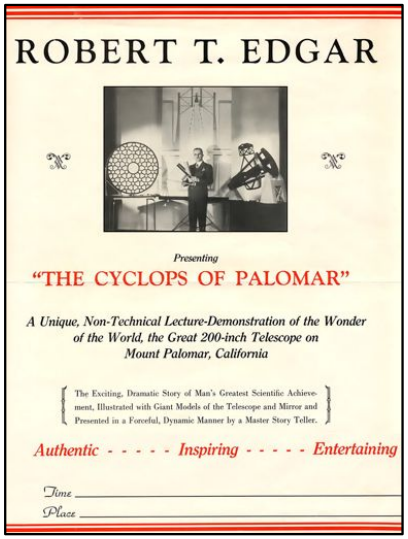


Cyclops of Palomar

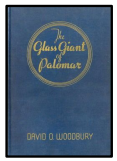
Wonder of the World …

The Exciting, Dramatic Story of Man's Greatest Scientific Achievement …

Presented in a Forceful, Dynamic Manner by a Master Story Teller.

2

" Barometer up and humidity down.
One of those crystal-clear nights
when the stars fairly crackle — "



Glass Giant of Palomar
David Woodbury 1939

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3

Horsehead Nebula

1951

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4

Contents

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5

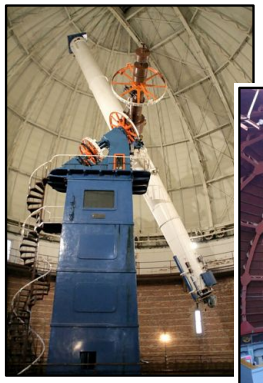
George Ellery Hale

George Hale (1868-1938) had a remarkable life.

His contributions to solar spectroscopy, such as his invention of the spectro-helioscope that imaged the Sun at different wave-lengths, were surpassed by his vision and drive to design and construct the largest telescopes in the world.

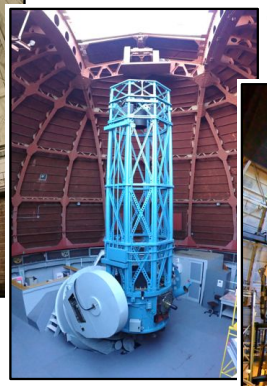
6

Largest Telescopes in the World



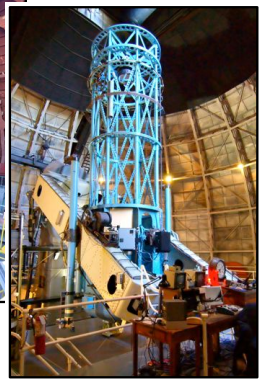
40" refractor 1900
Yerkes Observatory

Mount Wilson Observatory



60" reflector 1908

100" Hooker 1918



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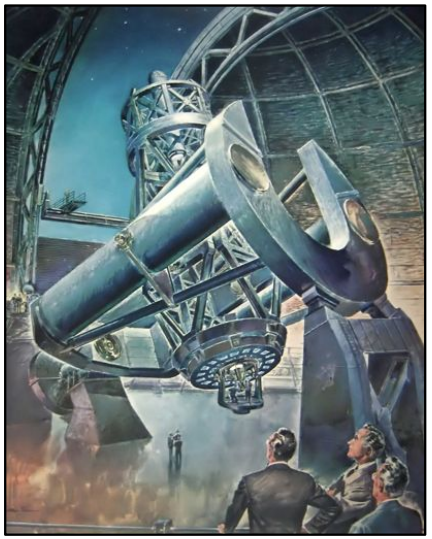


Birth of the 200"

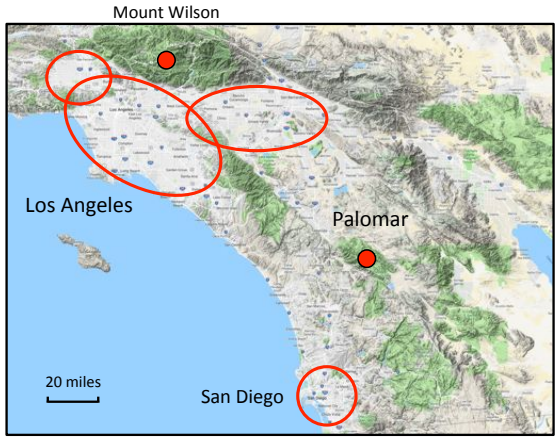
The 100" Hooker telescope was operational in 1918.

Hale now thought bigger... **More light!**

In 1928 he approached the Rockefeller Foundation and persuaded them to pledge $6 million to build the 200" telescope and observatory.

8

Selecting a Site for the 200"



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9

Palomar Mountain

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10

Altitude 1700m

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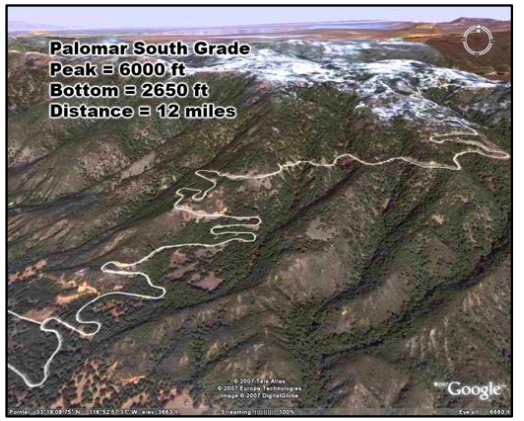
11

Palomar South Grade



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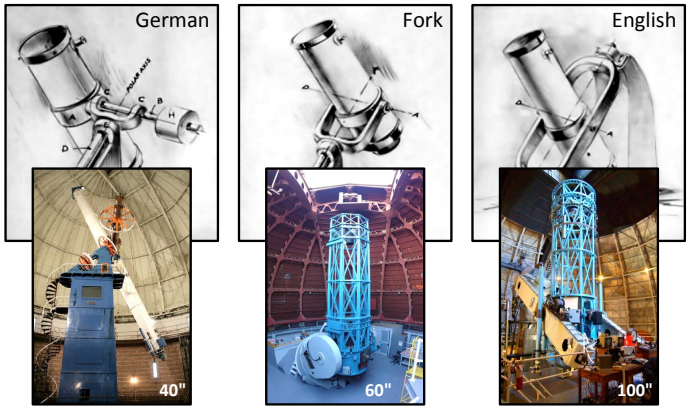
Telescope Mounts



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13

100" Hooker

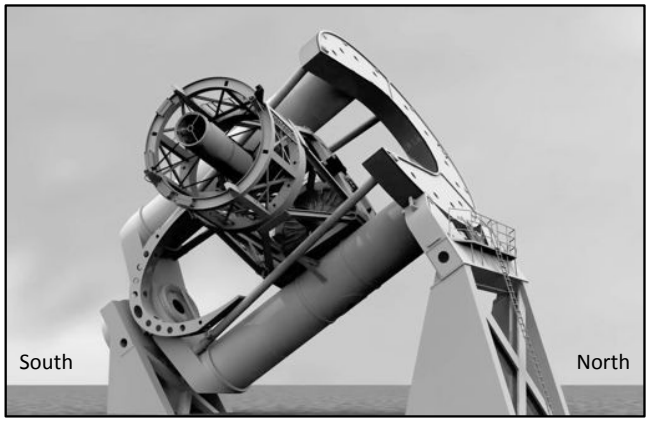
Hale did not want the 200" telescope to suffer from the same limitations as the 100" Hooker telescope.

The English (yoke) mount meant that no observations could be made within 30° of the north celestial pole.

More importantly, the plate glass mirror expanded and contracted with changing temperatures, distorting the mirror surface.

14

Horseshoe Yoke Mount



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100" Mirror

Can the 100" mirror be scaled up to make a 200" mirror?

Using plate glass would result in the same distortions with changing temperature, so Hale decided on the use of low-expansion glass.

To avoid having a mirror 8 times heavier, it would need to be made with innovative glass-pouring techniques.

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Making a Mirror

An empty mould results in a slab of glass that is roughly flat on its top and bottom surfaces.

After cooling to room temperature the glass slab can be ground down to make a curved surface and then coated with a thin layer of aluminium.

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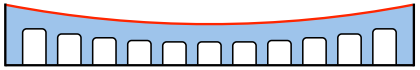
17

Making a Ribbed Mirror

If the mould is first filled with 'cores' made of fire bricks then the glass flows around them.



When the mirror has cooled the cores are removed.

The result is mirror with a front surface as before but now with a ribbed back, making it lighter and stronger.

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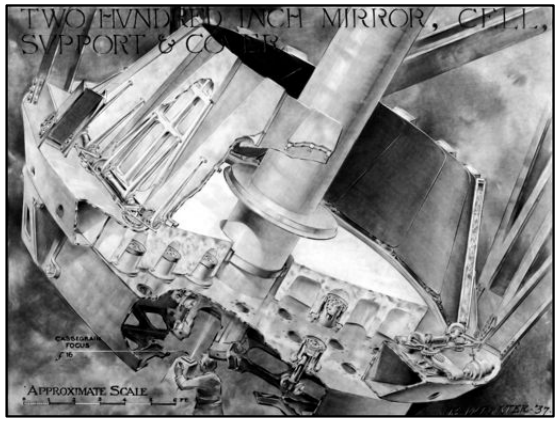
Mirror Section



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Russell Porter 1937

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Mirror Mould

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Casting the Mirror

1934

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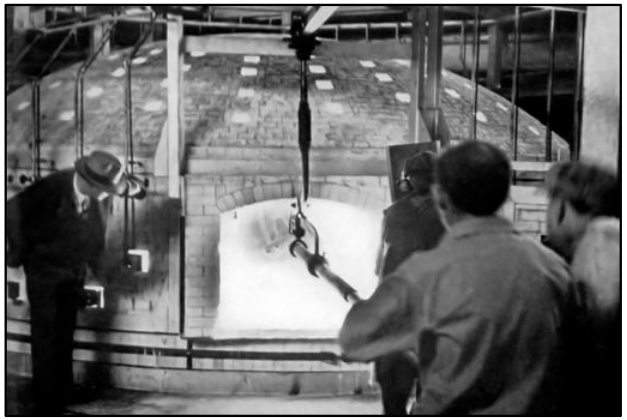
Casting the Mirror



1934

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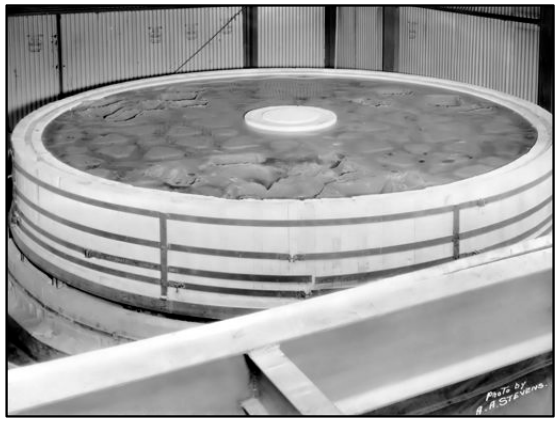
22

First Mirror



1934

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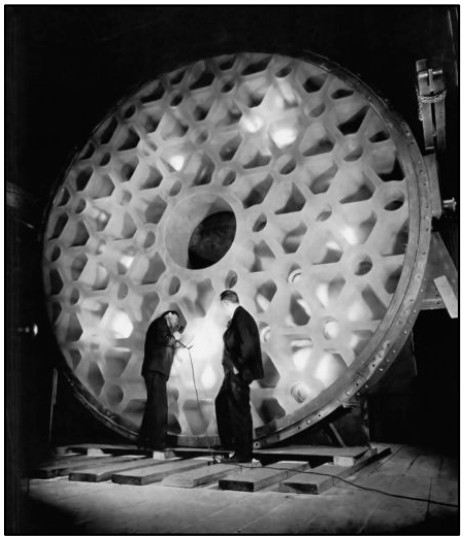
23

Inspection



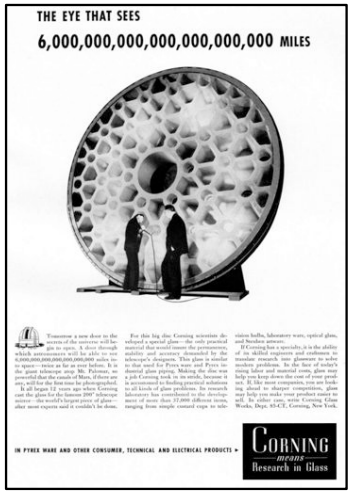
The first mirror blank was ruined by pieces of the mould floating to the surface, and by fire bricks falling from the inside wall of the annealing oven onto the mirror surface.

These problems were fixed for the casting of the second blank.

1935

24

Corning Advert



Creating the 200" mirror blank from low-expansion Pyrex glass took years of innovation on the part of Corning.

After overcoming problems with the annealing ovens, dealing with a flood of the nearby river and even an earthquake, they were keen to promote the successful casting of the 200" mirror as their flagship project.

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The Mirror Arrives at Caltech

1936

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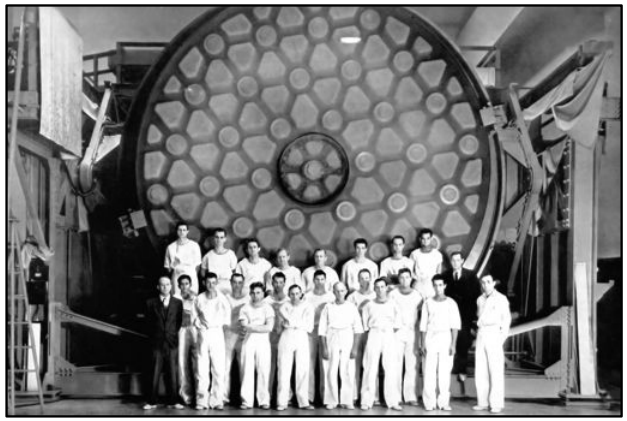
21 Men – 11 Years



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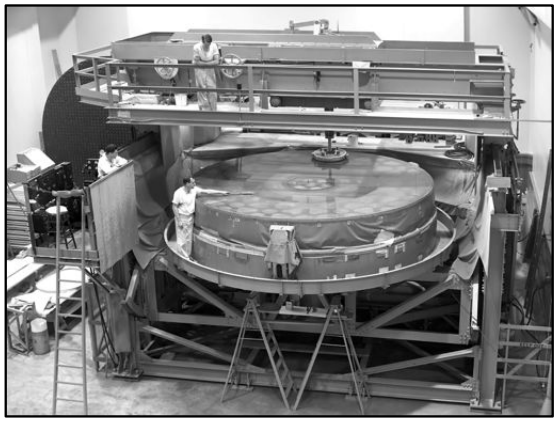
Grinding the Mirror Surface



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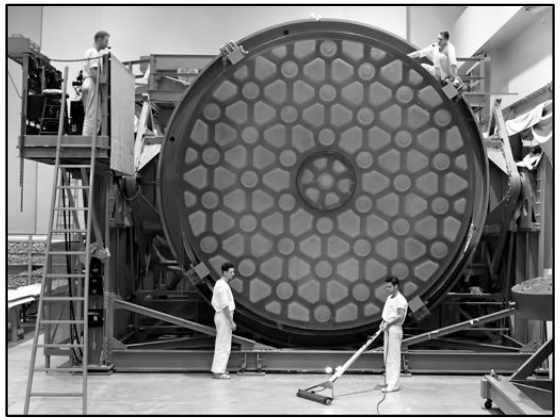
Mirror Vertical For Testing



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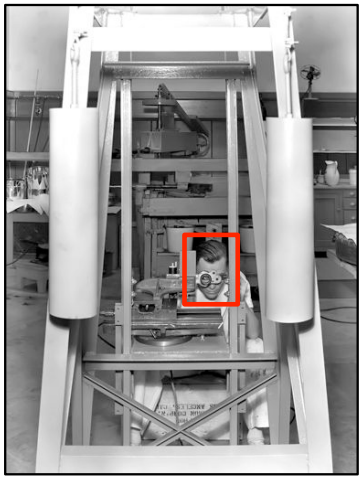
29

Testing the Mirror



As the mirror was slowly ground to the correct shape ('figured') it was checked using a 'knife-edge' test.

"Resistance is futile"

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Observatory Building Takes Shape

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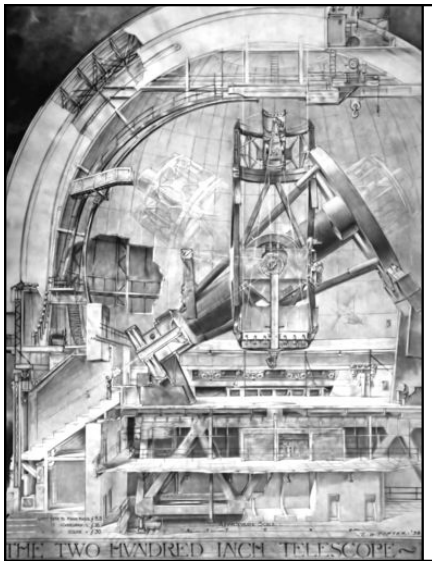
Constructing the Dome

1937

Now it starts to ***look*** like an observatory

32



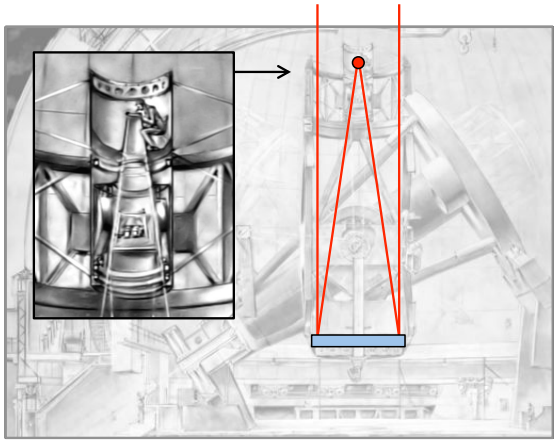
Palomar Observatory

Cutaway drawing of the 200" telescope and its observatory building by Russell Porter.

In this talk this drawing will be used as a guide to locate some parts of the telescope or mount or observatory.

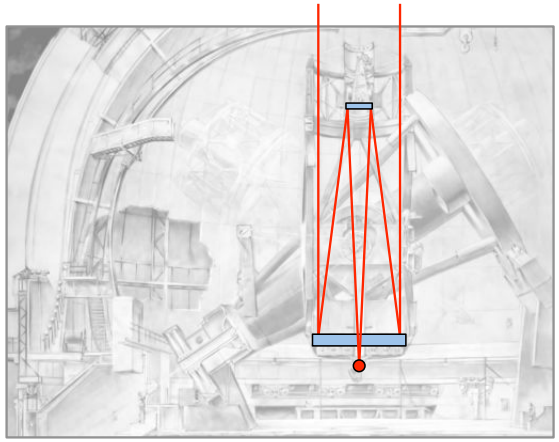
Russell Porter 1938 33

Prime Focus



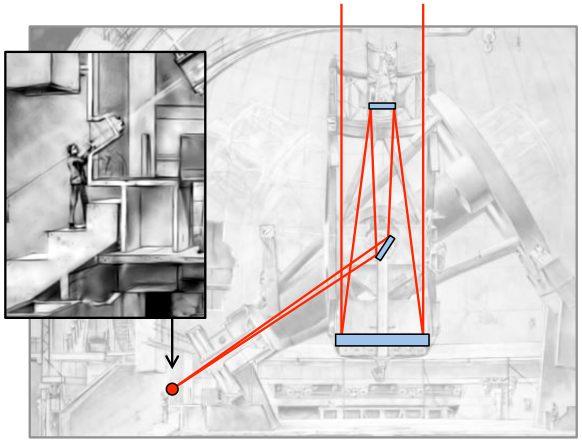
34

Cassegrain Focus



35

Coudé Focus



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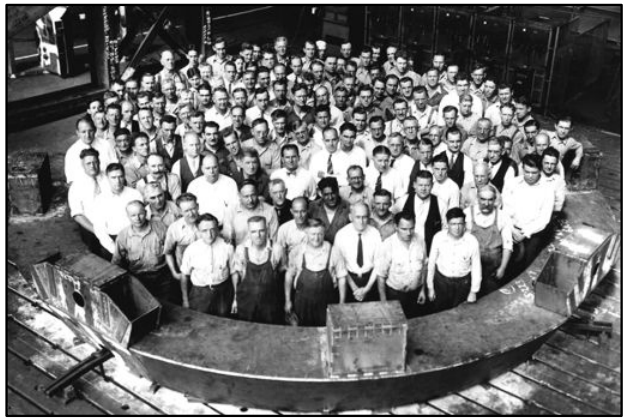
Westinghouse Construction Crew



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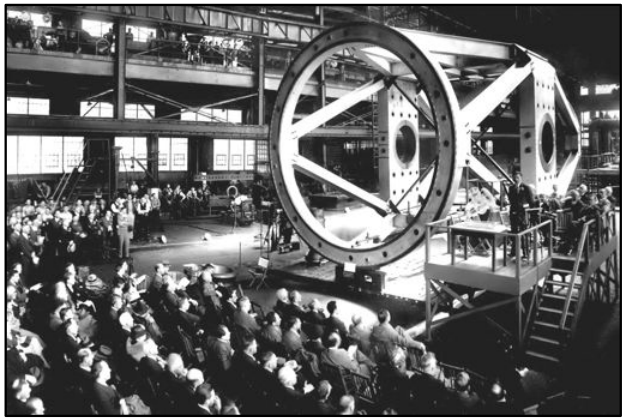
Construction at Westinghouse

1937



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Horseshoe Horn

Note the thickness of the curved steel plates forming the inside and outside surfaces.

The 4.5" thick plates were bent to shape in a 12000-ton forge press.

39

Checking the Horseshoe

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South Yoke

Looking like a huge telephone handset, the south end of the yoke is a bar with a hole for the south polar bearing in the centre.

41

Up To the Observatory

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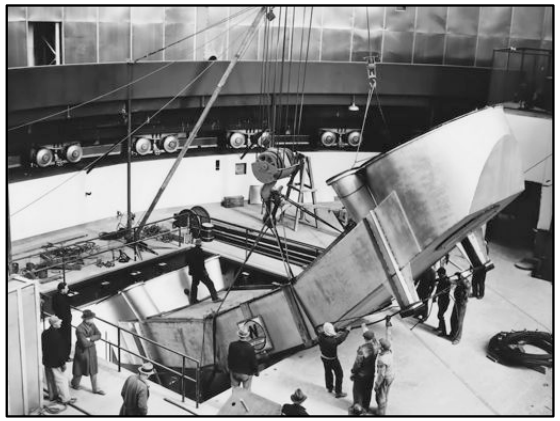
South Yoke Arrives

1938



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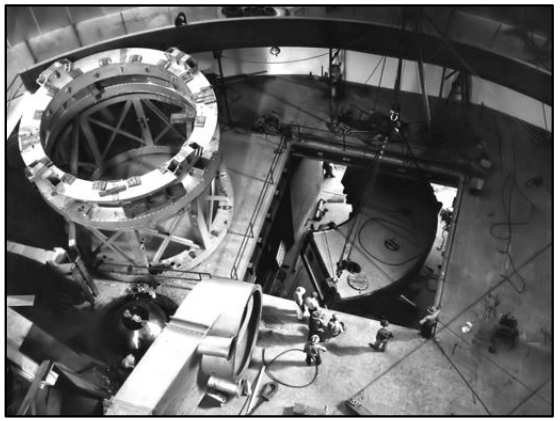
Horseshoe Arrives

1938



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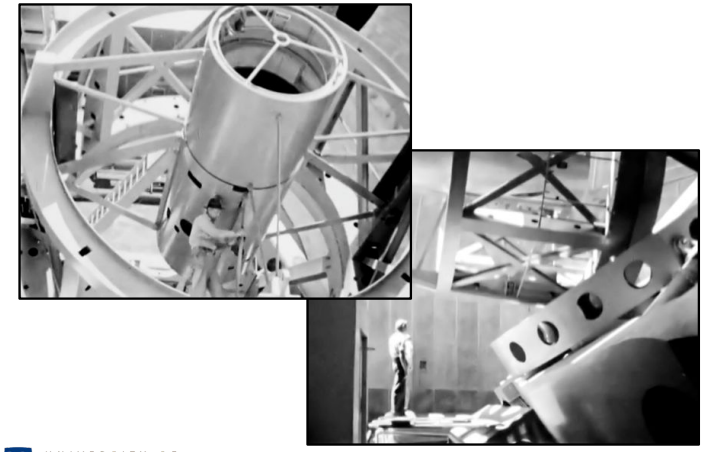
Working on the Telescope Tube



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RA Gear Wheel

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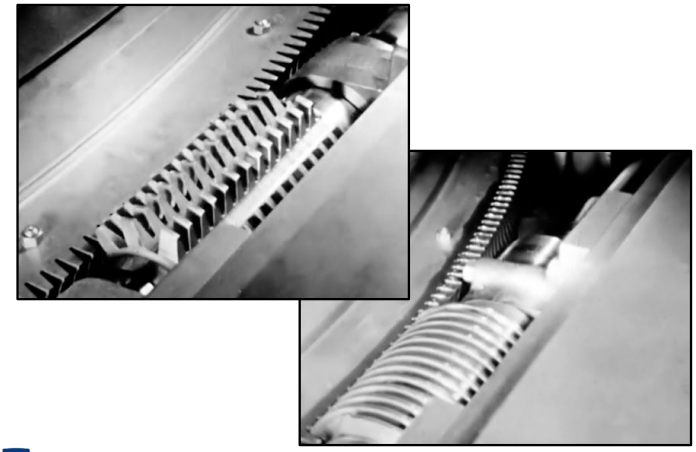
Cutting the Gear Teeth



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Russell Porter

The highly detailed drawings made by Russell Porter between 1937 and 1940 (some of which are shown in the next eight slides) give a unique insight into the design and construction of the 200" telescope.

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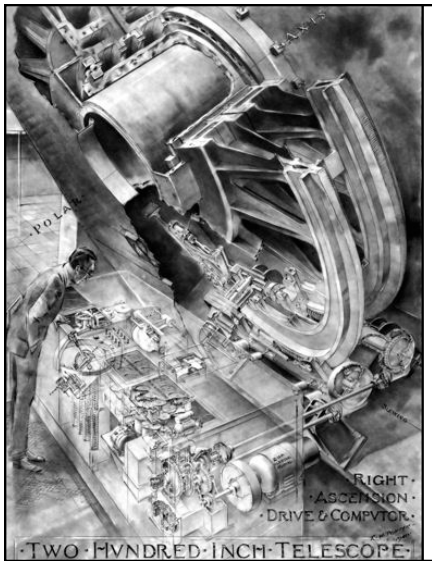
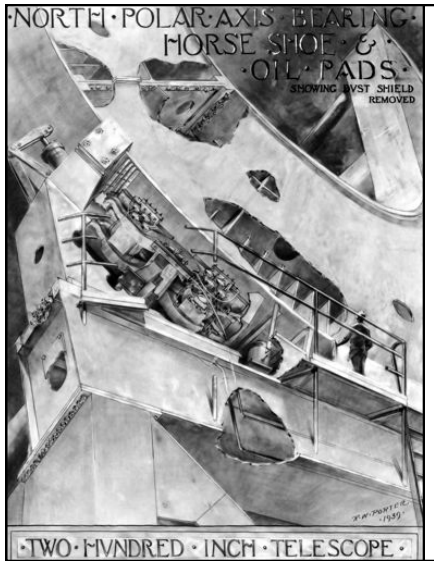


RA Drive

Right Ascension Drive and "Computor", an analogue computer comprising gears and cams that was designed to vary the drive speed automatically to account for very small variations in the apparent positions of the stars, such as those produced by refraction of starlight through the Earth's atmosphere.

Russell Porter 1940 49

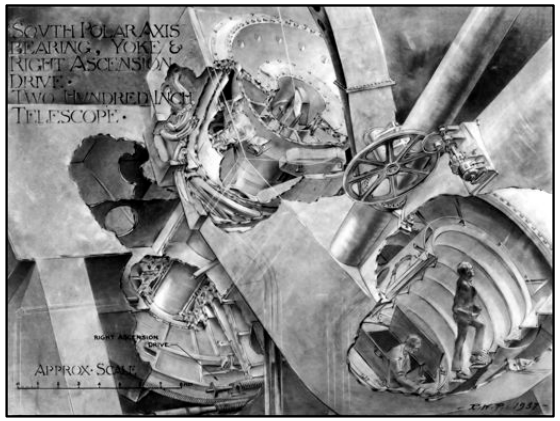


Polar Axis Horseshoe

The massive horseshoe bearing floats on four oil pads so that the friction is reduced to a thousand times less than would be the case for ball bearings or roller bearings.

Russell Porter 1939 50

South Polar Bearing



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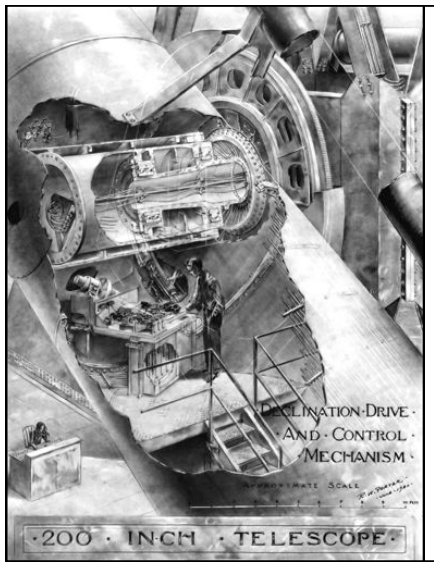
Russell Porter 1937 51

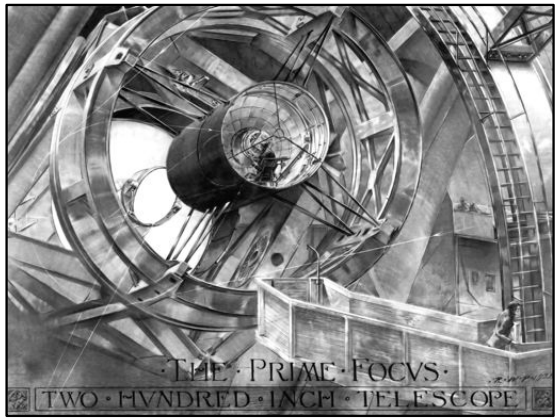


Declination Drive

The tubes of the yoke mount are hollow and one of them contains the declination drive motor.

Russell Porter 1940 52

Prime Focus Cage



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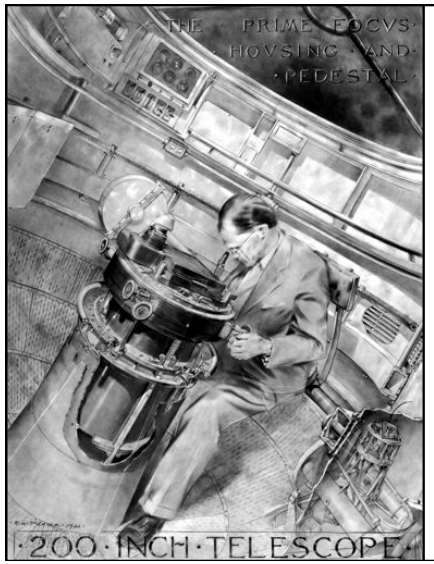
Russell Porter 1938 53

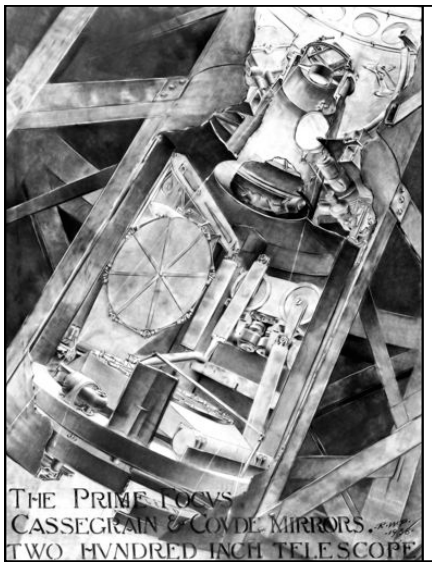


Prime Focus Pedestal

The pedestal is in the top half of the prime focus cage where the astronomer sits to take photographs.

For long exposures it may be necessary to guide the telescope by watching a guide star and making small manual adjustments to the drive motors.

Russell Porter 1940 54

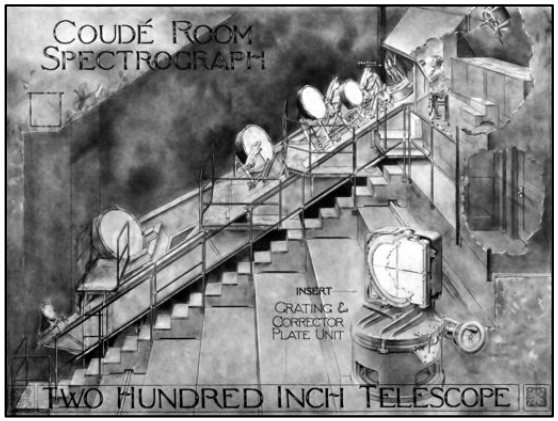


Prime Focus Mirrors

The bottom half of the prime focus cage contains mirrors that fold down into the light path when the astronomer wants to use the Cassegrain or the coudé focus.

Russell Porter 1938 55

Coudé Room



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Almost Complete?

Everybody thinks that the telescope is just months from being finished.

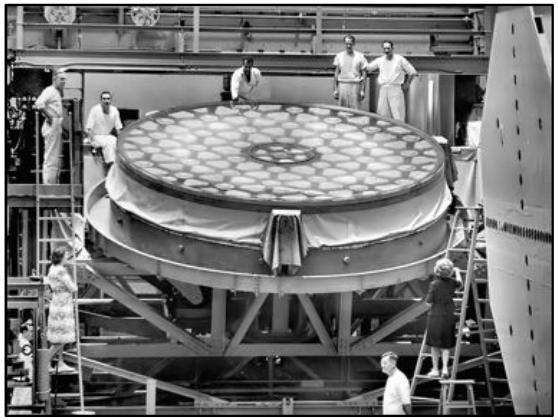
The telescope tube and mount are complete. The mirror has been ground to within a few millionths of an inch of the correct figure.

But … it is 1941. The USA is about to be dragged into World War II.

57

Mirror Grinding Resumes

1945



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Mirror Travels To Observatory

1947

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Dedication Ceremony

1948

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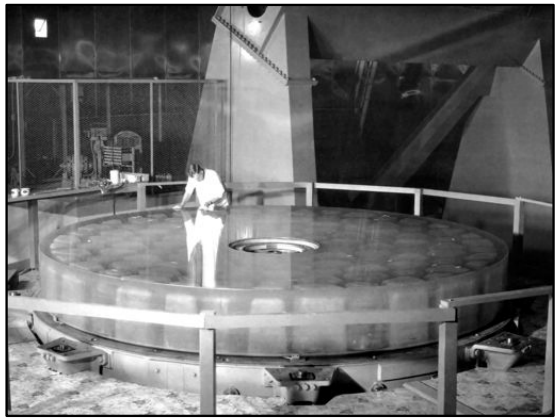
Final Corrections

1949



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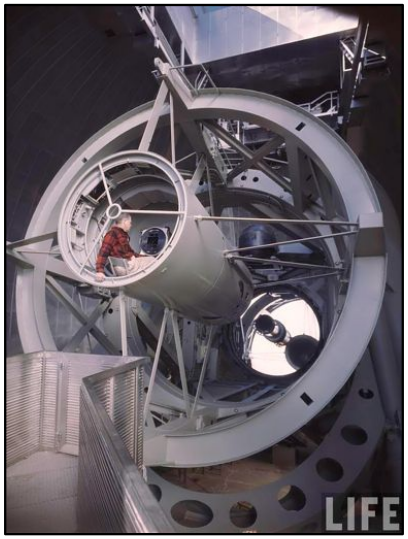
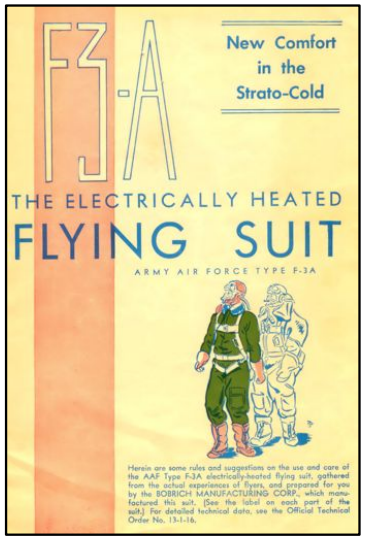
Operating the 200"



Edwin Hubble in the prime focus cage

62

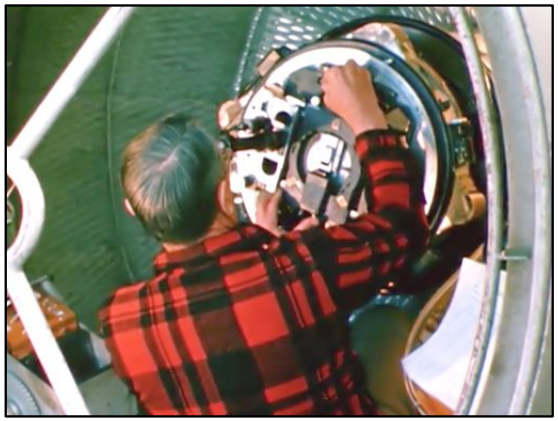
In the Prime Focus Cage



A night in the prime focus cage could be a very cold experience

63

In the Prime Focus Cage



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In the Coudé Room

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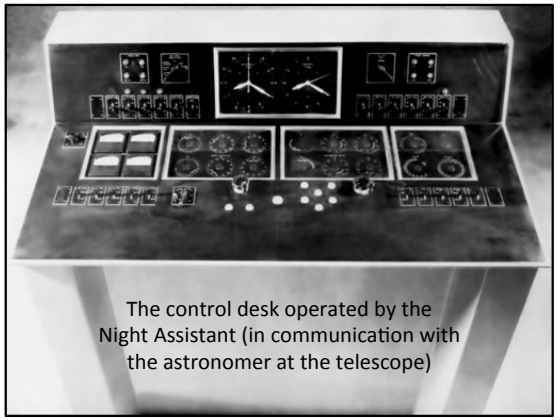
Main Control Desk



The control desk operated by the Night Assistant (in communication with the astronomer at the telescope)

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Horsehead Nebula

1951

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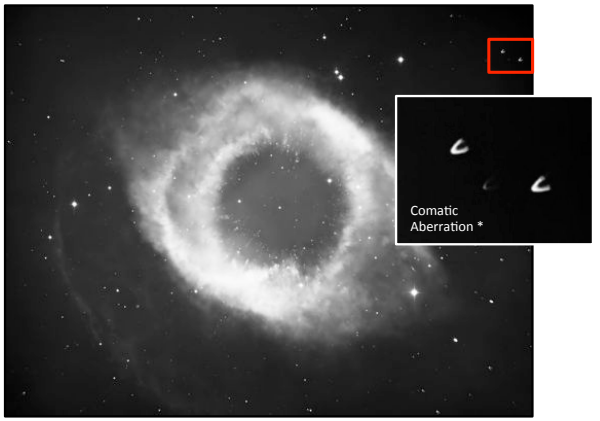
Helix Nebula

1952



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* See "Fiat Lux II"

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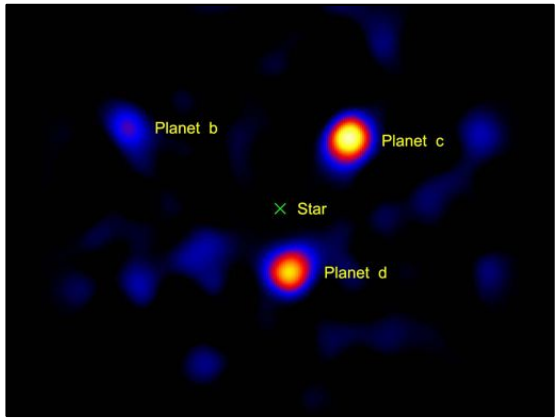
Adaptive Optics

2010



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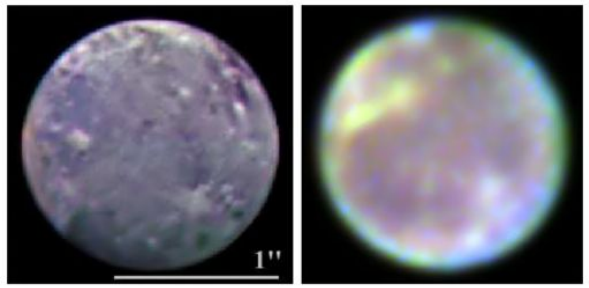
Adaptive Optics

2013

Ganymede



Hale 200" Telescope

Hubble Space Telescope

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Mirror Maintenance

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Hale Telescope Today

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Hale Telescope Today

Acknowledgements

Caltech archives

archives.caltech.edu

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'Palomar Skies' by Scott Kardel (Public Affairs Coordinator)

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Corning Museum of Glass

www.cmog.org/article/glass-giant

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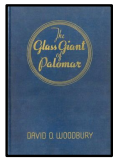
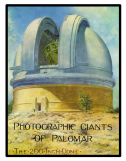
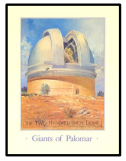
Acknowledgements



The Glass Giant of Palomar
David Woodbury 1939



Photographic Giants of Palomar
James Fassero and Russell Porter 1952



Giants of Palomar
Russell Porter 1983

The Perfect Machine
Ronald Florence 1995