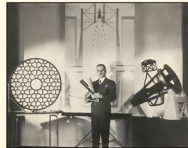




**ROBERT T. EDGAR**



Presenting  
**"THE CYCLOPS OF PALOMAR"**

*A Unique, Non-Technical Lecture-Demonstration of the Wonder  
of the World, the Great 200-inch Telescope on  
Mount Palomar, California*

{ The Exciting, Dramatic Story of Man's Greatest Scientific Achievement,  
Illustrated with Giant Models of the Telescope and Mirror and  
Presented in a Forceful, Dynamic Manner by a Master Story Teller. }

*Authentic - - - - Inspiring - - - - Entertaining*

Time \_\_\_\_\_  
Place \_\_\_\_\_

**Cyclops of Palomar**

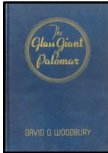
Wonder of the World ...

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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**Horsehead Nebula**



1951


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4

Contents	
<b>George Ellery Hale</b>	<ul style="list-style-type: none"> <li>• Billionaire–whisperer</li> <li>• 40" → 60" → 100" → 200"</li> </ul>
<b>Building the 200"</b>	<ul style="list-style-type: none"> <li>• Selecting a Site</li> <li>• Making the Mirror</li> <li>• Making the Telescope</li> </ul>
<b>Operating the 200"</b>	<ul style="list-style-type: none"> <li>• 75 Years On</li> </ul>
<b>Acknowledgements</b>	

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**George Ellery Hale**

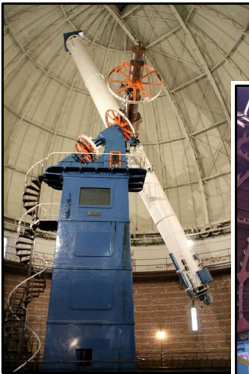
George Hale (1868-1938) had a remarkable life.

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.

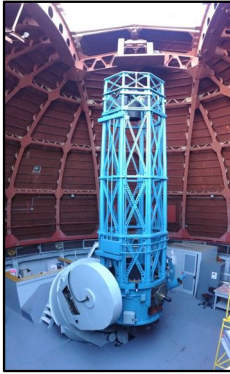
6

**Largest Telescopes in the World**


Mount Wilson Observatory



40" refractor 1900  
Yerkes Observatory




60" reflector 1908



100" Hooker 1918

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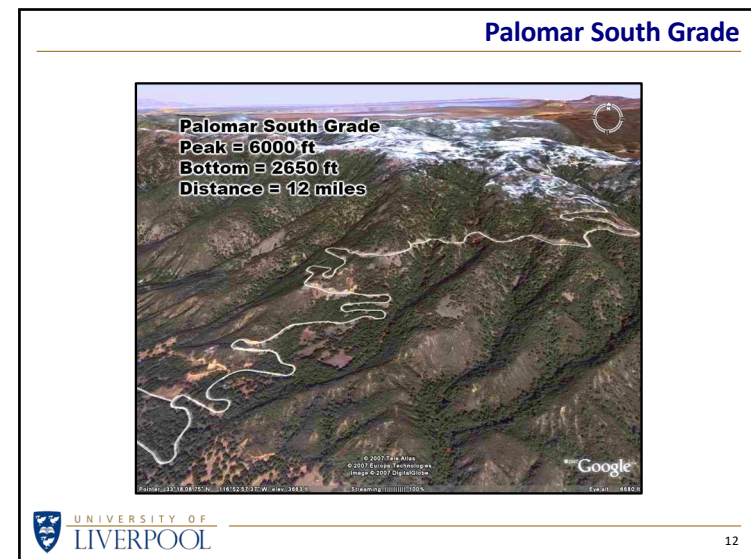
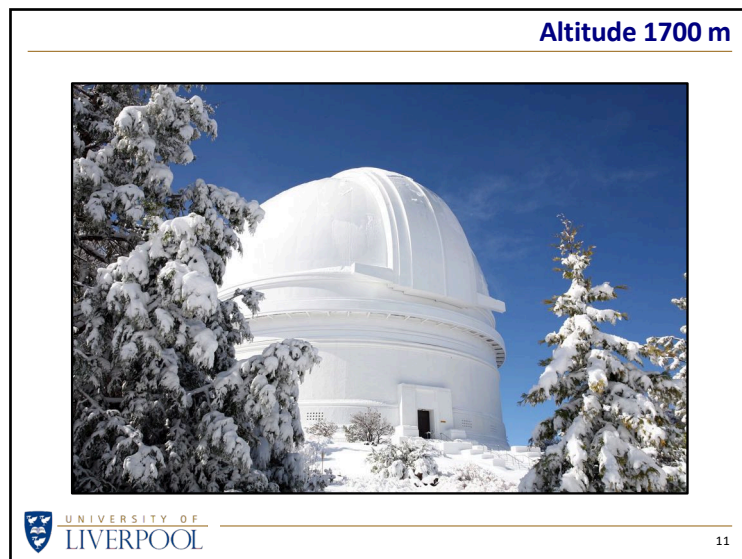
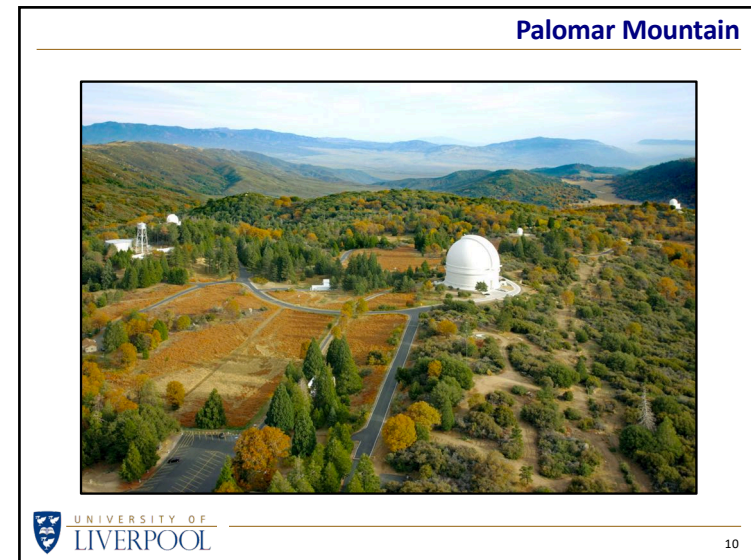
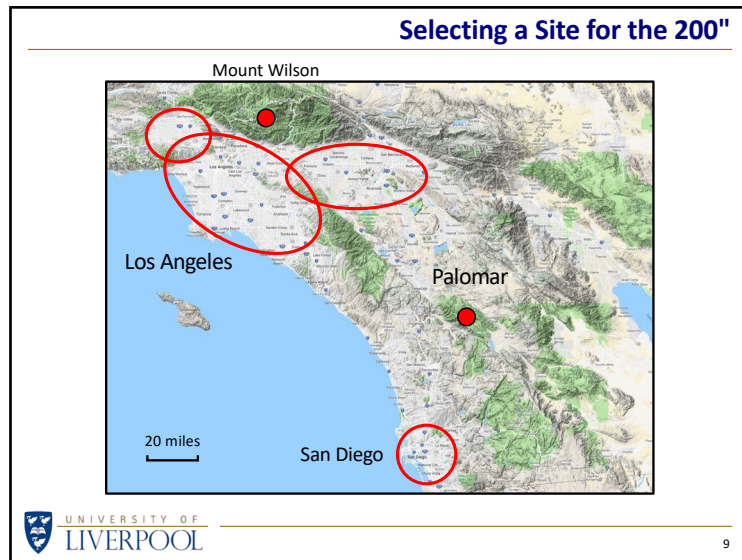
**Birth of the 200"**

The 100" Hooker telescope was operational in 1918.

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

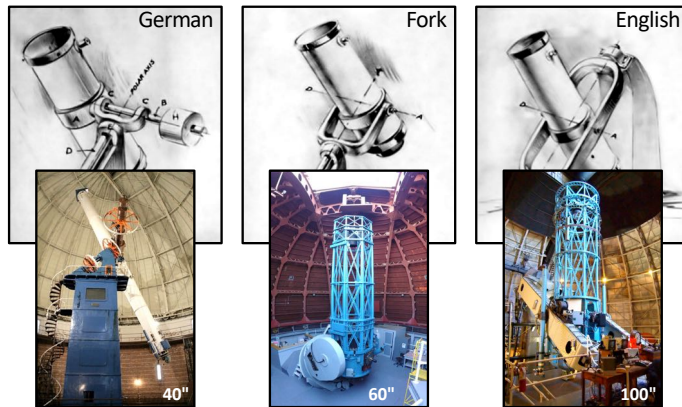
In 1928 he approached the Rockefeller Foundation and persuaded them to pledge \$6 million to build the 200" telescope and observatory.

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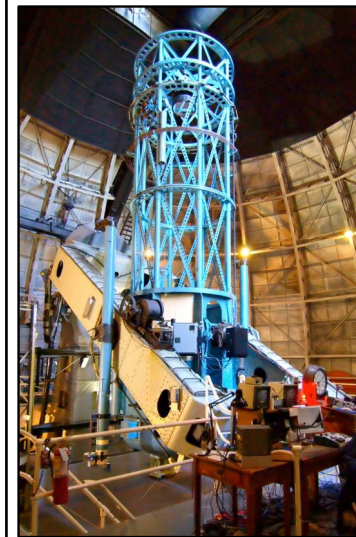




## Telescope Mounts



## 100" Hooker

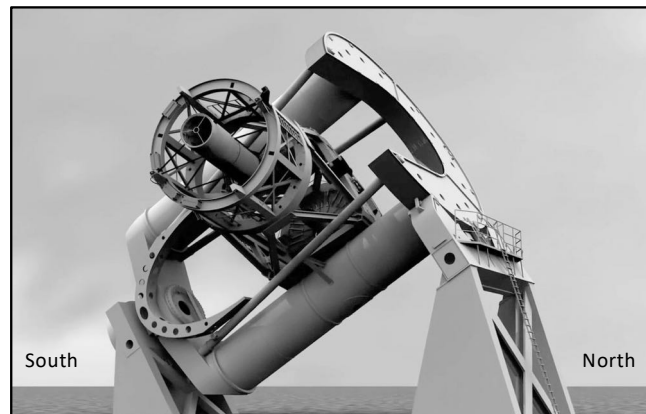


Hale did not want the 200" telescope to suffer from the same limitations as the 100" Hooker telescope.

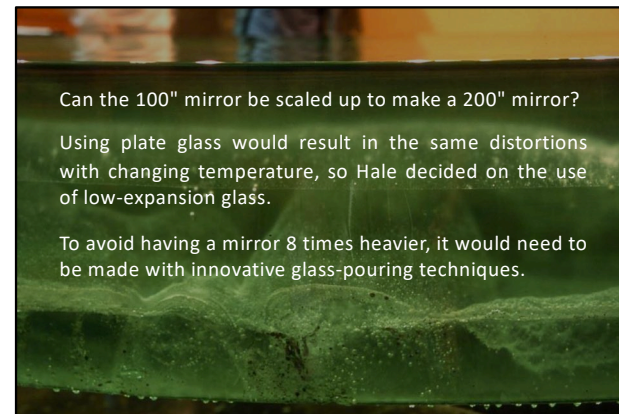
The English (yoke) mount meant that no observations could be made within 30° of the north celestial pole.

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

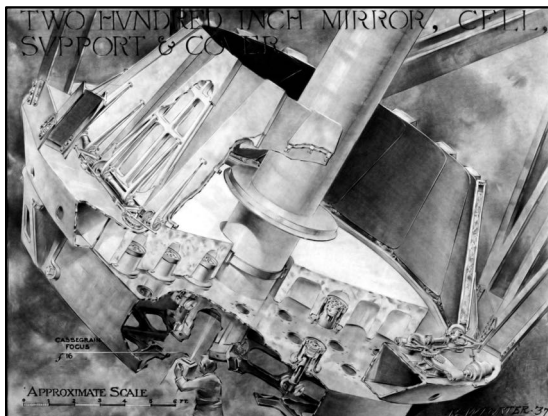
If the mould is first filled with 'cores' made of fire bricks then the glass flows around them.



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

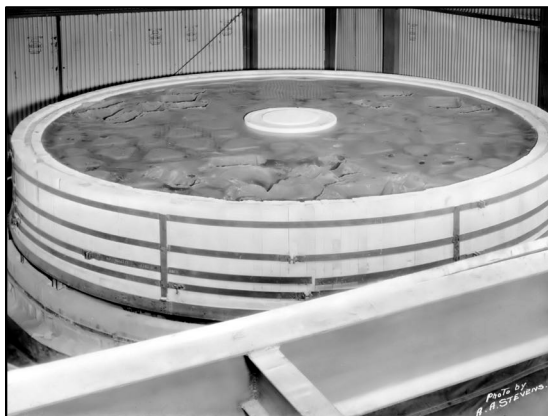
### Casting the Mirror



1934

22

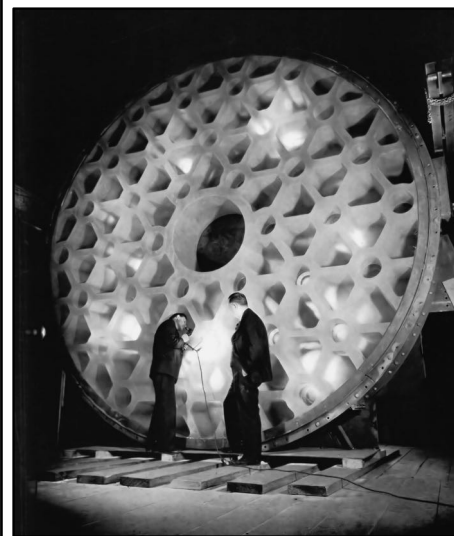
### First Mirror



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.

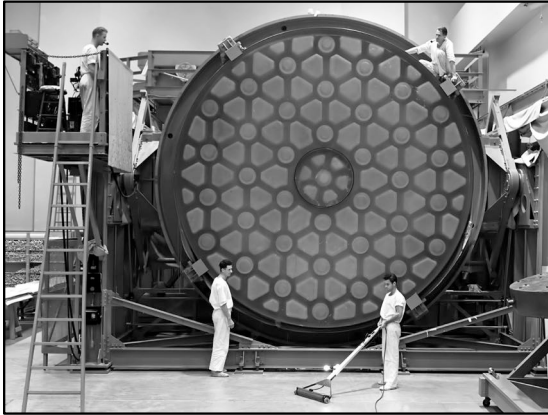
1935

24

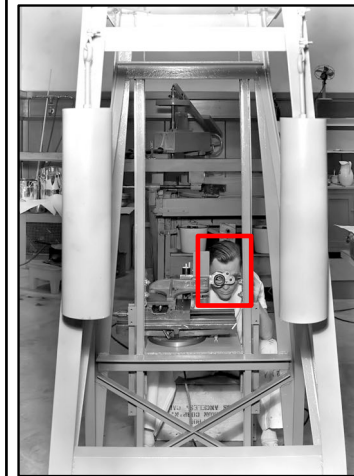




### Mirror Vertical For Testing



### Testing the Mirror



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

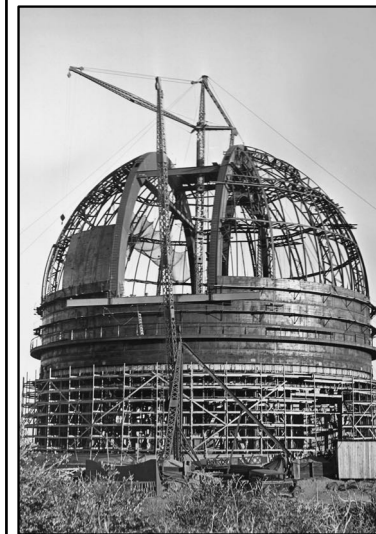


"Resistance is futile"

### Observatory Building Takes Shape



### Constructing the Dome

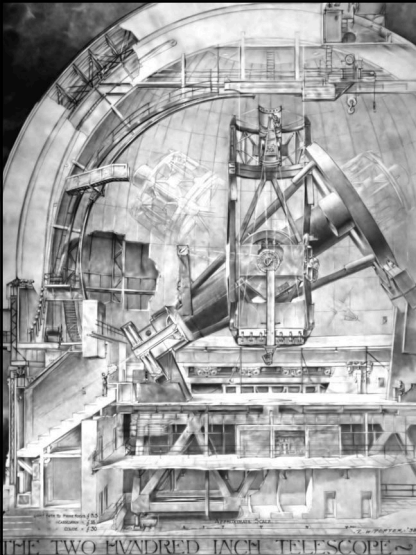


1937

Now it starts to *look* like an observatory



### Palomar Observatory



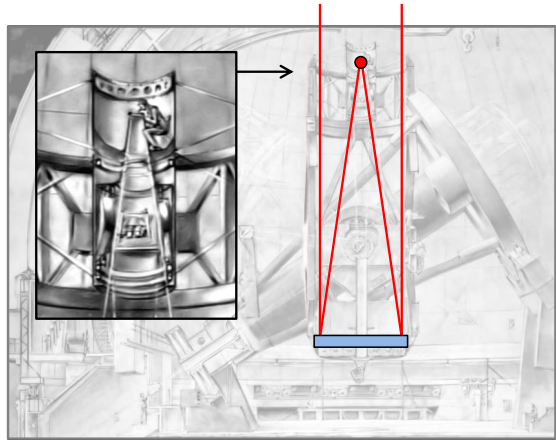
Cutaway drawing of the 200" telescope and its observatory building by Russell Porter.

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

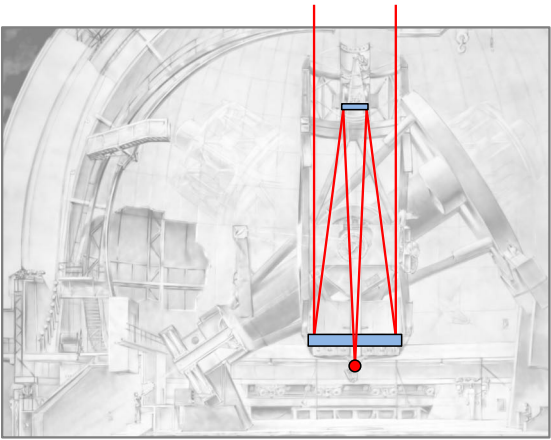
### Prime Focus



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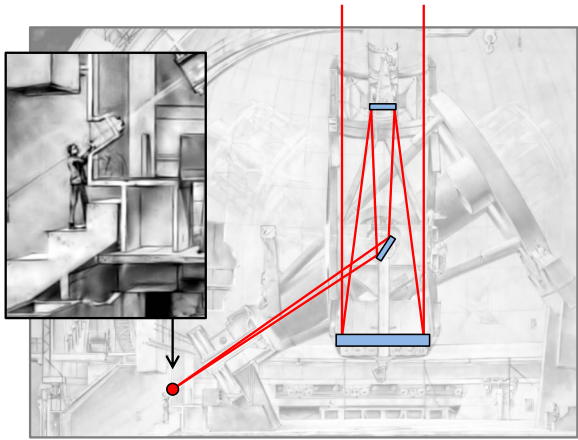
### Cassegrain Focus



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35

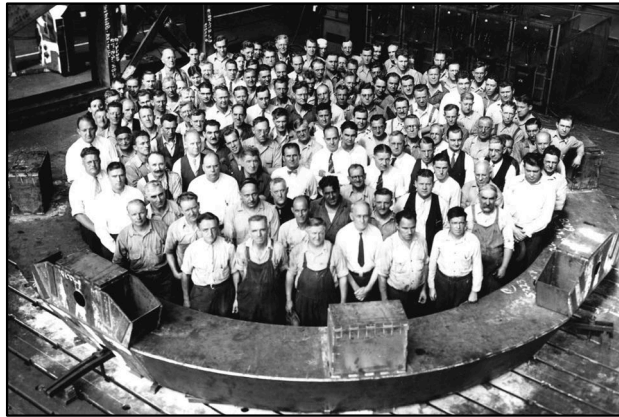
### Coudé Focus



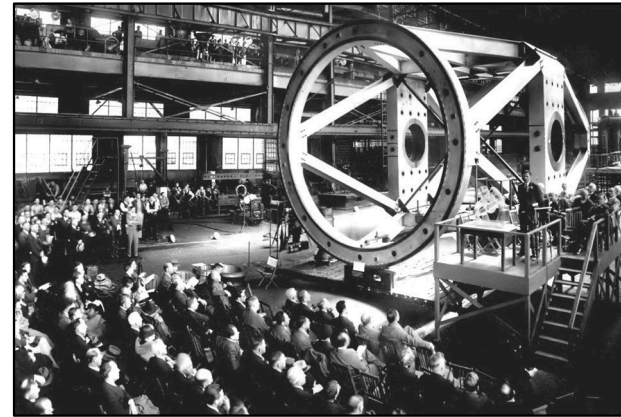
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### Westinghouse Construction Crew



### 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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### South Yoke Arrives

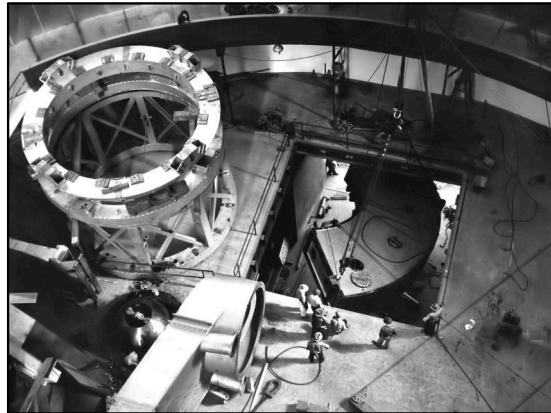


1938

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### Horseshoe Arrives



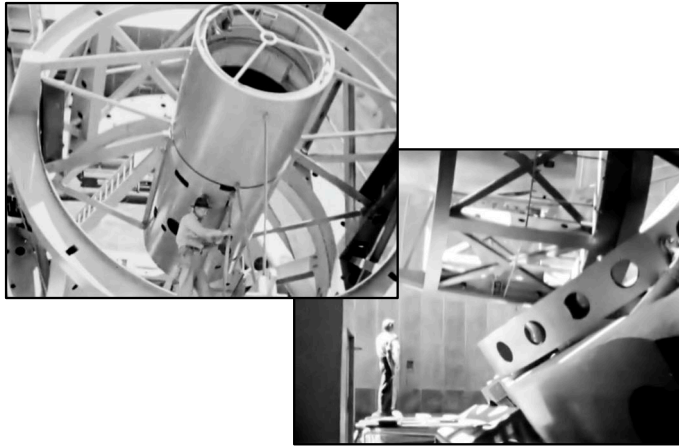
1938

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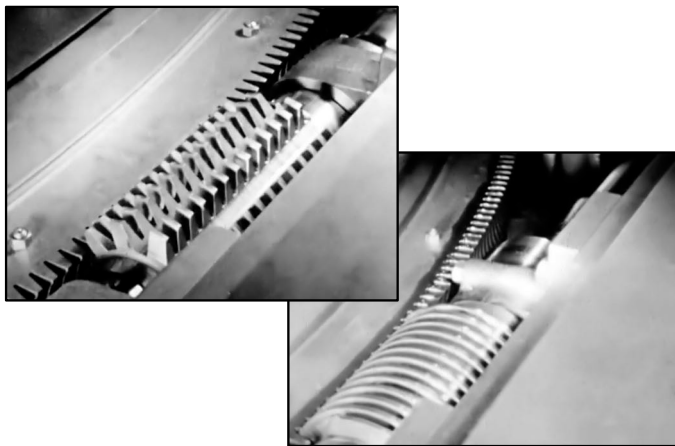
Working on the Telescope Tube



RA Gear Wheel



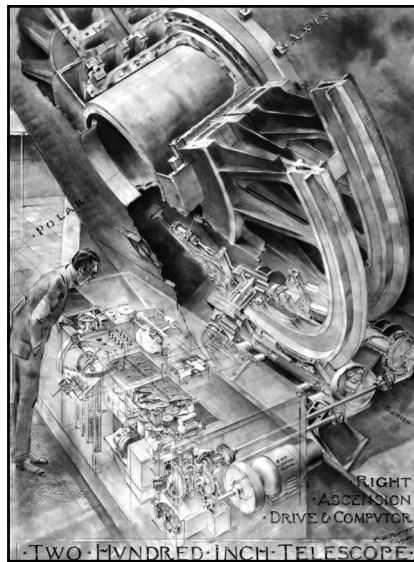
Cutting the Gear Teeth



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.

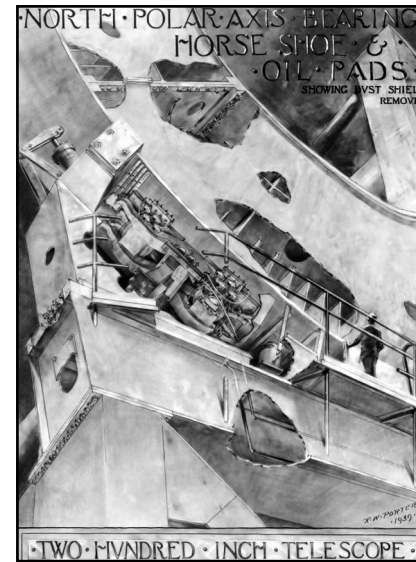


### RA Drive

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

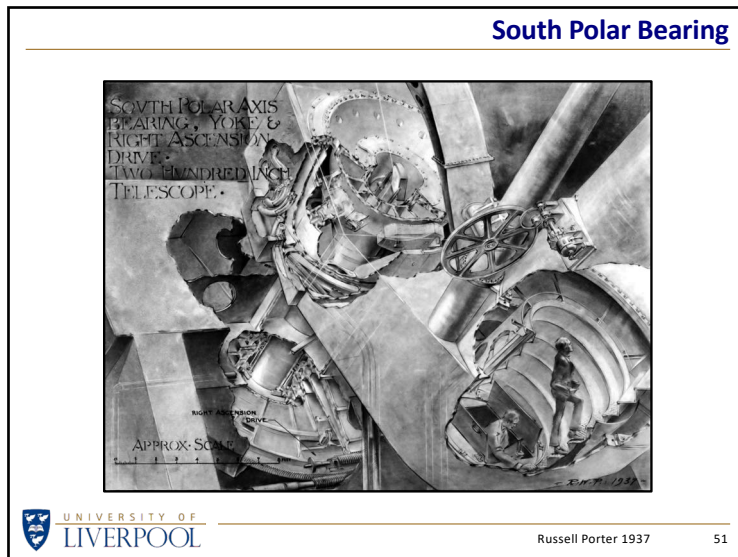


### Polar Axis Horseshoe

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

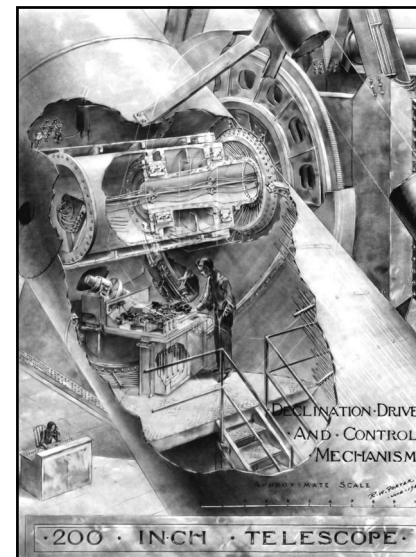


### South Polar Bearing



Russell Porter 1937

51



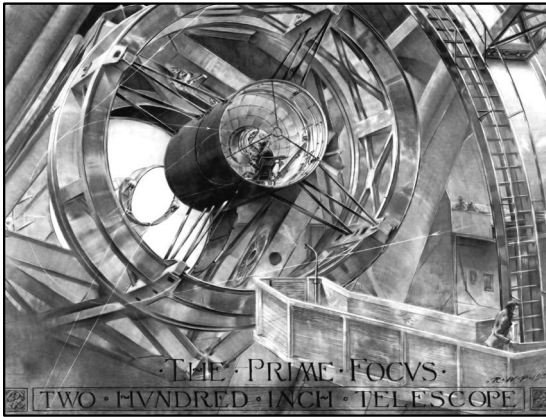
### Declination Drive

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

Russell Porter 1940

52

### Prime Focus Cage

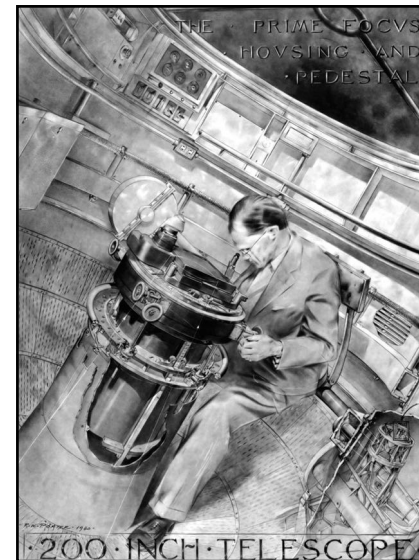


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Russell Porter 1938

53

### Prime Focus Pedestal



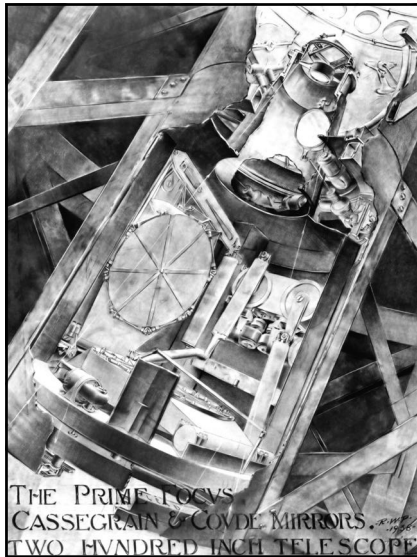
The pedestal is in the top half of the prime focus cage where the astronomer sits to take photographs.

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

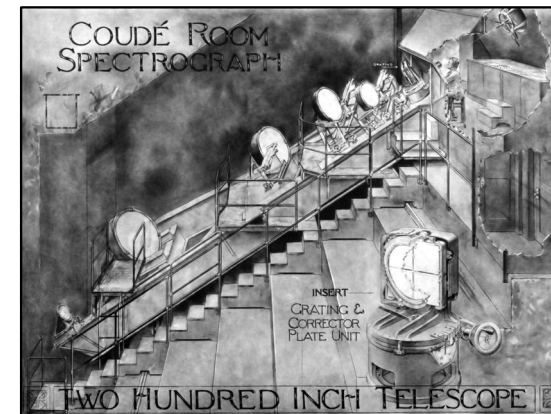


The bottom half of the prime focus cage contains mirrors that fold down into the light path when the astronomer wants to use the Cassegrain or the coudé focus.

Russell Porter 1938

55

### Coudé Room



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### Almost Complete?

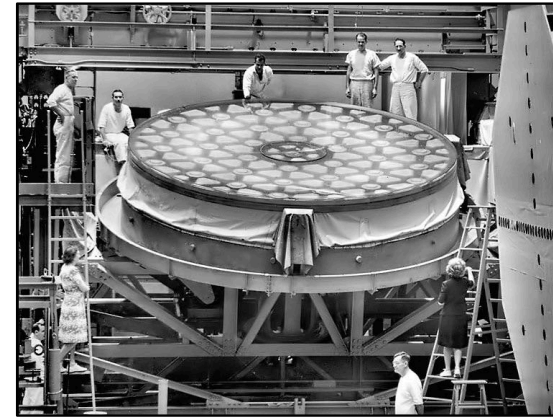
Everybody thinks that the telescope is just months from being finished.

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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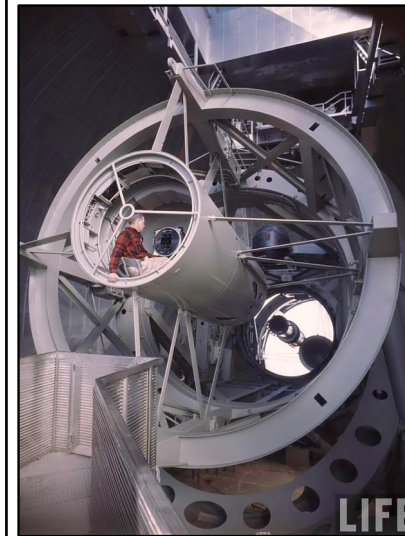
### Final Corrections



1949

61

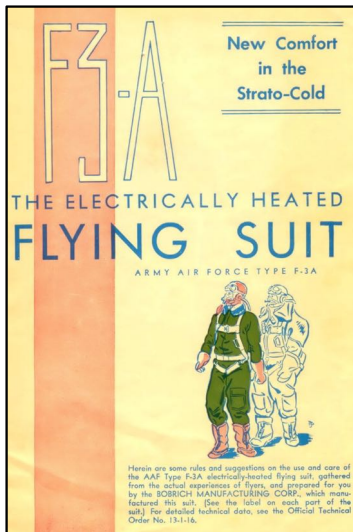
### Operating the 200"



Edwin Hubble in the  
prime focus cage

62

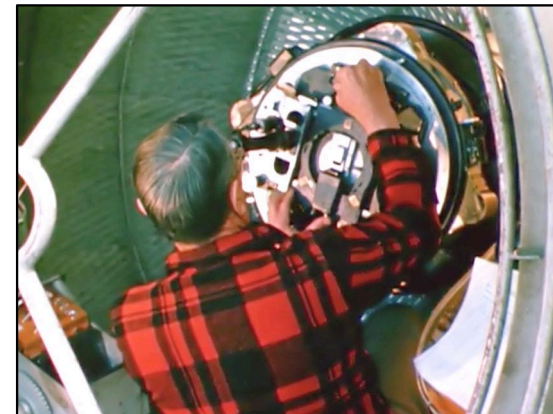
### In the Prime Focus Cage



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



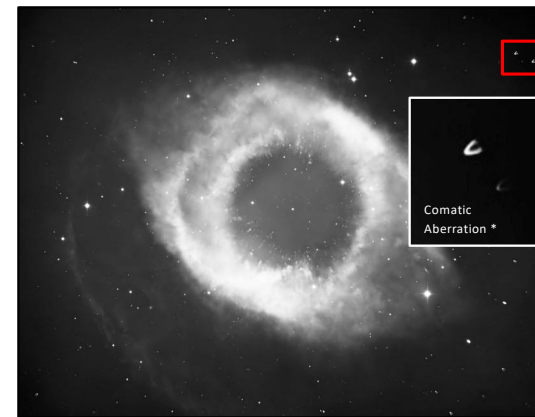
The control desk operated by the  
Night Assistant (in communication with  
the astronomer at the telescope)

Horsehead Nebula

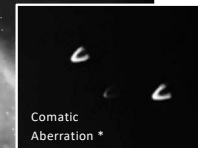


1951

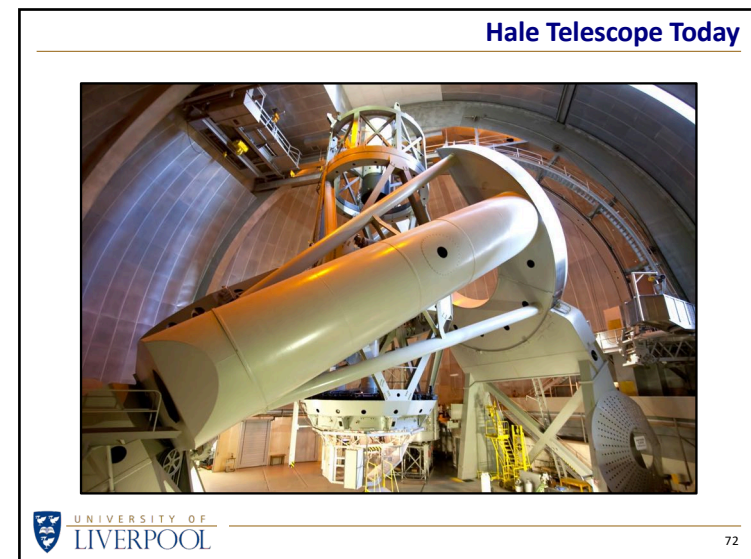
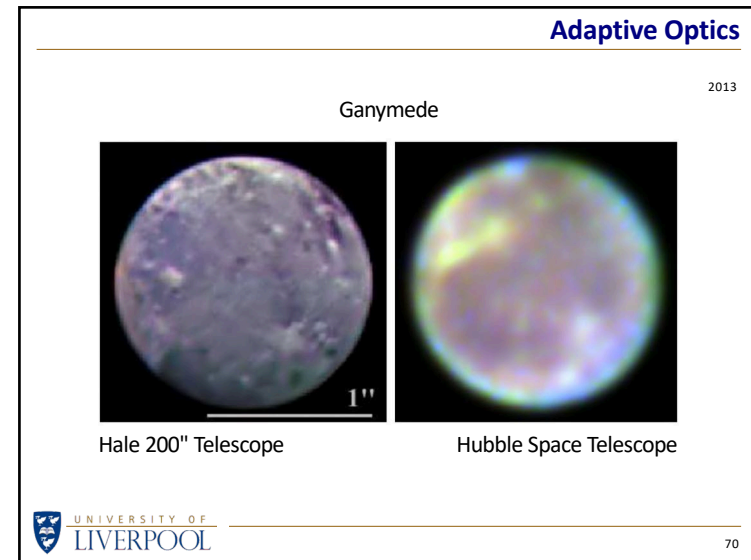
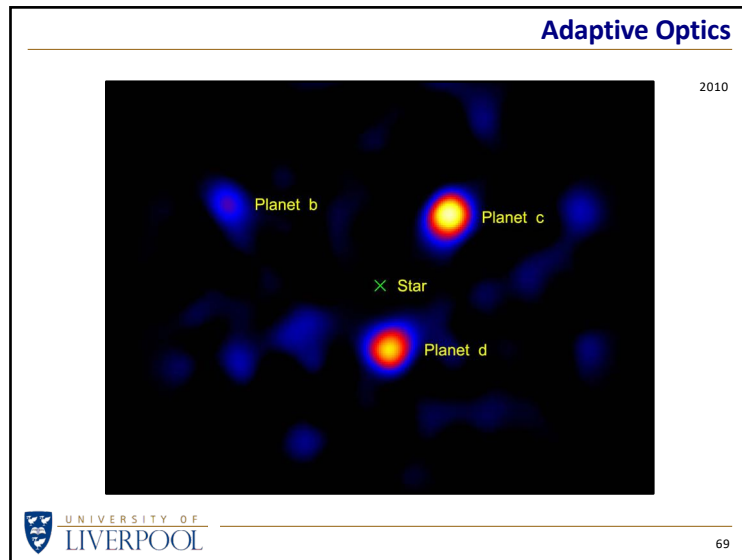
Helix Nebula



1952







### Hale Telescope Today



### Acknowledgements

Caltech archives

[archives.caltech.edu](http://archives.caltech.edu)

[archive.org/details/caltech](http://archive.org/details/caltech)

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

[palomarskies.blogspot.co.uk](http://palomarskies.blogspot.co.uk)

Corning Museum of Glass

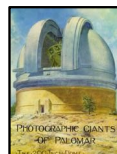
[www.cmog.org/article/glass-giant](http://www.cmog.org/article/glass-giant)

[www.cmog.org/article/hale-reflecting-telescope-palomar](http://www.cmog.org/article/hale-reflecting-telescope-palomar)

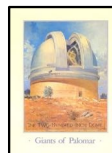
### Acknowledgements



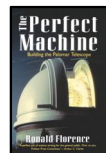
*The Glass Giant of Palomar*  
David Woodbury 1939



*Photographic Giants of Palomar*  
James Fassero and Russell Porter 1952



*Giants of Palomar*  
Russell Porter 1983



*The Perfect Machine*  
Ronald Florence 1995

