc by hand (page 26) to determine how many pulses the telescope will miss when changing directions. This is, of course, compensated by software: When a stellar coordinates are fed to the motors, the motors will rotate the telescope beyound the intended point, then reversed to point to the star. If it was bidirectional, the necessary resolution could have never been reached.

For Astro photography, only the declination gear is involved. It is controlled by software to receive so many pulses per second to cancel earth's rotation. The number of pulses could easily be calculated by dividing the 4,147,200 pulses (calculated at bottom of page 26) by 24 hours (4,147,200 pulses/24x60x60seconds), or 48 encoder pulses per second. As you'll see, the backlash on the motor's encoder disc is 1.5 turns, or 540 pulses, or 0.047 degrees, or 2.81 Arc Minutes.

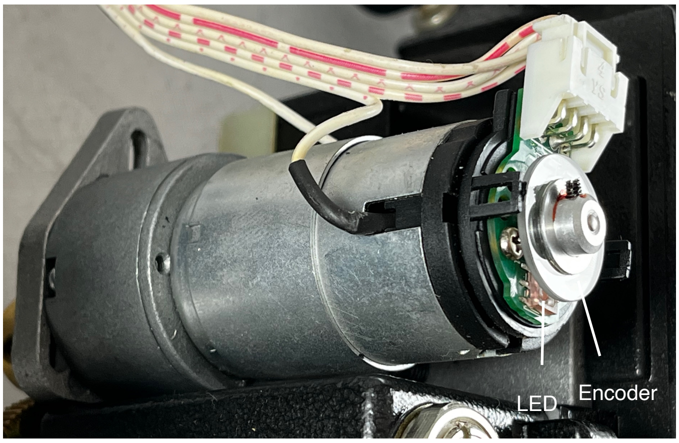
The dovetail mount (left), and north-pole alignment knobs (right). There is a connecting cable called: "Dec Port", that connects the right ascension drive motor with the main electronics control box (right).

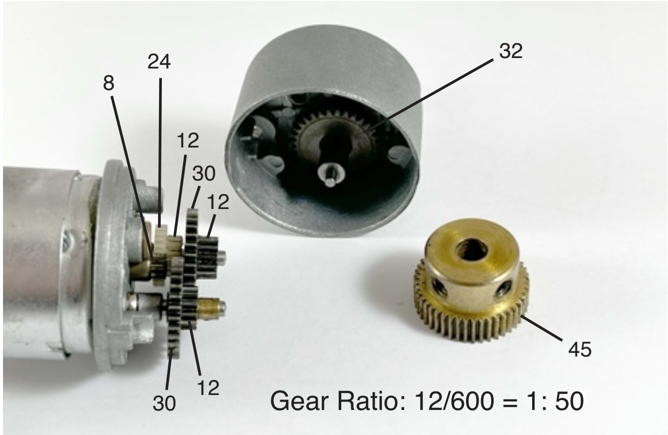


There are two proportional plastic covers: One for the main electronics control box, two for right ascension drrive motor.

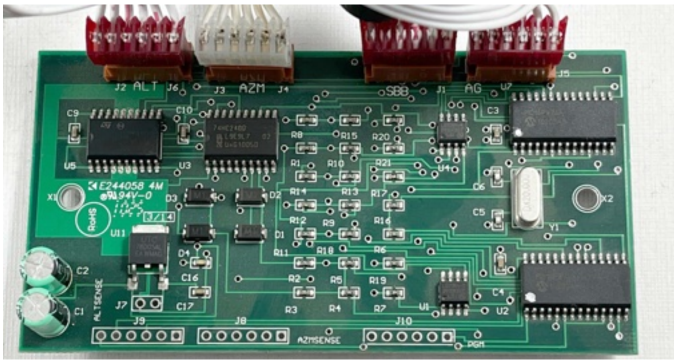


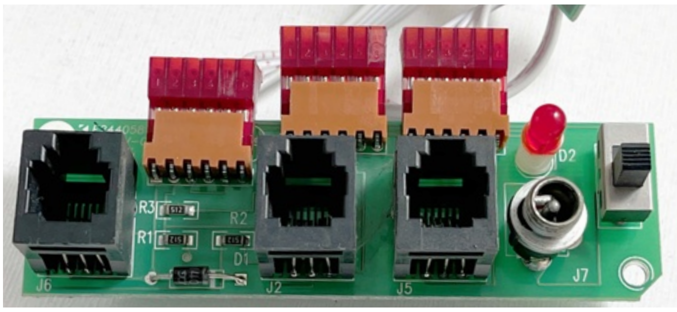
The right ascension drive motor (above) is identical to the later designed ES model (discussed earlier) but with less gear reduction ratio (1/133.33 reduction compared to 1/286.5). The difference is motors in ES utilize large axis gears, whereas in GT, worm gears are utilized. A worm gear drive (arrowed) has much finer control than a regular gear utilized in SE.



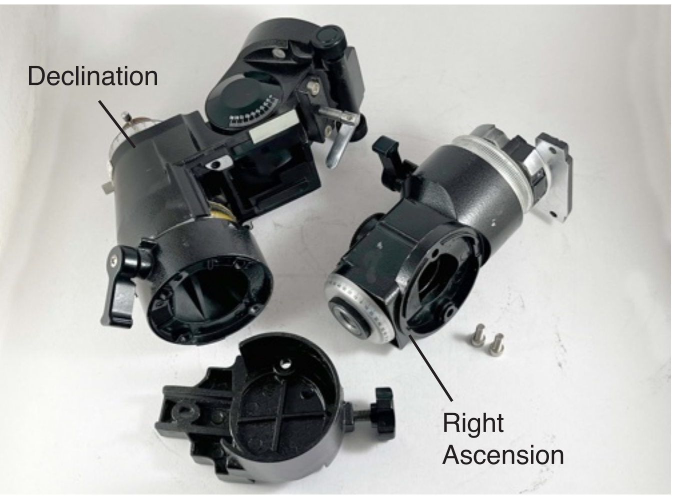


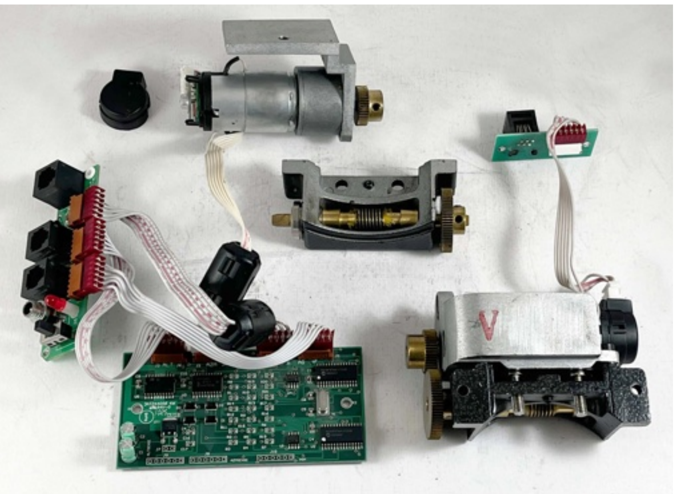
The encoder in GT gernerates 11,520 pulses per degree. The motorzed backlash is 1.5 encoder turns, or 0.047 degrees.

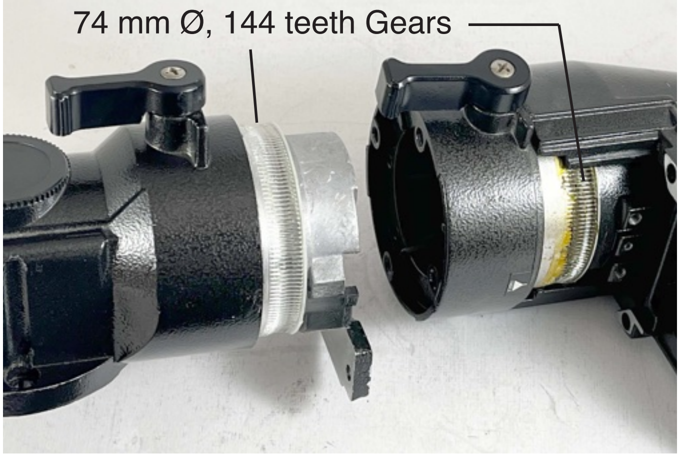




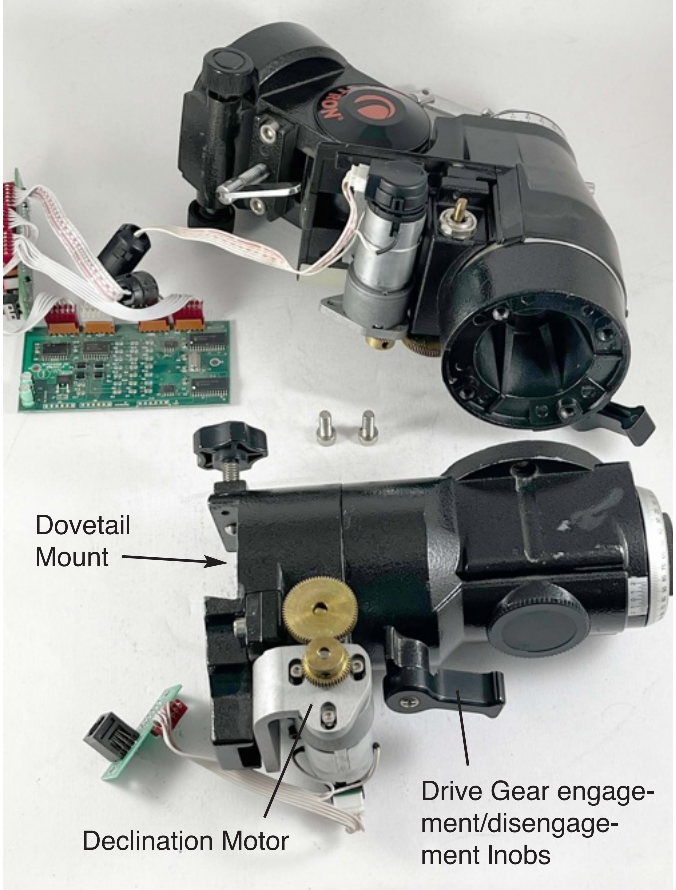
Left, GT utilizes the same processor board as SE (P. 20)

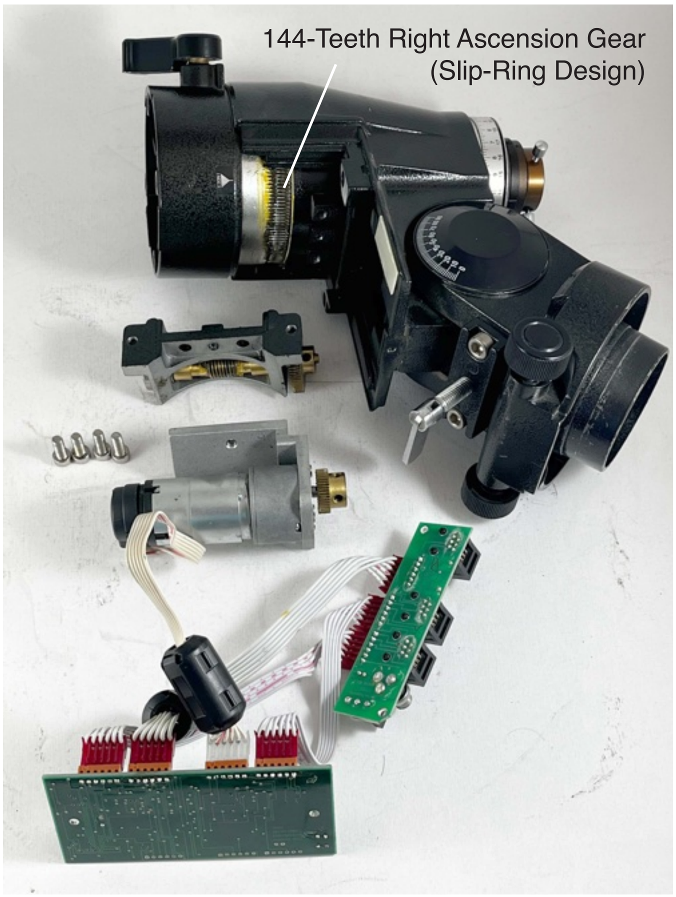


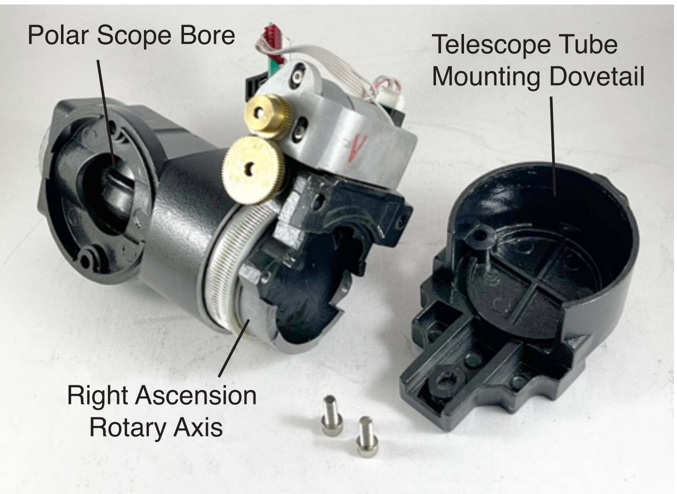


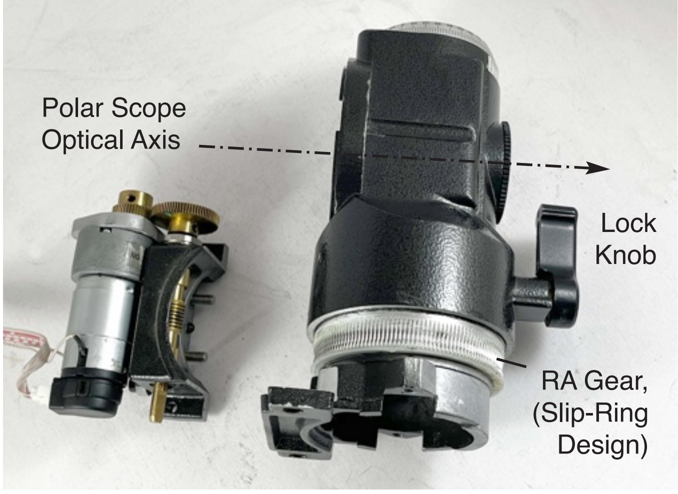


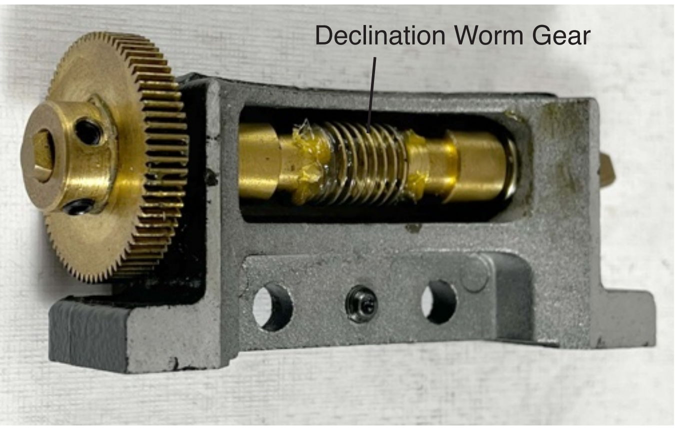
Top/right, calculating the angular resolution of axis by counting the number of pulses the encoder sends to the electronics board is done the same way we did for SE: 8/24x12/30x12/30x12/32x45/72 = 0.0125, divide by 360, we get 28,800 pulses for each rotation of small worm gear. Every full turn of 144-teeth declination gear will generate 4,147,200 pulses. Dividing that by 360 we get 11,520 pulses per each degree, or 0.3125 arcseconds angular resolution per pulse. This is very close resolution to we saw in SE. The gears in GT mount are more robust to accommodate heavier telescope tubes.

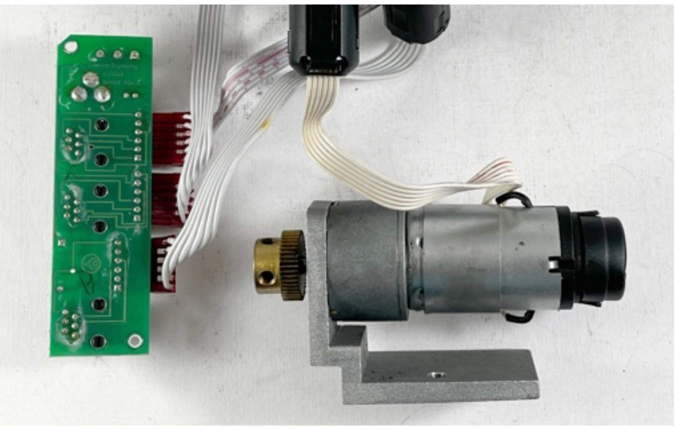












Further disassembly of the drive gear assembly reveals well made Aluminum diecast pieces at its core. The rotary axis utilizes Teflon washers, with ball bearings (page 24). Middle/above: 144-tooth worm gears would slip unless clamped utilizing its lock lever. This is for manualy pointing the telescope tube anywhere, then utilizing worm gears for precise control. The worm gear was eliminated in SE’s gear train to produce a more compact, and easy to carry design.

Testing of Mirror Surface Accuracy

Fig. 1 shows a Michaelson interferometer setup to test a spherical mirror. Newtonian telescope mirrors may not be tested using this method because they are parabolic in shape. Celestron mirrors are not parabolic because it is the job of its front corrective lens to focus the rays to a point. So, if you take out the main mirror from a Celestron, you can't make a Newtonian telescope out of it. So you are basically dealing with a spherical mirror, that could be easily tested as below:

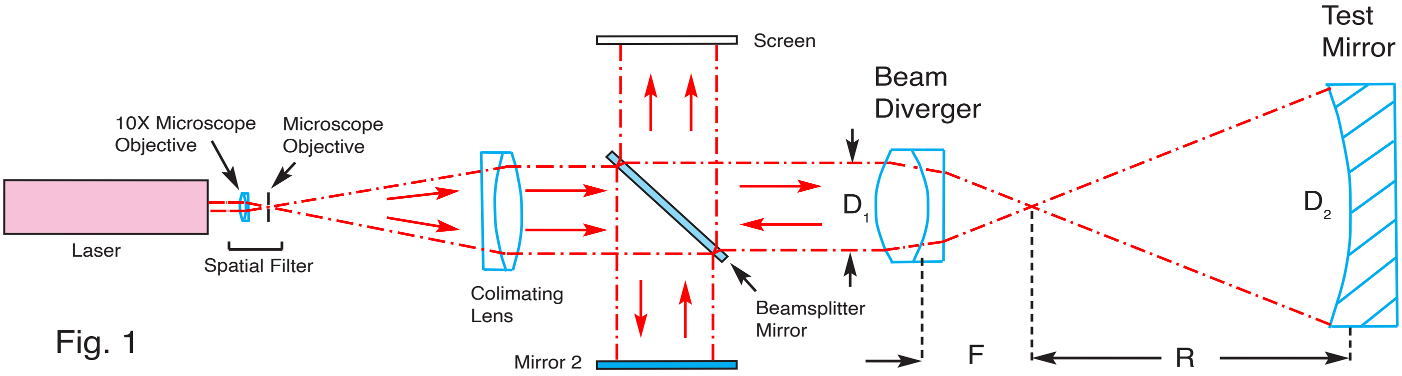


Fig. 1

Interfreometric teting of a large mirror utilizing small optics

Testing a Spherical Mirror

Fig. 2 shows the Michaelson interferometer to test the surface accuracy of a spherical mirror. The flat test mirror in Fig.1 is now replaced with a beam diverger to focus the beam at its focal point F. The beam then diverges out to cover the surface of a spherical mirror. Basically, to cover the entire surface of the test mirror, the f number of the beam diverger F/D_1 should match the f number of the test mirror 2R/D. In this arrangement, we are comparing the curved surface of the spherical mirror with a perfectly flat (1/10 λ or better) reference mirror. I have seen reference mirrors as good as 1/20 wave. I will show you how the wavefront is curved through the beam diverger to match the curvature of the spherical mirror, and how it gets flat again when it goes back through the diverger.

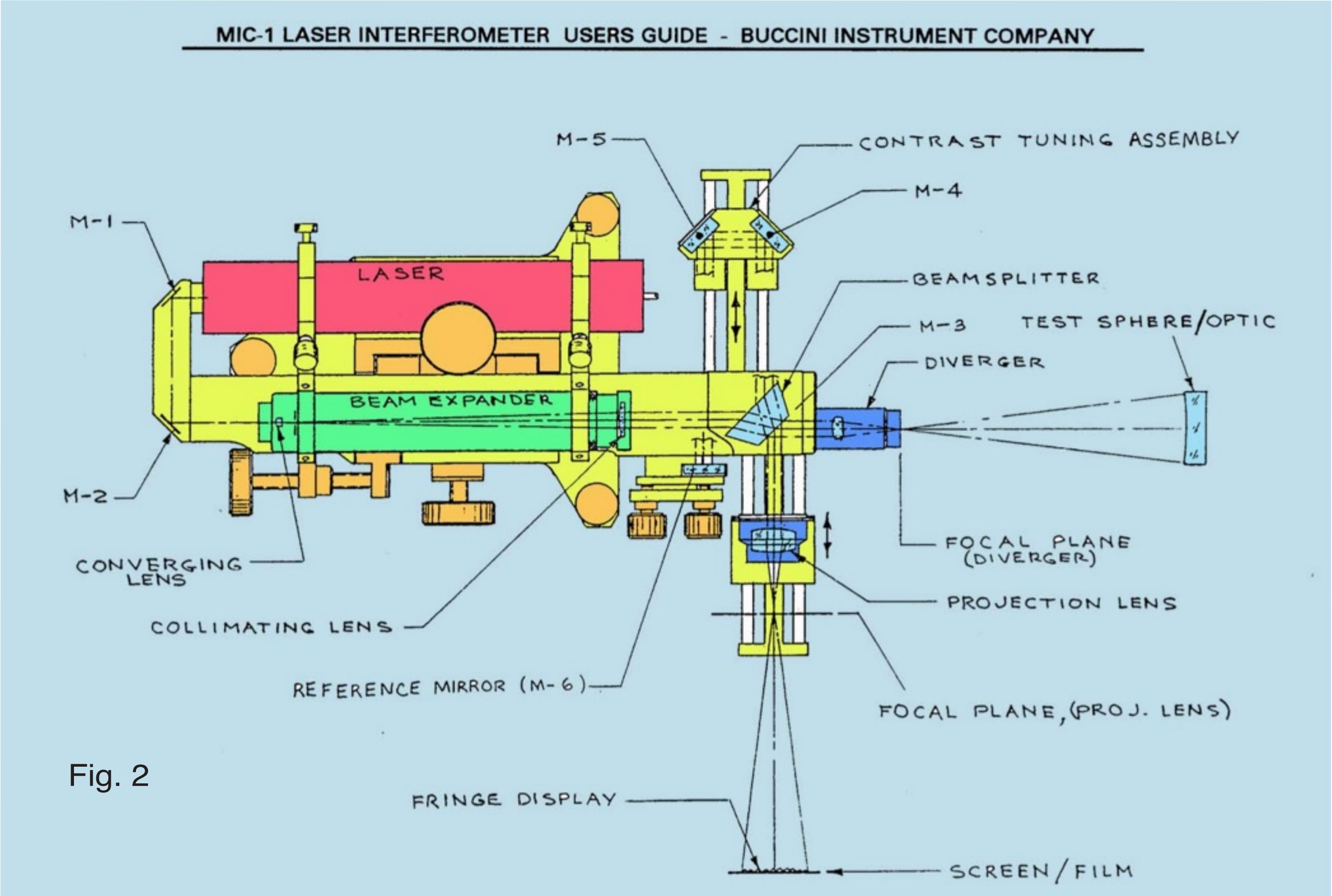
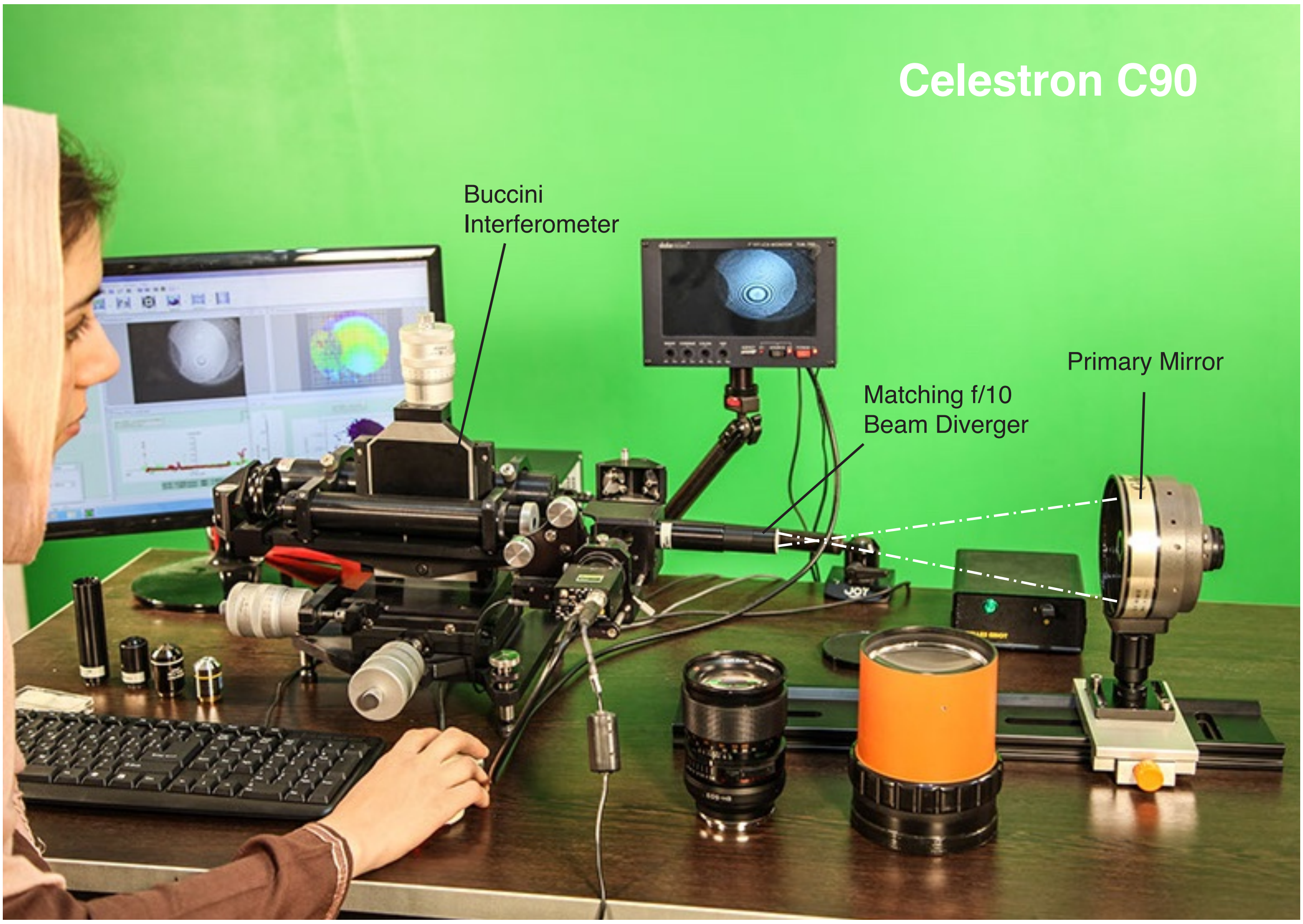


Fig. 2



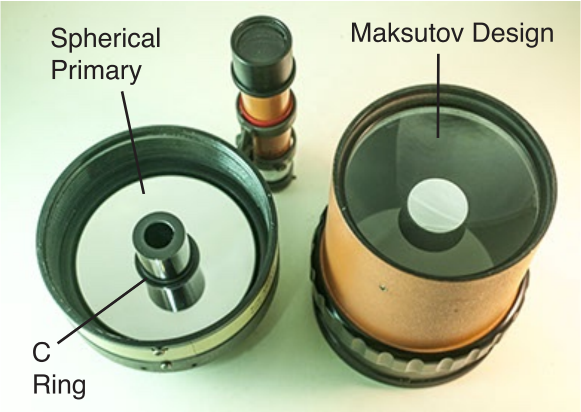
Testing the primary mirror of C9 reveals better than 1/10 wave surface accuracy. The primary mirror in this telescope is spherical, corrected by its Maksutov front lens. In this design, the secondary mirror is at the rear surface of its front lens.

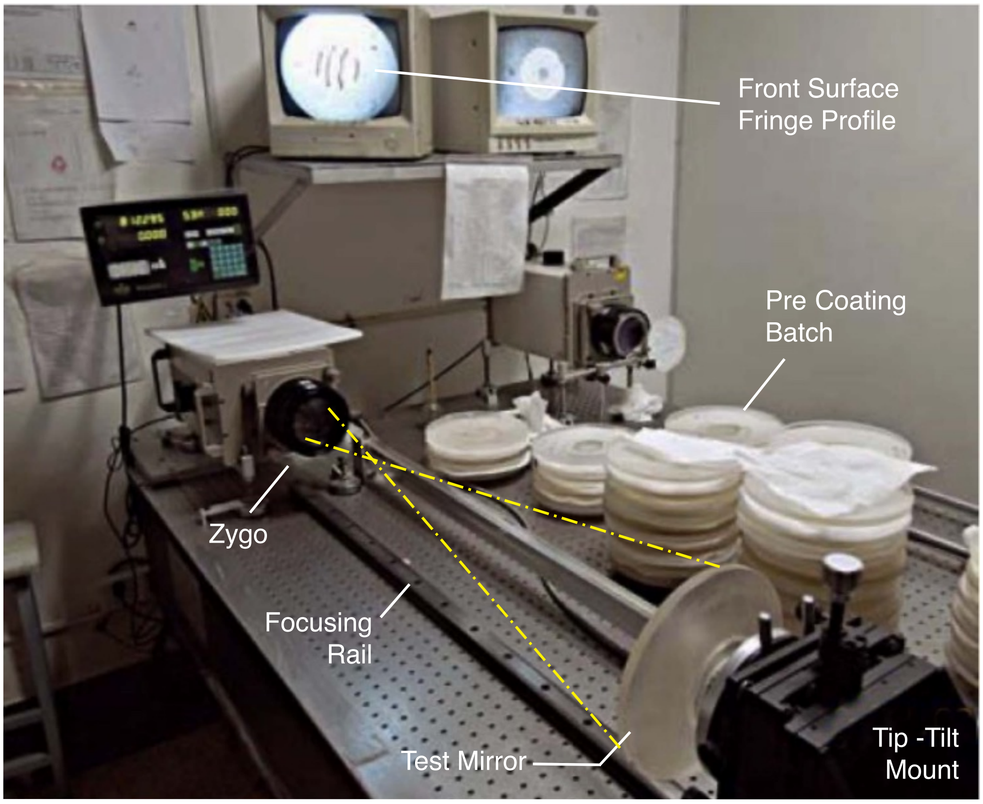
Primary Mirror Testing with an Interferometer

The interferometer (above) is equipped with interchangeable focusing objectives that focus the interferometer beam to a point, then it starts to diverge again to cover the mirror. With f/10 objective, the beam covers the entire mirror surface. By adjusting the interferometer's height, tilt adjustment, and direction of its beam propagation, the focal point of the primary mirror of telescope lines up with the focal point of f/10 objective. With this precise alignment, the interferometer sees telescope's reflection as a flat wavefront, and compares it with its own reference flat for surface accuracy.

C90 is as high quality as it can be for a 90 mm aperture telescope. C90 is so compact, and versatile. Having an effective focal length of 1000 mm at f/11, it can be directly mounted on a full frame 35 mm SLR via a T-mount adapter for 20X magnification. To disassemble this telescope, the tripod mount is first removed, and there is a Phillips screw that limits the front focusing barrel. The focusing barrel could then be removed to test the main mirror via an interferometer (below). The spherical mirror on this telescope shows better than 1/10 wave surface accuracy. C90 is perfect for viewing the craters on the moon, the ring of Saturn, and moons of Jupiter.

C90's front element removed to test its spherical mirror. The 1000 mm F/11 lens may also be utilized as a telephoto lens. The mirror is centrally held by a C-Ring. C90 is one of the most beautifuly designed telescopes.

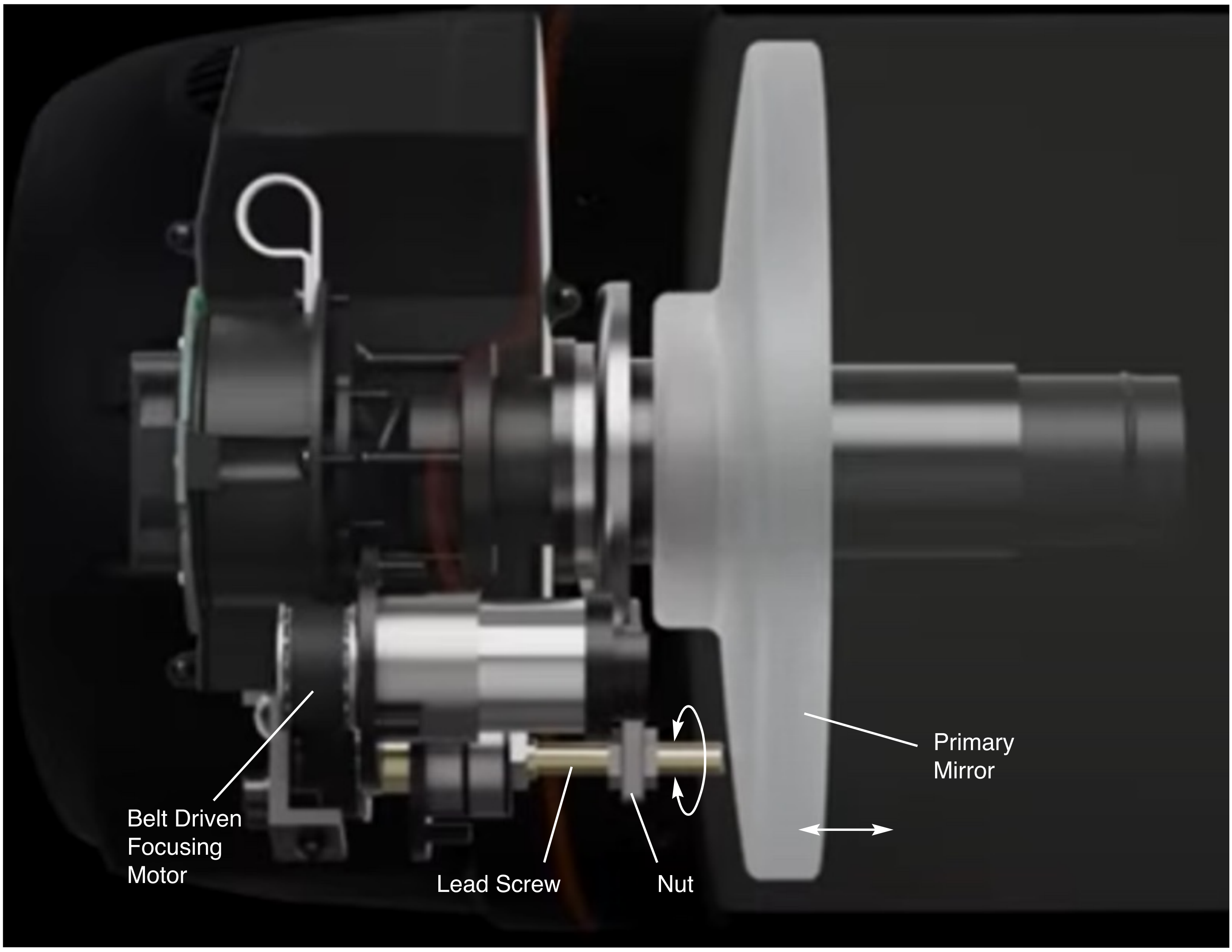




Surface Profile Testing

The interferometer is the greatest tool for spherical mirror testing. Celestron mirrors in general are spherical because correcting the spherical aberrations is the job of the corrective optics. Therefore, standard interferometers without a null corrector may be utilized to test most Celestron mirrors.

Shown is a Zygo interferometer to evaluate the surface accuracy of a batch of fabricated mirrors on top of an optical table. To secure the test mirror, elaborate tip/tilt mount is needed to send back Zygo's laser wavefront directly back at its source.



Mirror focus design in Celestron with optional motorized focus

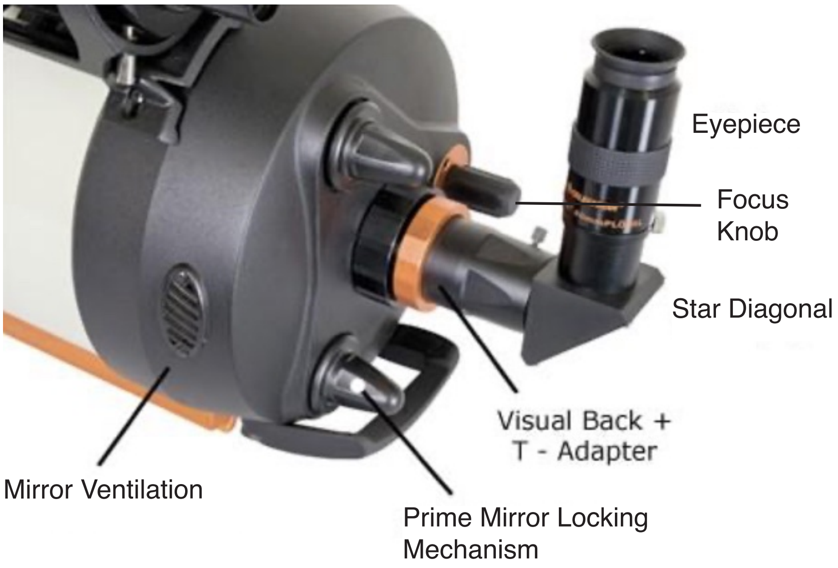
The Focusing Assembly

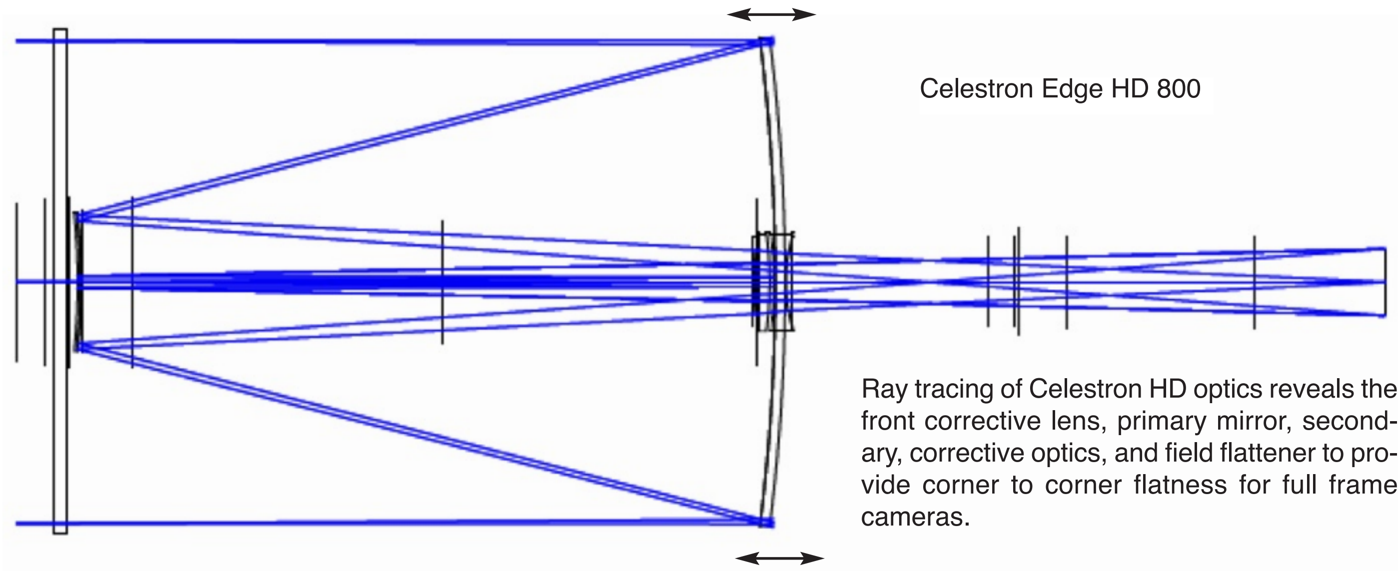
The focusing mechanism in Celestron has a unique design. Instead of the eyepiece having a focusing barrel, the primary mirror is translated back and forth instead. The goal of the designer must have been to provide the camera a rigid/stationary platform. The result is a sealed telescope tube with front and back covered, and the convivence of Schmidt Cassegrain design.

Not all Celestron telescopes are Schmidt Cassegrain, of course. Some models, like the StarBright XLT 10 that I tested, has a planar front glass just for securing the secondary mirror. These models also have a mirror locking mechanism for the primary mirror. The locking knobs reduce focus drift inherent with its primary mirror focusing design, so image degradation during long exposures is reduced.

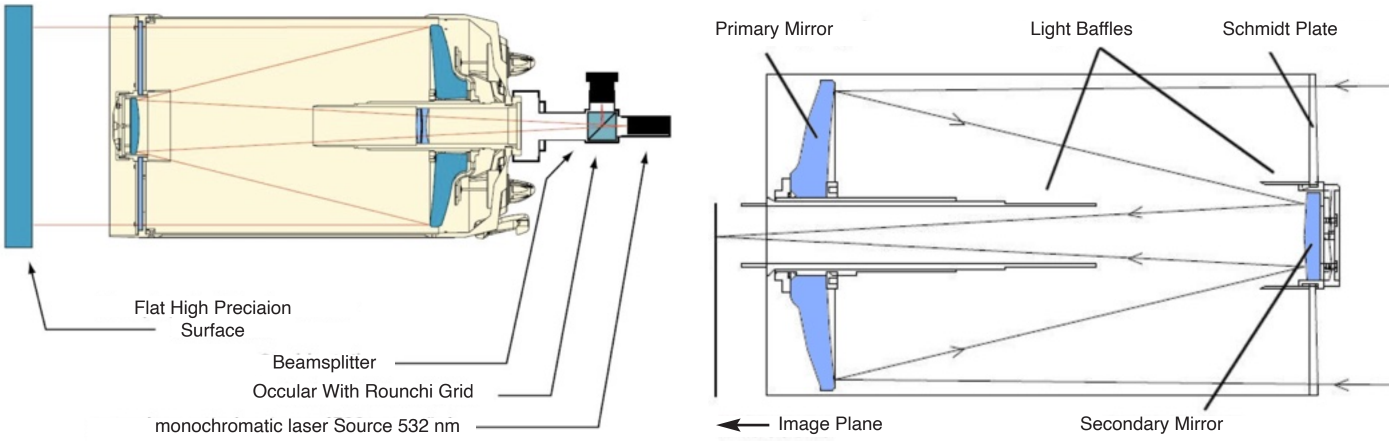
EdgeHD (below) is an advanced, flat-field, aplanatic optical design for visual observing and imaging with astronomical CCD cameras and full-frame digital SLR cameras. EdgeHD offers clean, diffraction-limited images for high power observation of the planets and the Moon.

As an aplanatic, flat-field astrograph, EdgeHD's optics provide tight, round star images all the way to the edges of a wide, 42mm diameter flat field of view for stunning color, monochrome, and narrow-band imaging of deep sky objects. Typical focal ratio is f/10 to f/11.

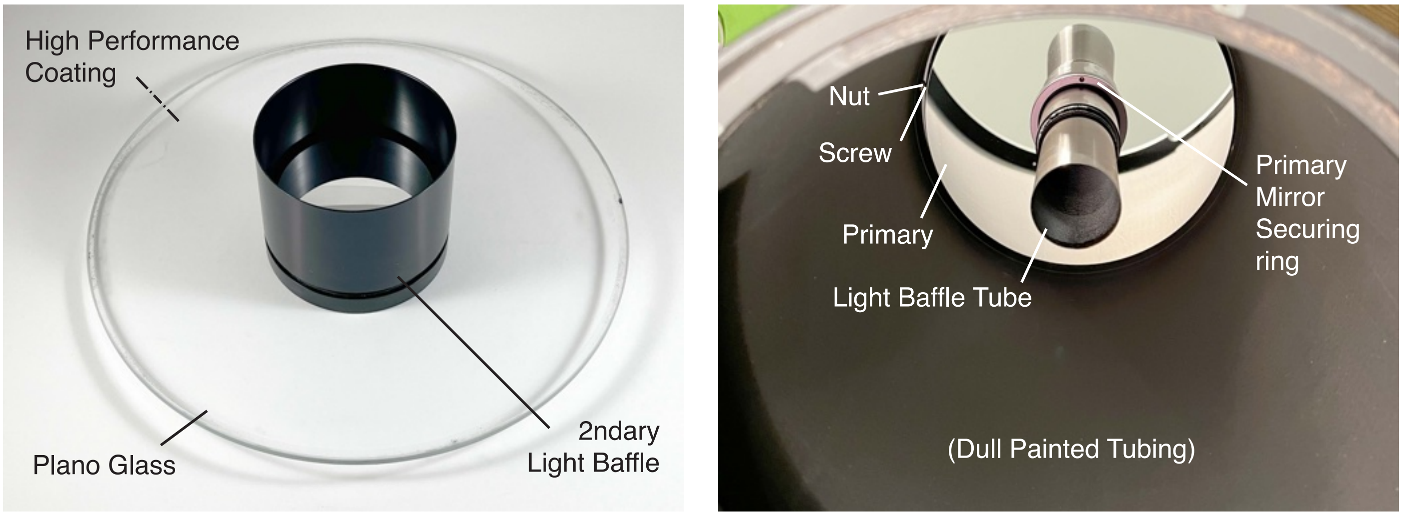




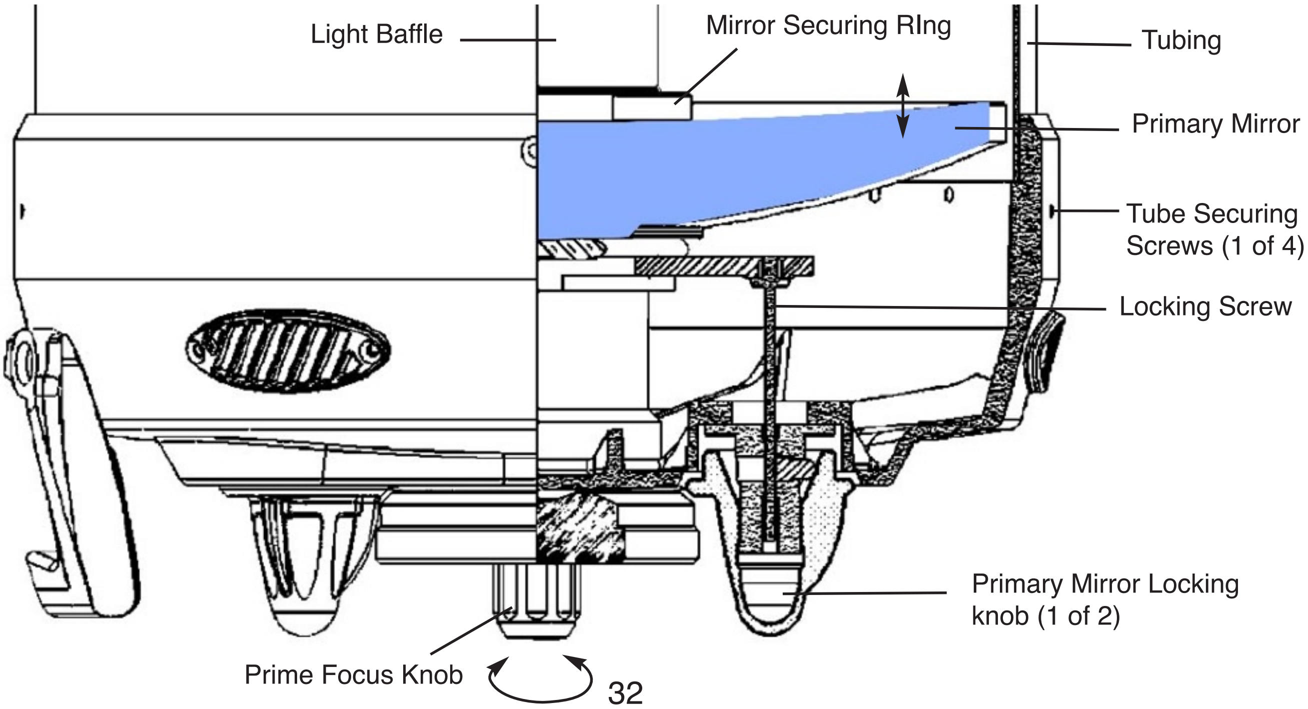
Ray tracing of Celestron HD optics reveals the front corrective lens, primary mirror, secondary, corrective optics, and field flattener to provide corner to corner flatness for full frame cameras.

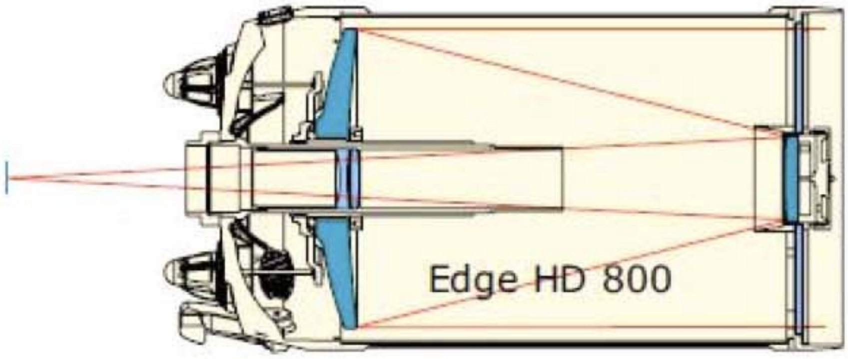


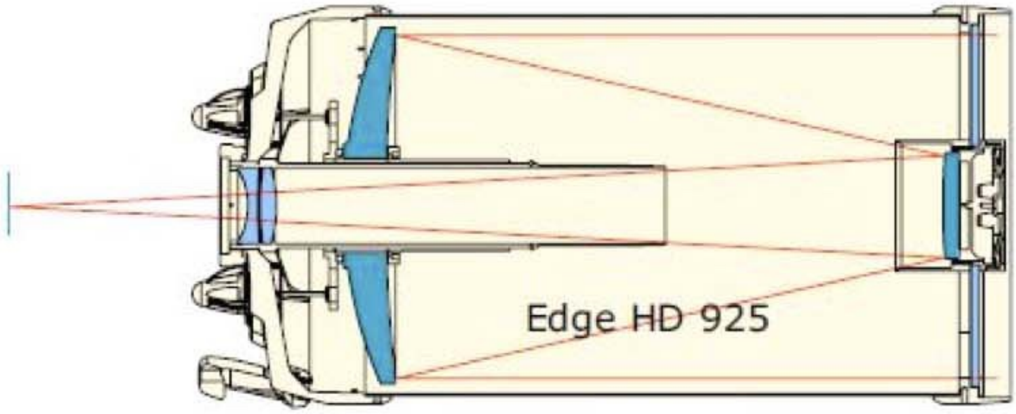
Left, alignment of telescop optics utilizing an autocollimator. A flat mirror is placed infront of the telescope to reflect back collimator's reticule, attached in place of the eyepiece. Right, the role of light baffles inside the telescope is displayed.

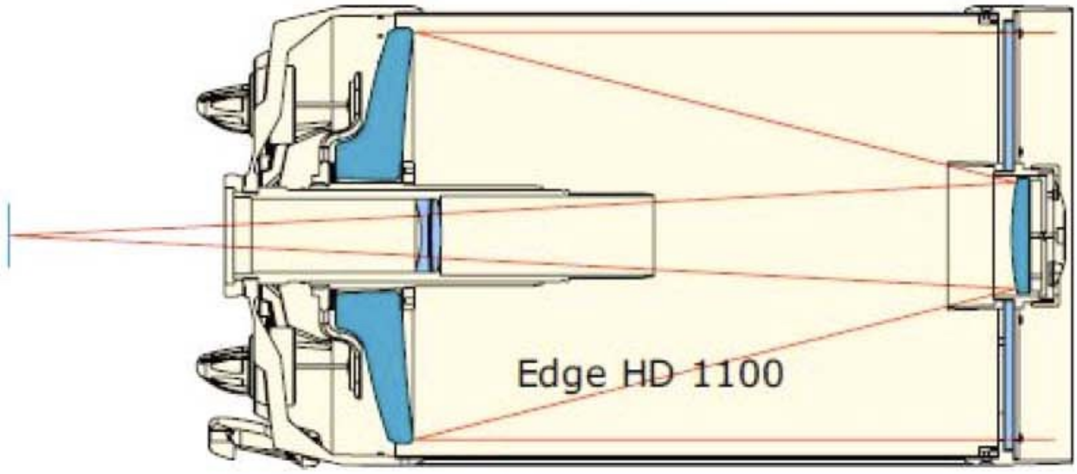


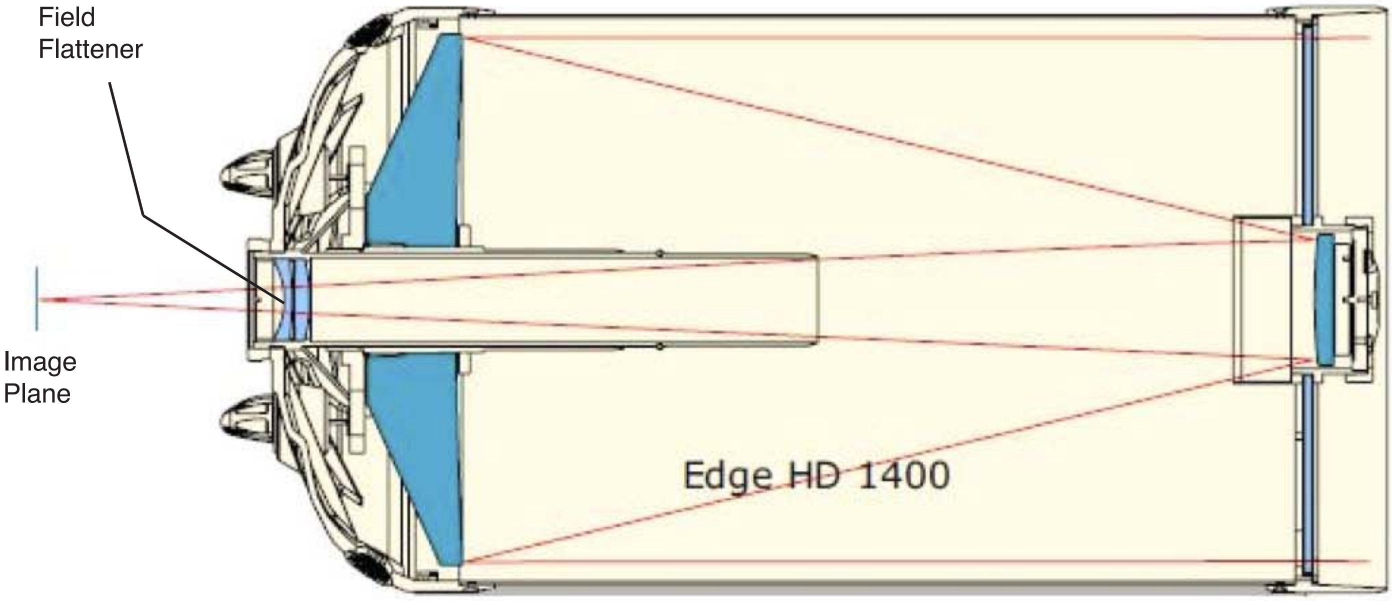
Show is the front glass, and secondary Mirror (left), and primary mirror (right) of Celestron StarBright XLT 10 with composite tubing. Do not try to disassemble a Celestron mirror. The housing is designed to be difficult to open without special tooling. To remove the main mirror, for example, four tube securing screws must first be removed. The knots, and bolts can only be tightened with the primary mirror first removed. This is because there is less than 1/4" clearance around the mirror to reach the bolts (above, right). This design requires the main tubing be assembled first, then the mirror installed, and secured in place via a specially made tubular spanner wrench. Ordinary spanner wrenches won't do the job.




Edge HD 800


Edge HD 925

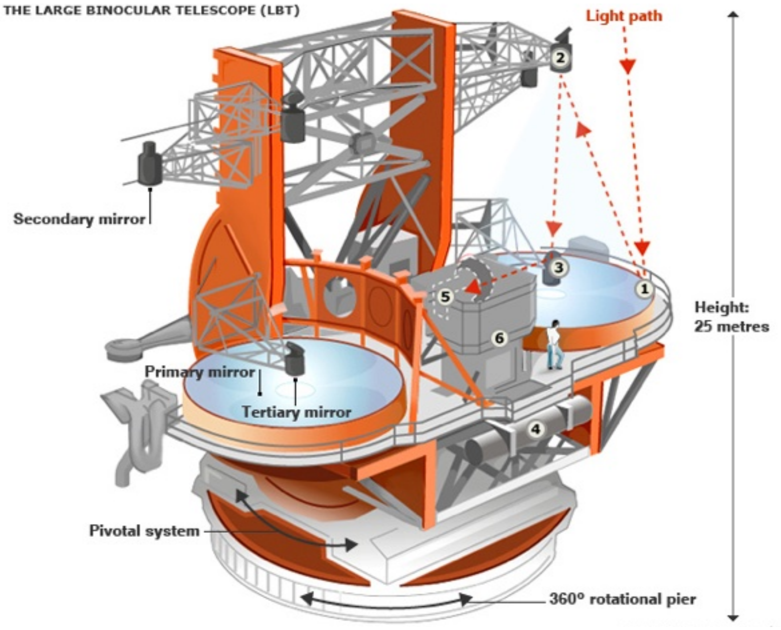

Edge HD 1100

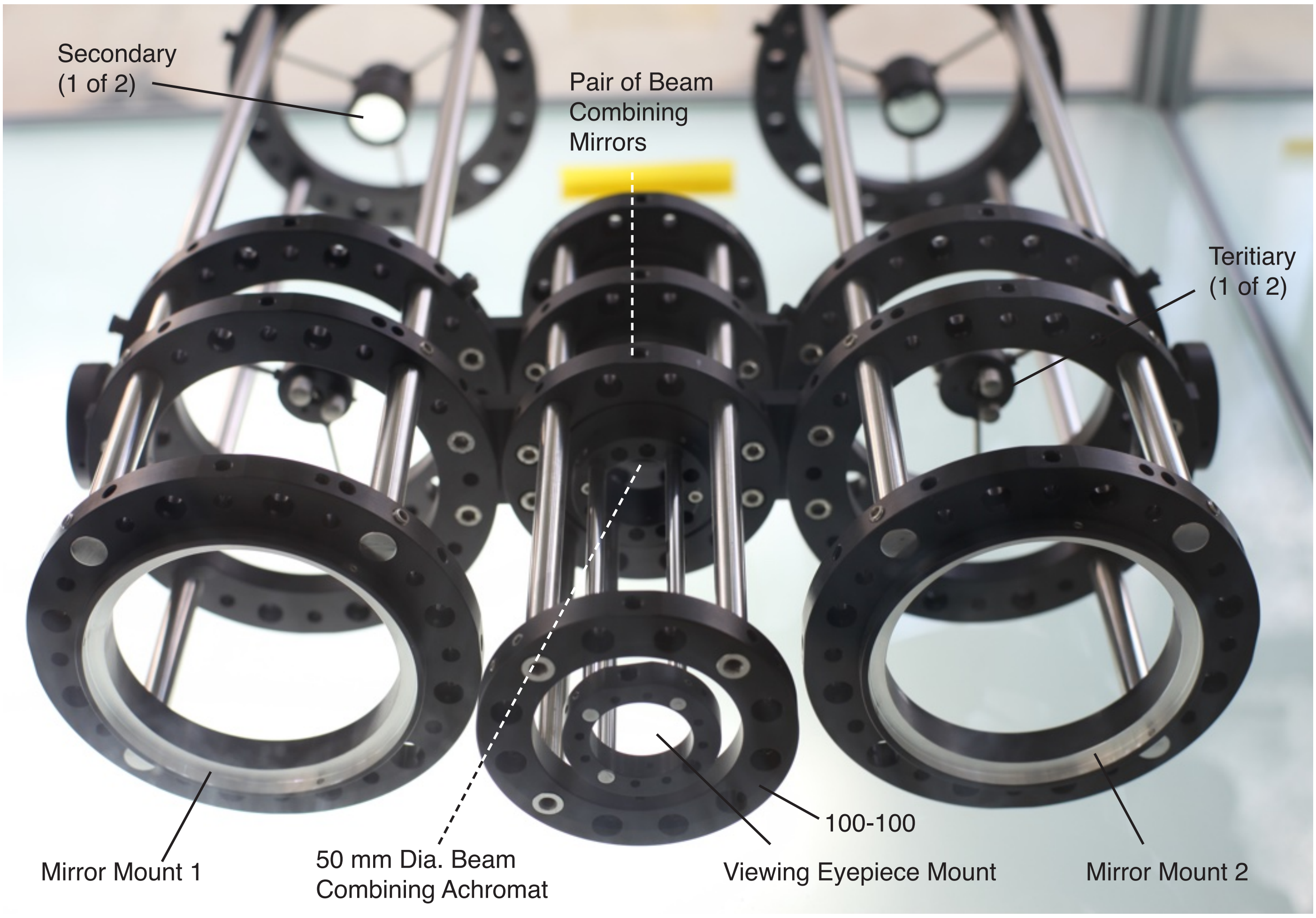

Field Flattener
Image Plane
Edge HD 1400

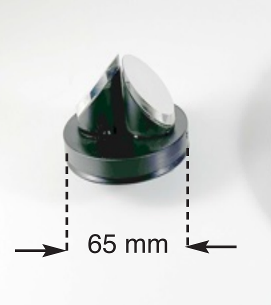
Large Binocular Telescope (LBT)

Schematic representation of the optical layout of the Large Binocular Telescope. The diameter of the two identical primary mirrors is 8.4 meters and their linear separation (center to center) amounts to 14.4 meters. For interferometric observations the incoming light of the two optical paths (right) is reflected horizontally at the tertiary mirror (located slightly above the primary mirrors) towards the central platform of the telescope. The two beams are combined to produce a single image. Various secondary, tertiary mirrors swing in and out to achieve different light paths.

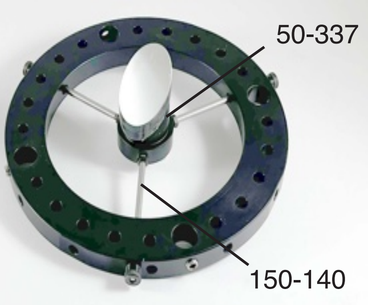
To better understand this design, a working model of LBT is built utilizing Optoform mounts ranging from 150 mm in diameter to 30 mm (below). Some of the individual parts to build the model are shown at the bottom:



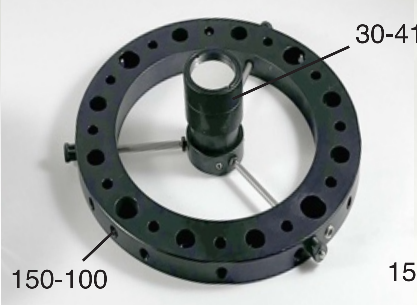




Pair of Beam Combining Mirrors



Teritiary (1 of 2)



Secondary (1 of 2)

110 mm Mounted Mirror (1 of 2)

Hasselblad Design

In classic cameras, one of the most outstanding designs is that of the Hasselblad. Its body design is comparable to Rolex: not entirely uncluttered, yet unmistakably minimalist in its discipline and purpose. The Hasselblad is essentially a mirror box with a lens mounted on the front, a focusing screen and interchangeable viewfinders on top, and a detachable film magazine at the rear. The base allows for attachment of a hand grip or tripod, while the right side accommodates various shutter-cocking, and film winding controls. Both the lens and the film magazine possess their own independent internal mechanisms, yet when mounted to the main body, they operate in perfect harmony as a single system. In a previous issue (Oct–Dec 2023), I explored the internal workings of this camera; in this issue, I will focus on its bodydesign.

I was a student at National Camera before it closed down — the only camera repair training school in America at the time, located in Denver, Colorado. My instructors had high hopes for me because on the very first day I presented a camera I had designed and built using my small Unimat lathe and milling machine. The president of the school was Dennis Wack, and I visited his office many times, as I never quite fit into the standard classroom environment. Among my teachers were Jim Henkchin, Jim Gerrits, and another instructor named Keith, who was confined to a wheelchair.

Hasselblad 500 C/M

Hasselblad SWC

Hasselblad 500 ELX

Hasselblad 500 ELX

My true passion lay in design rather than repair. Nevertheless, I graduated and worked as a camera technician for several years. Since there were no American companies designing and manufacturing cameras, I began learning Japanese. Although I never traveled to Japan, after inventing Optoform and founding my own company, I conducted business with Japanese firms. The principles I learned from cameras later revealed themselves in the design of many other optical instruments.

There is no formal “school” for camera design. One learns through observation, experimentation, and practice. I have written several books on camera design, and through studying both internal mechanisms and external forms, I came to understand that the inner workings of a camera always dictate its outward appearance.
The SLR (single-lens reflex) remains my favorite design. When Yoshihisa Maitani began designing cameras for Olympus, he revolutionized their appearance by reorganizing their internal architecture. Today, camera design is far less constrained, as digital displays have replaced reflex mirrors, and many mechanical limitations — including interfaces with interchangeable lenses — are now fully electronic.

Victor Hasselblad holdig the first mockup of his camera made of wood. He asked his design team to built it to this size.

As Victor Hasselblad once stated in an interview with Swedish television, he was not a technical man but knew precisely what he wanted. His first prototype was constructed from wood. He then handed it to his design team to refine. The final version emerged larger than the original, yet its essential functionality was preserved. The magazines, advance knobs, viewfinders, focusing screens, and lenses were all interchangeable — a hallmark of the Hasselblad system.

Overseeing the design of ELM camera (left). Right, the design drawing shows mirror mechanism, and battery housing.

In the wooden prototype, the rear edge of the film magazine was horizontally curved, whereas in the final production model it became vertically curved. The camera body is effectively sliced in half to allow detachment of the film magazine, with a gently curved rear and a nearly flat front to support the lens assembly. The outer form follows the logic of its internal mechanics — yet the question remains: how did it become so aesthetically beautiful?

The answer lies in its balance of reliability, versatility, and precision — enhanced further by its exceptional Carl Zeiss lenses. The body design was crafted by Sixten Sason, the same industrial designer responsible for the iconic Saab automobiles. It was rare for camera manufacturers to commission external industrial designers, making this collaboration

Since then ..

Hasselblad H4D-50

Hasselblad Lunar

all the more significant. The result was a machine so dependable and refined that it accompanied Apollo 11 to document humanity’s first steps on the moon.

With the rise of the digital age, classic Hasselblads gradually found their way into collectors’ hands. The company later introduced new models, including the controversial Lunar — essentially a rebadged Sony camera with a wooden grip. Its excessive price and lack of originality displeased many loyal Hasselblad enthusiasts. Since then, the company has returned to its roots, embracing its original design philosophy and regaining its place as a premier choice among professional medium-format photographers.

Hasselblad X2D

Anniversary model 907X-AE

Hasselblad CFV II

...to be continued.

God’s hope

By Ali Afshari

As I mentioned in my last article, God is silent about the current world situation for a reason. I previously discussed the Enneagram (Oct–Dec 2020) and suggested that perhaps the most influential personality type is Type 3 — the Achiever — like our illustrious president, Donald Trump. This type is opportunistic and is often willing to distort the truth to reach personal goals. Many politicians fall into this category. However, I have also encountered people who climbed the same ladder not to dominate others, but to uplift the meek rather than serve their own self-interest. When you look into their eyes, you realize you have been keeping the wrong company.

Bertrand Russell, when asked why Communism failed, stated that despite Marx’s desire to improve workers’ living conditions, his philosophy was rooted in hatred toward capitalism and aristocracy. In Islam, although social equality and justice are highly emphasized, it discourages harboring resentment against the wealthy. Instead of advocating revenge against aristocracy — as seen in the Chinese, French, and Russian revolutions — Islam teaches education, reform, and moral dominance over persecution and vengeance.

If you study the greatest social influencers in history, many did not emerge from poverty. They often came from aristocratic backgrounds and rose against the injustices of their own systems. They first liberated themselves from the corruption that accompanied power, then became advocates for social equality and justice. They became, in a sense, God’s hope on Earth. Examples include Che Guevara and Salvador Allende in Central America, Emiliano Zapata in Mexico, Gandhi in India, Ali La Pointe in Algeria, Mohamed Mossadegh in Iran, and Malcolm X, and Dr. King. We know them as leaders of liberation, but where did they come from? Which class did they belong to? One thing is certain: they were among the most intelligent, determined, and ambitious figures of their time.

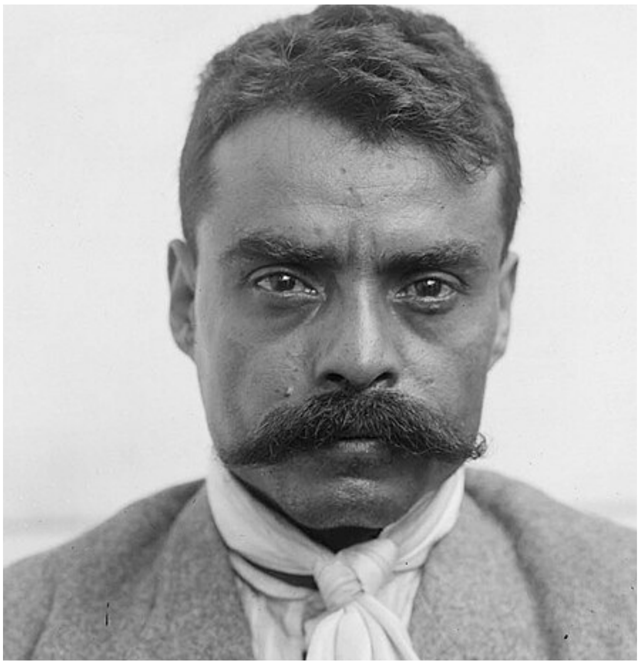
Reflect on your own circle of friends. Who among them do you think will be most influential in our lifetime? Many of my friends are among the smartest, richest, or most talented in their fields, and their desire is to improve the world around them. But what happens when someone powerful is arrogant and even criminal? Why would they change? How does God transform such individuals? The first requirement is independent thought rather than blind obedience. This was evident in the case of Eichmann, who was responsible for the murder of Jews.

Maslow’s hierarchy of needs addresses this transformation. I have seen it many times: people who were ruthless in their youth, obsessed with wealth, change after the age of 50 or 60. Reality eventually confronts them with a question: Is there more to life than material gain? This is human nature. Buddha, born into wealth, chose hardship to find truth. Gandhi chose suffering to serve humanity. This path demands a strong soul and a powerful will.

The story of Ali La Pointe is equally striking. Like Malcolm X, he was a thief and pimp, but he transformed after encountering the Algerian freedom movement in prison. He joined the FLN and became a revolutionary leader, ultimately dying as a mar-

Richard Attenborough with Ben Kingsly playing Gandhi

Che Guevara (1928-1967) of central America



Emiliano Zapata (1879-1919) of Mexico

tyr. The film “The Battle of Algiers” directed by Gillo Pontecorvo vividly documents his tranformation in the Algerian revolution. Salvador Allende of Chile was also such a hope.

As much as there is ugliness and evil in the world, there is an equal need for greatness to restrain it. Truth holds immense power, but it requires extraordinary individuals to deliver it to the masses. When Richard Attenborough directed Gandhi, he portrayed him as a figure capable of humbling the British Empire. A memorable scene shows Gandhi walking barefoot to meet the British ambassador, his face illuminated with peace. The eyes are windows to the soul. We are in need of such greatness more than ever.

In the early part of Rumi’s Masnavi, the story begins with a king who falls in love with a slave girl. His physicians fail to cure her illness, so he turns to God. In a dream, he is told that a healer will come. When the healer arrives, the king sees light upon his face. The healer discovers that the girl’s illness stems from her love for a jeweler from her past. Her cure was to reunite her with him. The tale ends tragically, and the girl ultimately returns to the king. This story illustrates how spiritual encounters transform destinies.

When Prophet Moses was sent to Pharaoh, God instructed him to speak gently, perhaps he might listen. The Persian verse — “Since colorless was enslaved by color, Moses entered a war with Moses” — reflects this encounter. In Islamic history, a similar encounter occurred between Imam Hossein (grand son of prophet Mohamed), who was an advocate of free elections, and Hur, a general in Yazid’s army. This was the battle of Karbla between Yazid’s well armed forces of nearly 10,000 against Imam Hossein’s 72, in year 681 CE. On that day, Hur ultimately lowered his flag and joined Imam Hossein’s army, becoming the first martyr. This is the transformative power of truth when it reaches a receptive heart.

Many who watched Dances with Wolves may not have realized the meeting between the army lieutenant and the Native American holy man was such a transformative encounter. It changed him entirely. We lack such guiding figures in our lives today. Robert Bly’s documentary “A Gathering of Men,” by Bill Moyers, conveyed this same message: we lack great men who profoundly influence our souls.

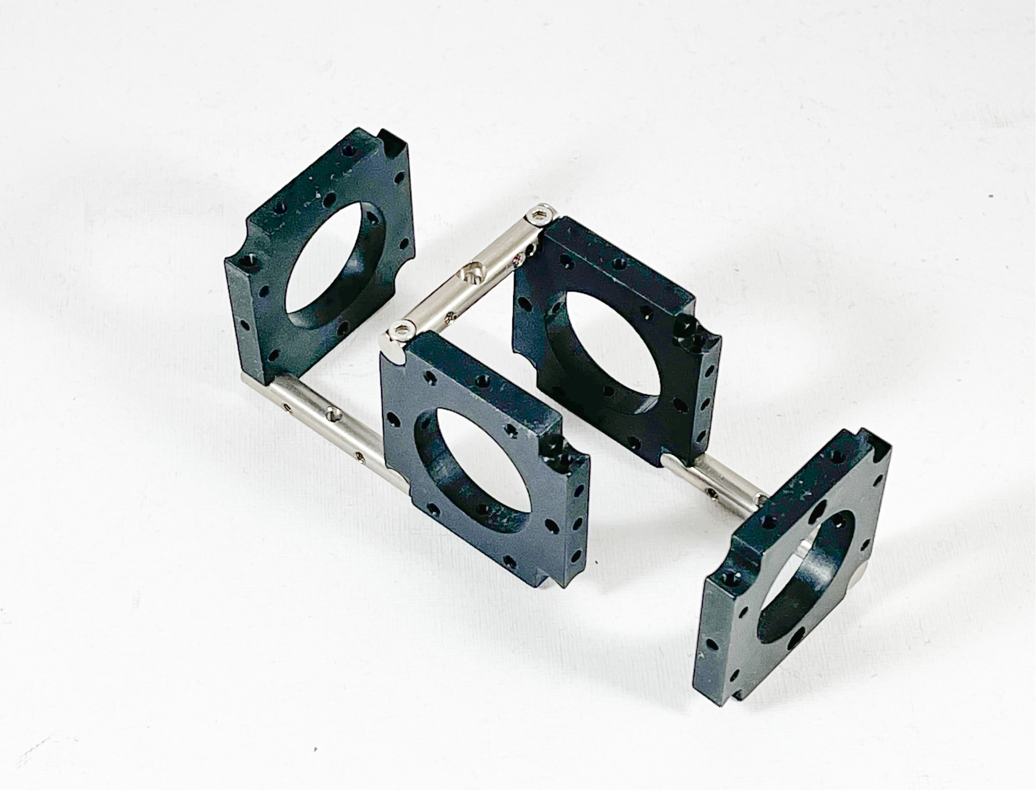
New York City mayor-elect Zohran Mamdani’s history of public service, and genuine smile carried him a long way toward being elected. He used his friendliness again, turning the meeting he had requested with Donald Trump into an Oval Office lovefest. Princess Diana was such a voice within the aristocracy — a beacon of compassion. As Elton John sang at her funeral, “You lived your life like a candle in the wind.”

In conclusion, faith, and truthfulness is more powerful than weapons. It often seems that the more human lives are lost in challenging inequality, and injustice; the more things stay the same. For the powerless, school of no-fight seems to be the most effective. It’s like not purchasing Zionist backed products, and peaceful protest. Prophet Mohamed’s wars were never for expansion of Islam through force; they were all defensive. Desmond Tutu and Nelson Mandela showed us good examples of that. They elevated humanity through their integrity and remained loyal to it until the end.

Ali_La_Pointe 1930-1957 of Algeria (Ali Lapuan)

Dezmond Tutu with Mandela of South Africa

Lady Dianna (1961-1997) of Britain



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