



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


3

Horsehead Nebula



1951


4

Contents	
George Ellery Hale	• Billionaire-whisperer • 40" → 60" → 100" → 200"
Building the 200"	• Selecting a Site • Making the Mirror • Making the Telescope
Operating the 200"	• 70 Years On
Acknowledgements	

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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.

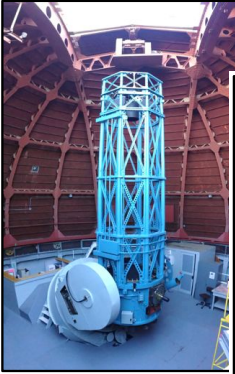
6

Largest Telescopes in the World

Mount Wilson Observatory



40" refractor 1900
Yerkes Observatory

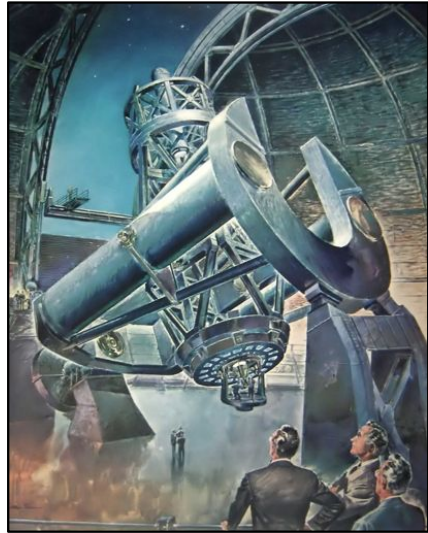


60" reflector 1908



100" Hooker 1918

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Birth of the 200"

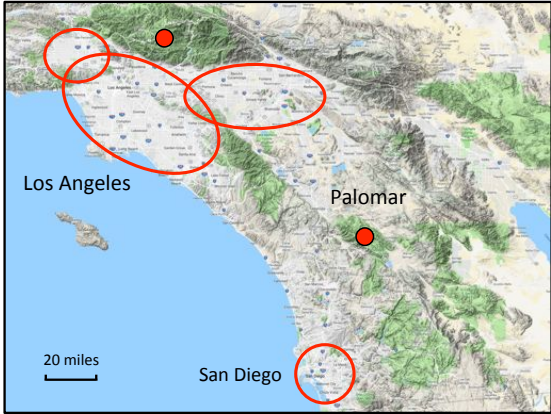
The 100" Hooker telescope was operational in 1918.

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"



Mount Wilson

Los Angeles

Palomar

San Diego

20 miles

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9

Palomar Mountain



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10

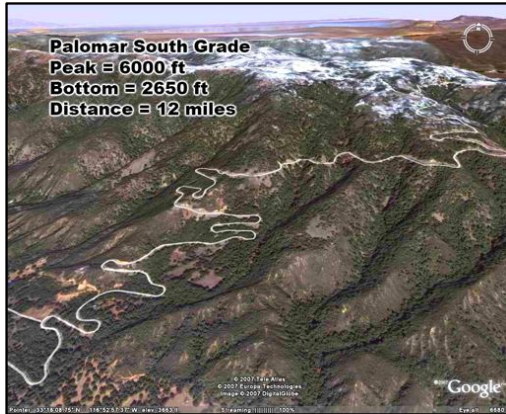
Altitude 1700m



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11

Palomar South Grade

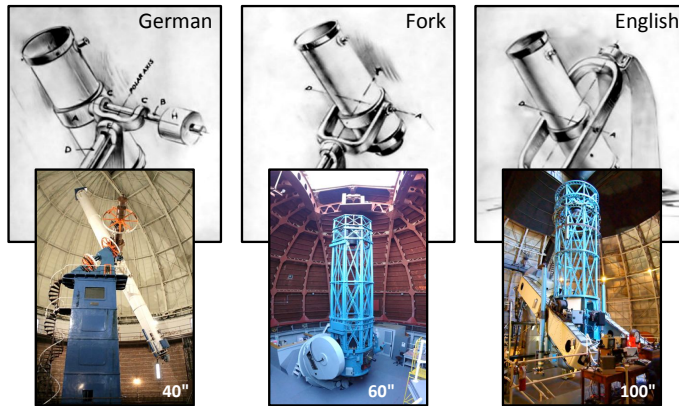


Palomar South Grade
Peak = 6000 ft
Bottom = 2650 ft
Distance = 12 miles

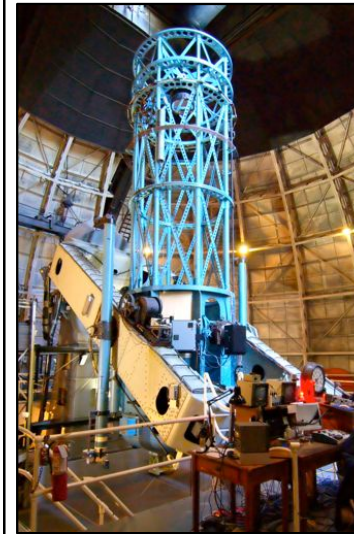
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12

Telescope Mounts



100" Hooker

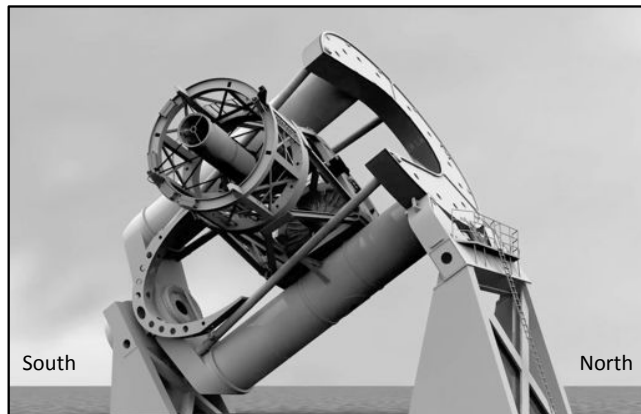


Hale did not want the 200" telescope to suffer from the same limitations as the 100" Hooker telescope.

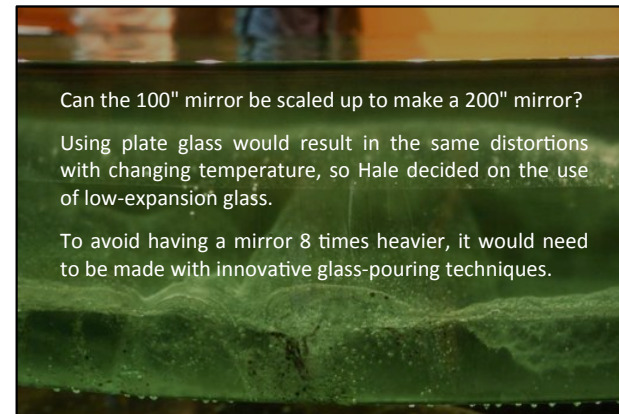
The English (yoke) mount meant that no observations could be made within 30° of the north celestial pole.

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

Horseshoe Yoke Mount



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.

Making a Mirror

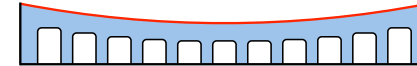
An empty mould results in a slab of glass that is roughly flat on its top and bottom surfaces.



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.

Making a Ribbed Mirror

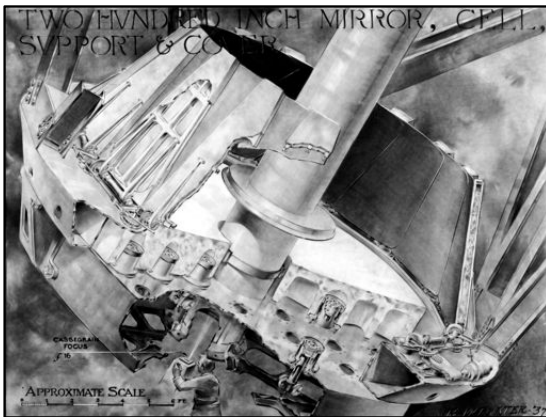
If the mould is first filled with 'cores' made of fire bricks then the glass flows around them.



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.

Mirror Section



Mirror Mould



Casting the Mirror



1934

21

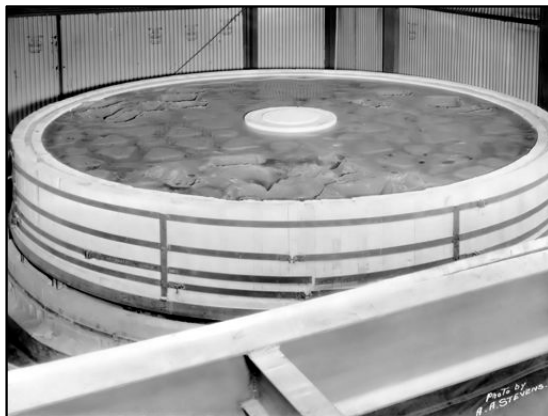
Casting the Mirror



1934

22

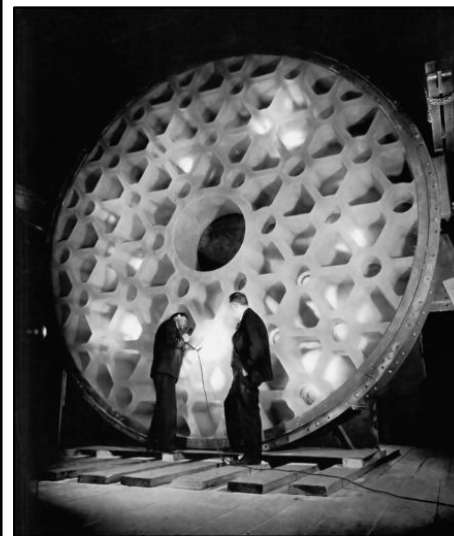
First Mirror



1934

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

**THE EYE THAT SEES
6,000,000,000,000,000,000 MILES**



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

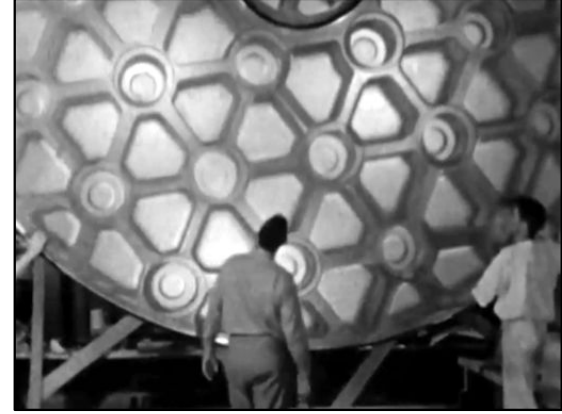
After overcoming problems with the annealing ovens, dealing with a flood of the nearby river and even an earthquake, they were keen to promote the successful casting of the 200" mirror as their flagship project.

CORNING
Research in Glass

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25

The Mirror Arrives at Caltech

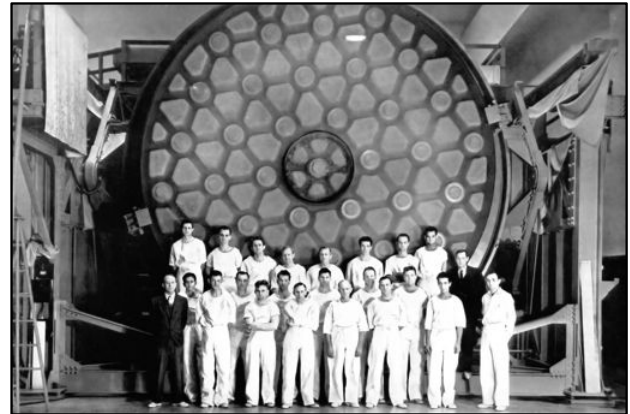


1936

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26

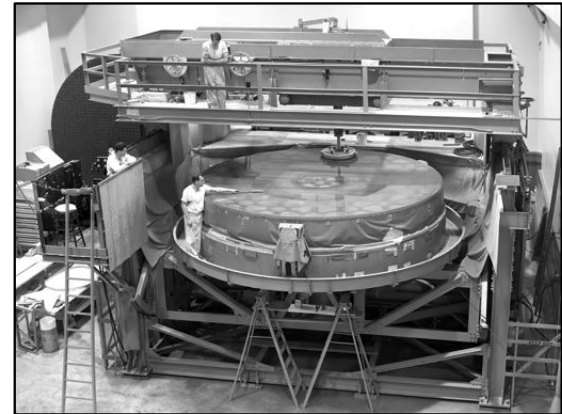
21 Men – 11 Years



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27

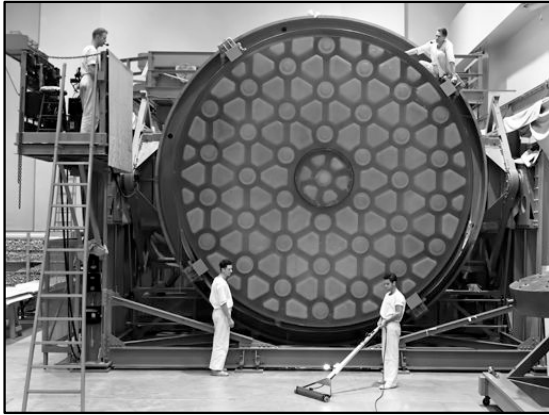
Grinding the Mirror Surface



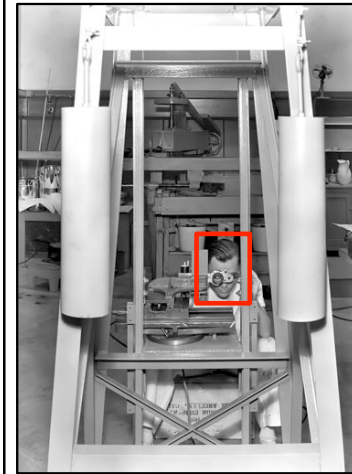
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28

Mirror Vertical For Testing



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"

Observatory Building Takes Shape

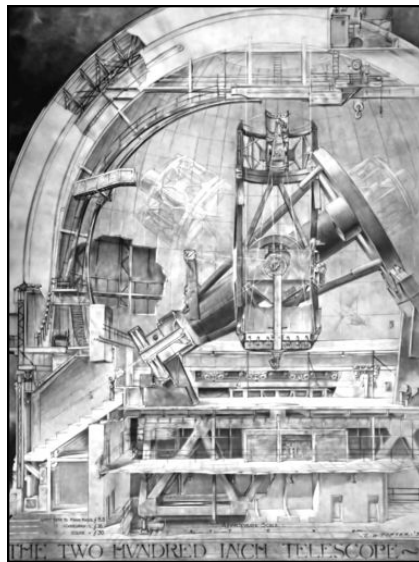


Constructing the Dome



1937

Now it starts to *look*
like an observatory



Palomar Observatory

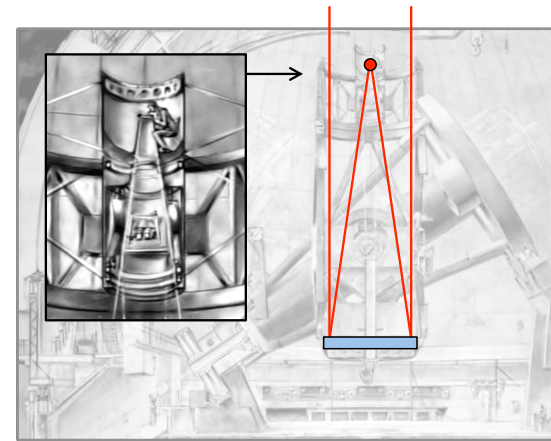
Cutaway drawing of the 200" telescope and its observatory building by Russell Porter.

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

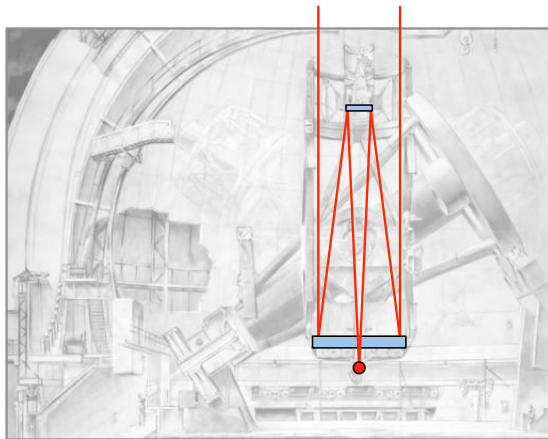
33

Prime Focus



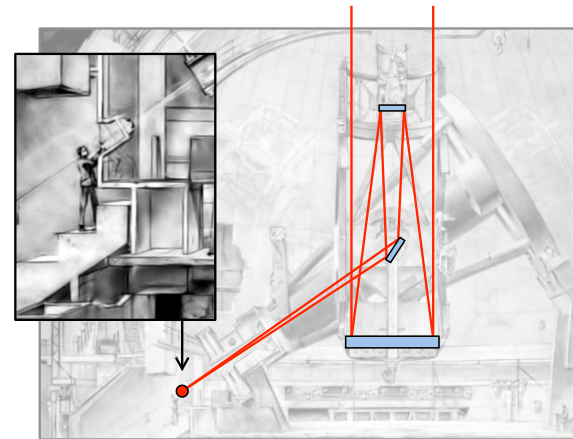
34

Cassegrain Focus



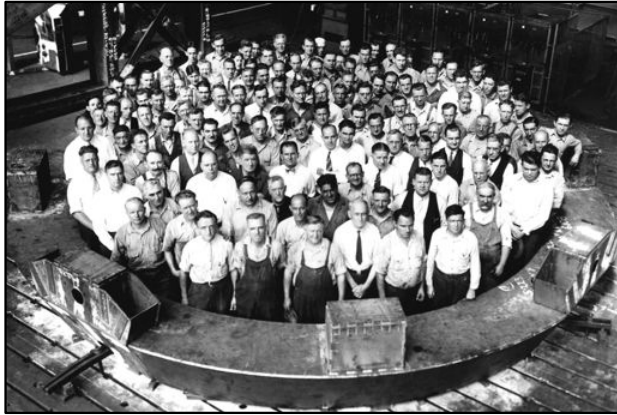
35

Coudé Focus

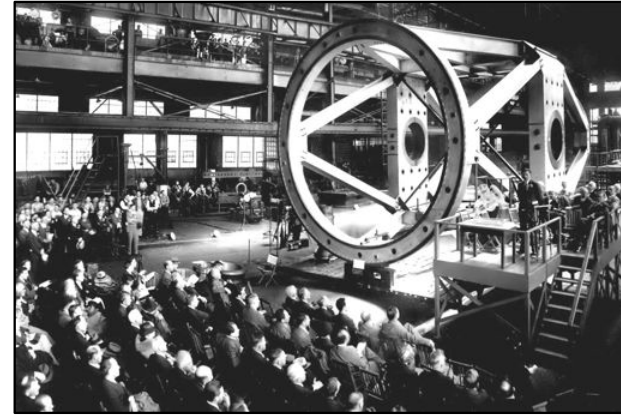


36

Westinghouse Construction Crew



Construction at Westinghouse



1937



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.

Checking the Horseshoe



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



Palomar/South Grade
Peak = 6000 ft
Bottom = 2650 ft
Distance = 12 miles

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42

South Yoke Arrives

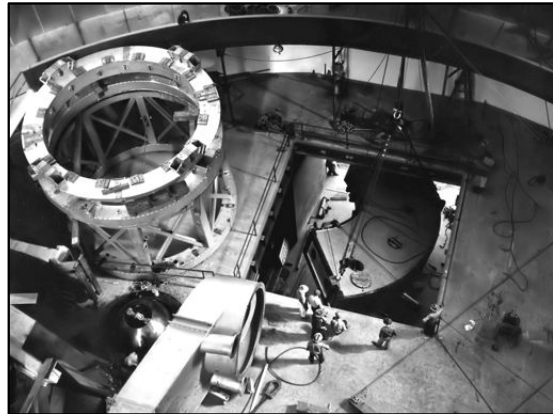


1938

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43

Horseshoe Arrives

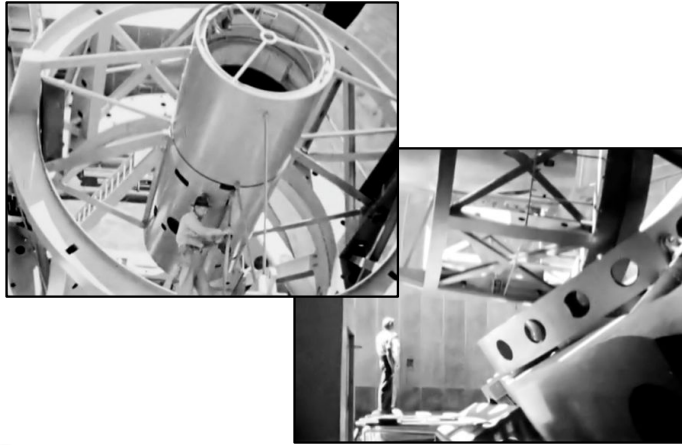


1938

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44

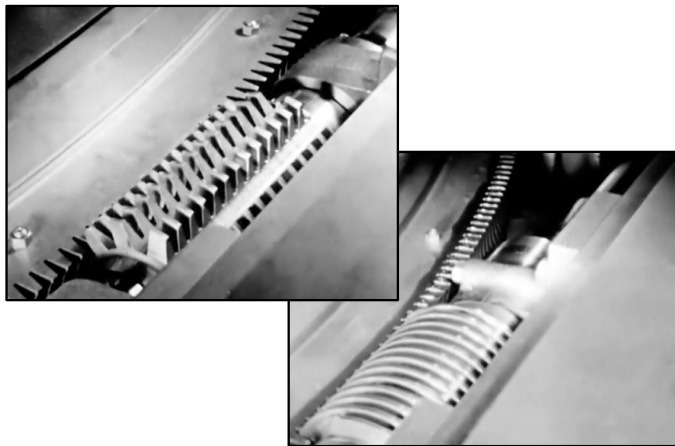
Working on the Telescope Tube



RA Gear Wheel



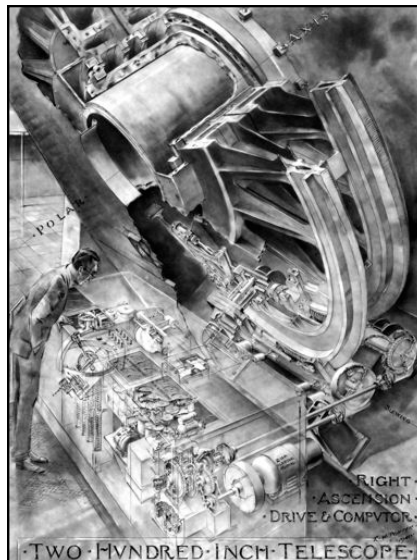
Cutting the Gear Teeth



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.



RA Drive

Right Ascension Drive and "Computer", 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

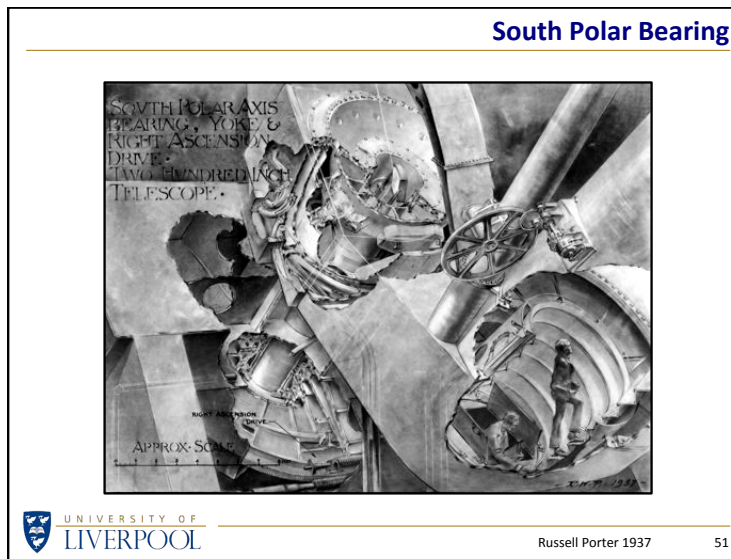


Polar Axis Horseshoe

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

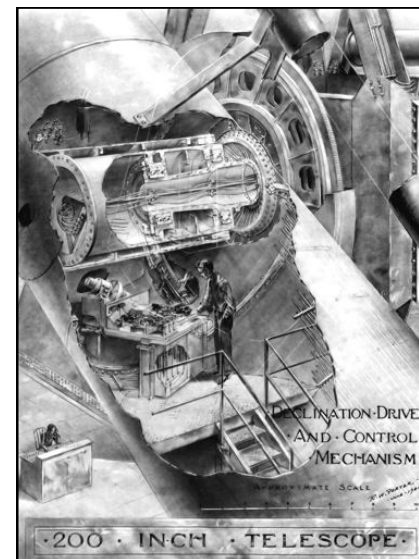


South Polar Bearing



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



Russell Porter 1938

53

Prime Focus Pedestal



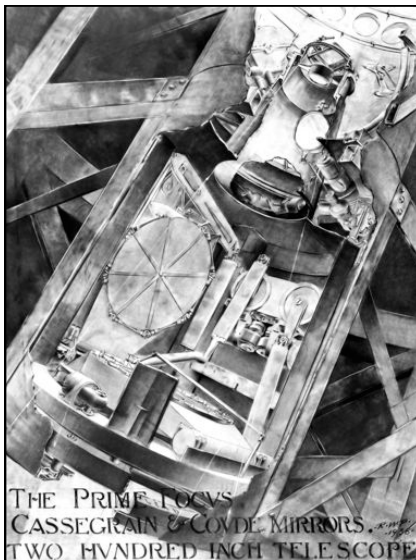
The pedestal is in the top half of the prime focus cage where the astronomer sits to take photographs.

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

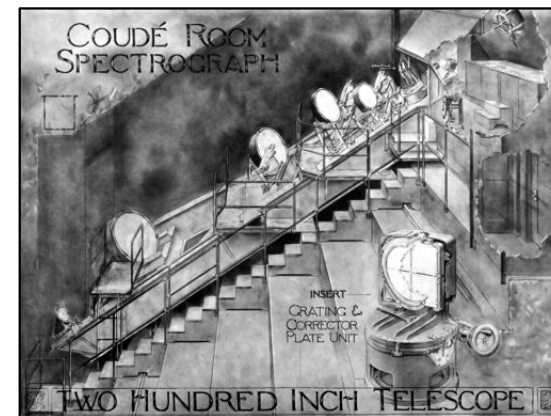


The bottom half of the prime focus cage contains mirrors that fold down into the light path when the astronomer wants to use the Cassegrain or the coudé focus.

Russell Porter 1938

55

Coudé Room



56

Almost Complete?



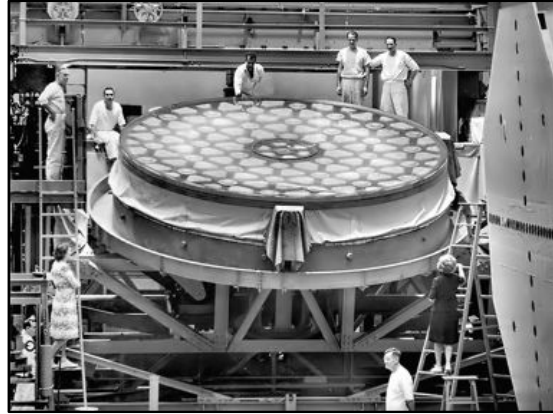
Everybody thinks that the telescope is just months from being finished.

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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58

Mirror Travels To Observatory



1947

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59

Dedication Ceremony



1948

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60

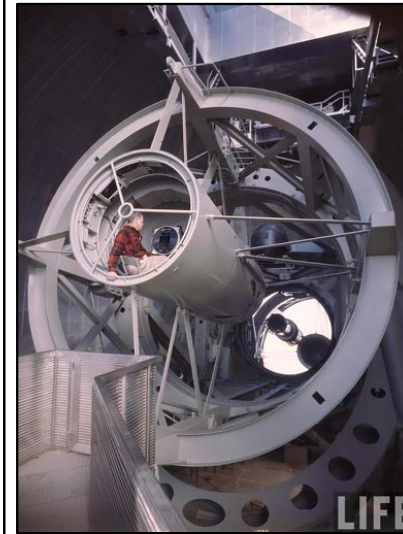
Final Corrections



1949

61

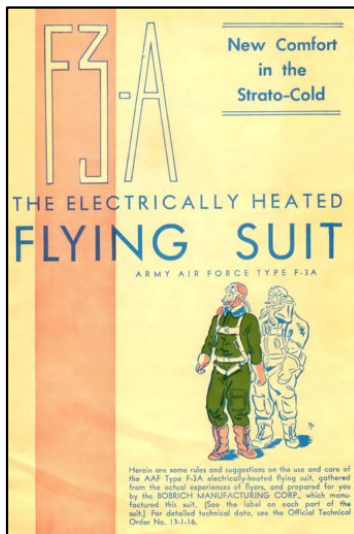
Operating the 200"



Edwin Hubble in the
prime focus cage

62

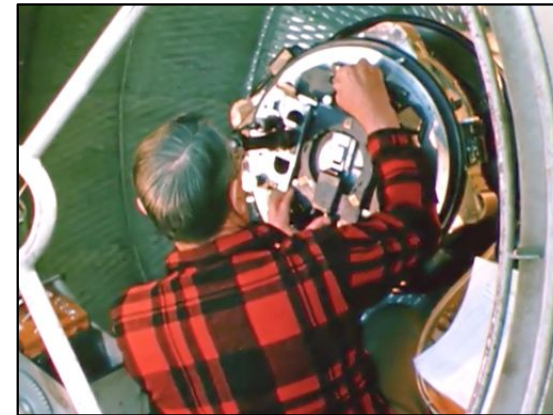
In the Prime Focus Cage



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

63

In the Prime Focus Cage



64

In the Coudé Room



Main Control Desk



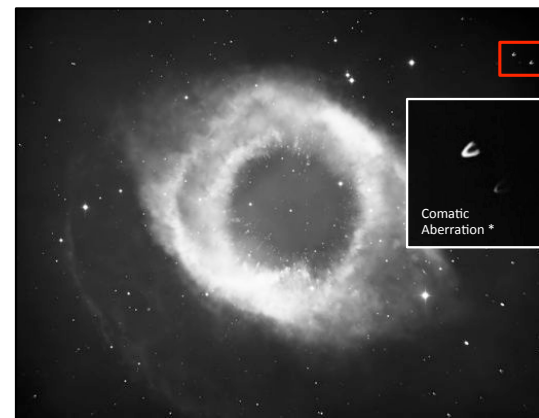
The control desk operated by the
Night Assistant (in communication with
the astronomer at the telescope)

Horsehead Nebula



1951

Helix Nebula

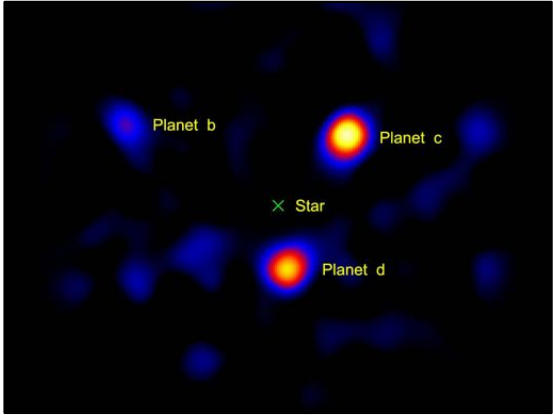


1952

Comatic
Aberration *

Adaptive Optics

2010



Planet b Planet c
× Star
Planet d

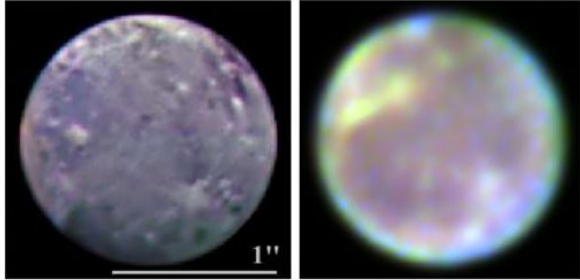
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69

Adaptive Optics

2013

Ganymede

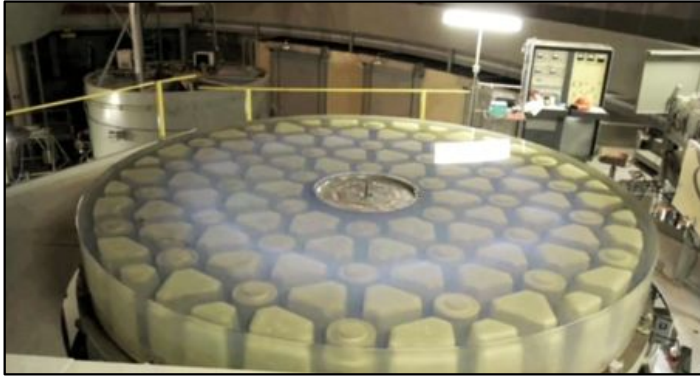


Hale 200" Telescope Hubble Space Telescope

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70

Mirror Maintenance



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71

Hale Telescope Today



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72

Hale Telescope Today



Acknowledgements

Caltech archives

archives.caltech.edu

archive.org/details/caltech

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

palomarskies.blogspot.co.uk

Corning Museum of Glass

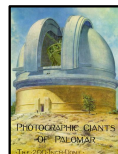
www.cmog.org/article/glass-giant

www.cmog.org/article/hale-reflecting-telescope-palomar

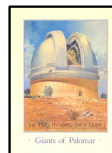
Acknowledgements



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

