Space Telescopes and Their Amazing Mirrors

By Jim Fishbein

Credit to NASA for most images and facts

Milestones in Telescope Development

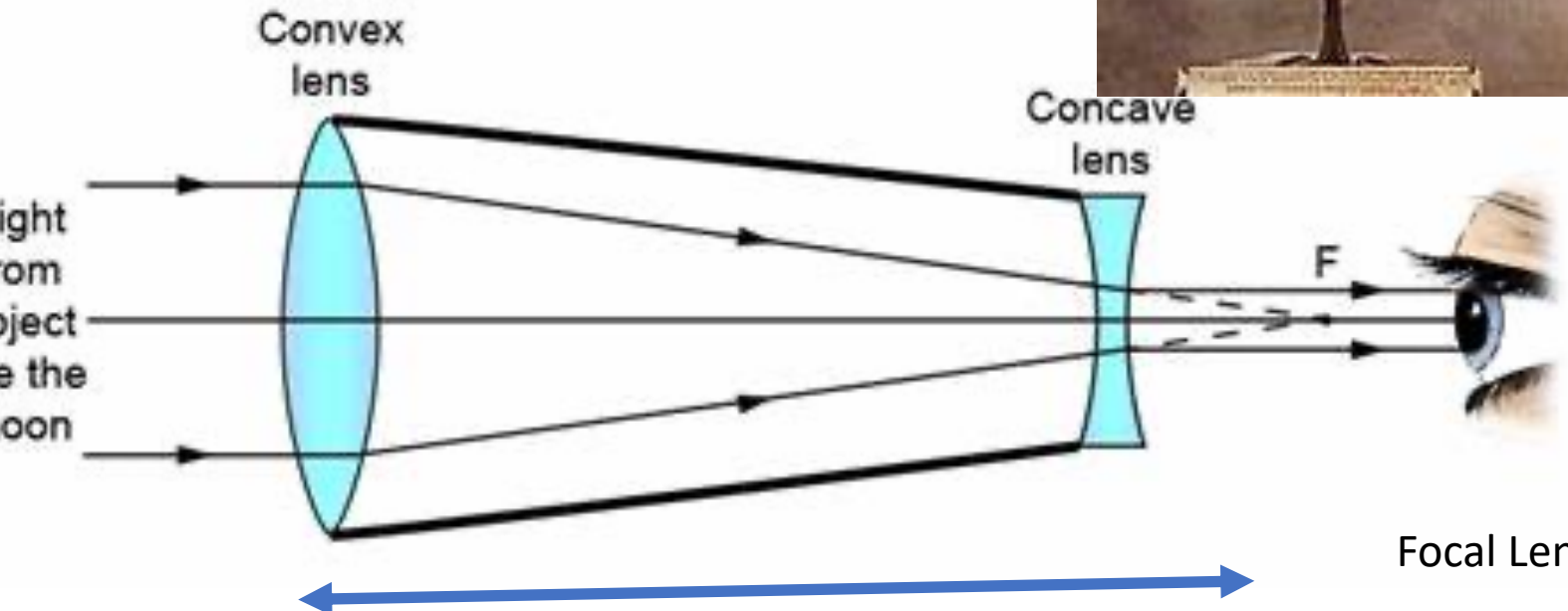
Earth-based glass type

Tube	Refracting		
Galilean 2-4 inch	4-10 inch	72 inch	200 inch
Galileo 1609	Newton 1672	Parsons 1845	Palomar 1948

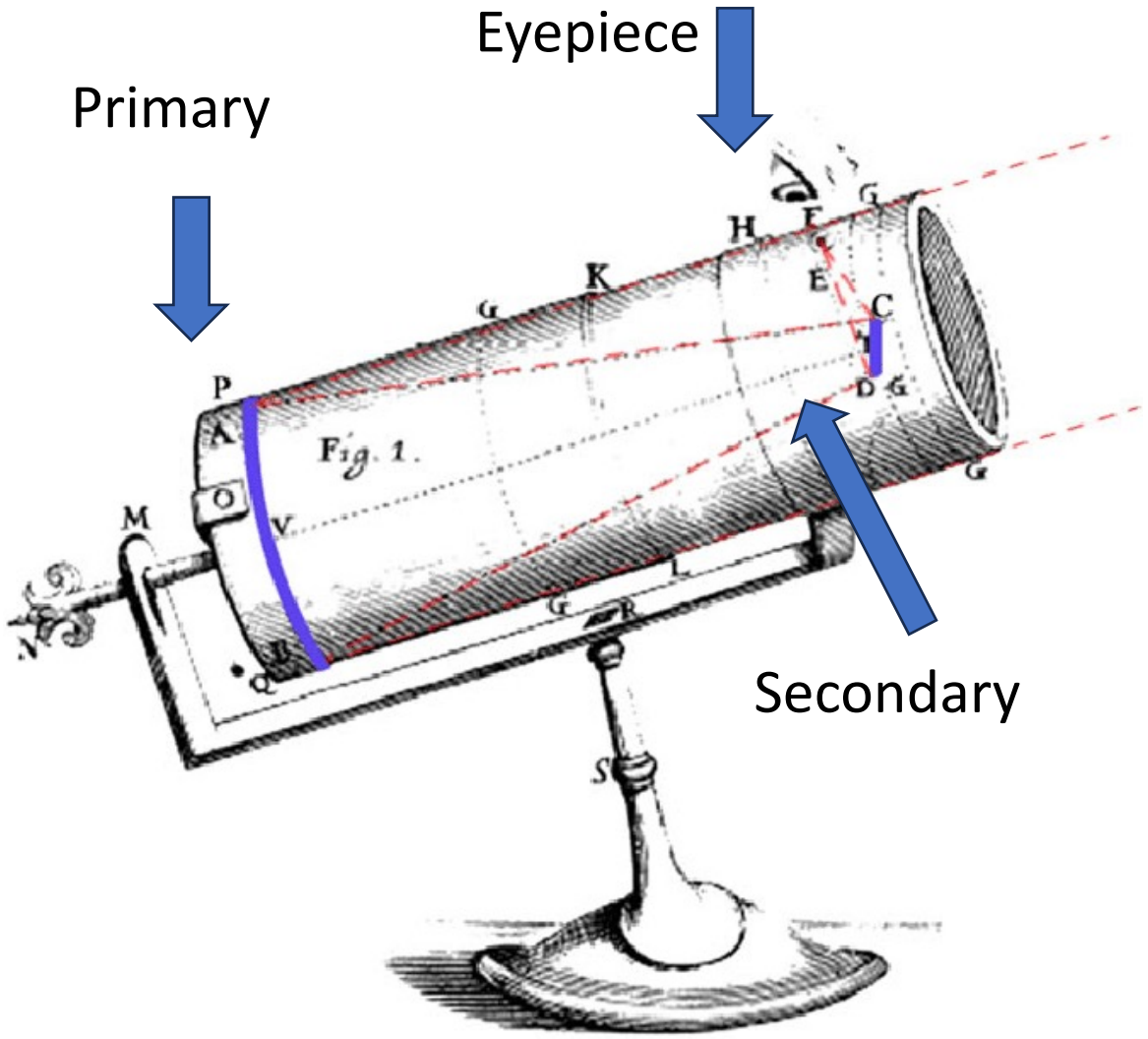
Space-based Multi-Mirror type

Edwin Hubble 1990	James Webb 2021

Galilean Telescope: two glass lenses, One converging and one diverging 1609



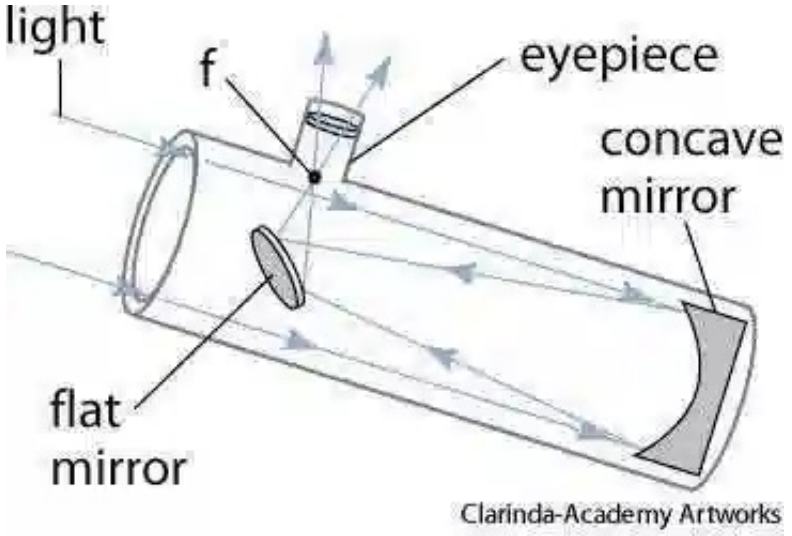
Isaac Newton's Reflecting Telescope 1672



Breakthrough: longer focal length

Reflecting Telescopes Have Three Major Mirrors

- Primary Mirror… the main reflector, light gatherer
- Secondary Mirror… capture image (s) from Primary and direct it to the Tertiary mirror
- Tertiary Mirror… guides the image into the recording and analytic devices



From Earth into Space

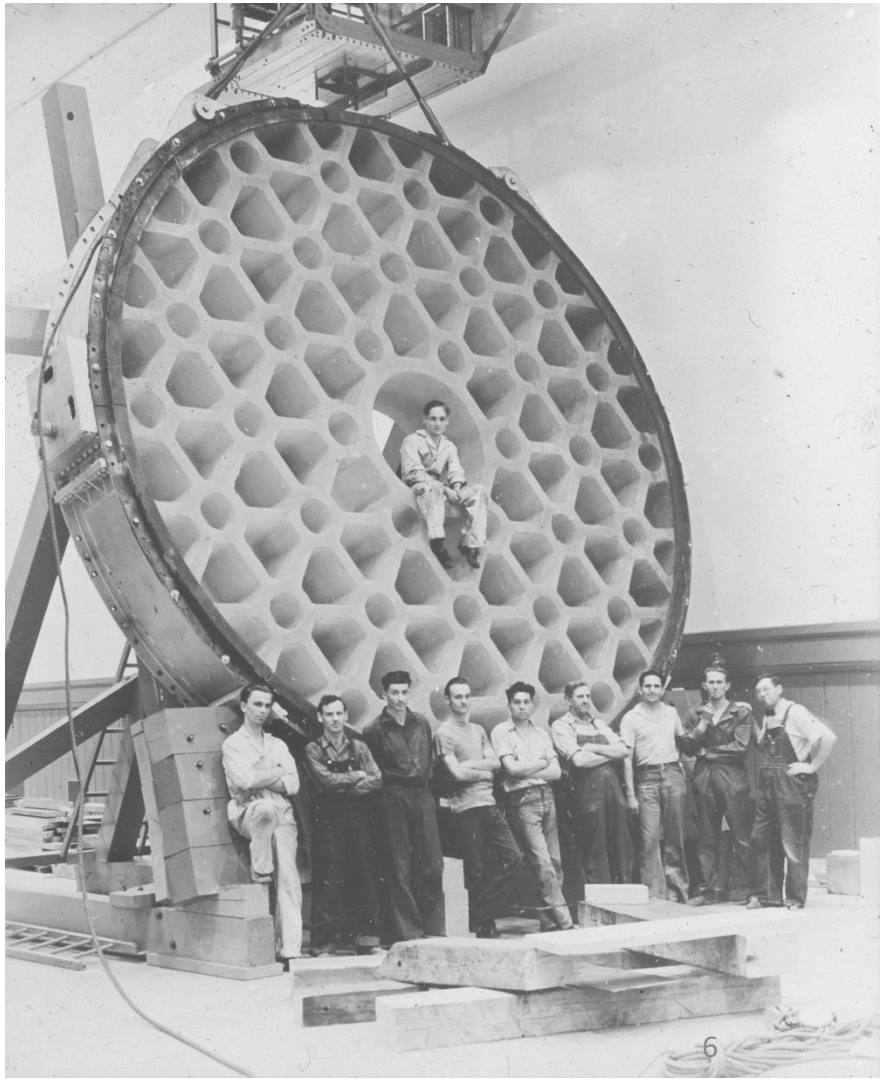
Glass primaries on Earth: A single, pure block of glass

The largest telescopes with glass primaries:
1904 Mount Wilson 100 inch = 8 ft
1948 Mt Palomar Telescope - 200 inch = 17 ft

BUT: Glass lenses maxed out size : too big to cast and polish!

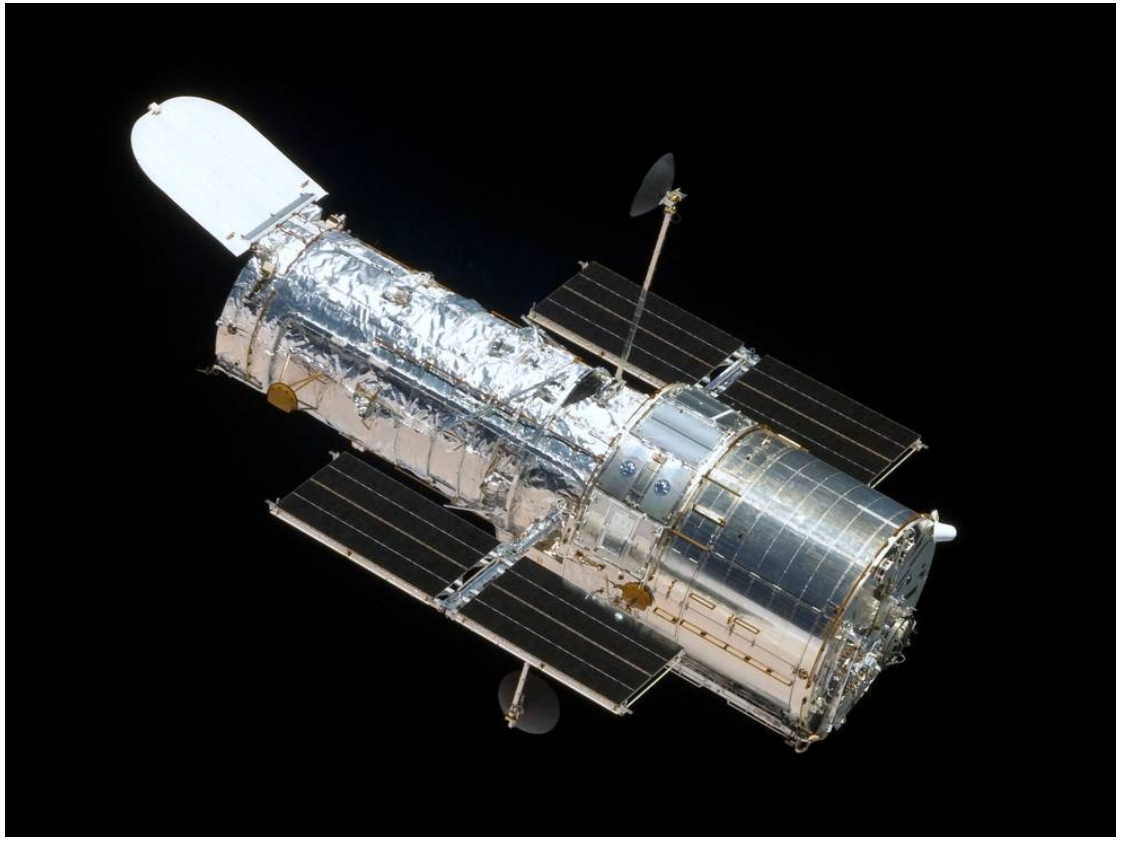
Two breakthroughs: multiple primaries, space

- Less dust/humidity, constant temp, weather, solar power



The Edwin Hubble Telescope

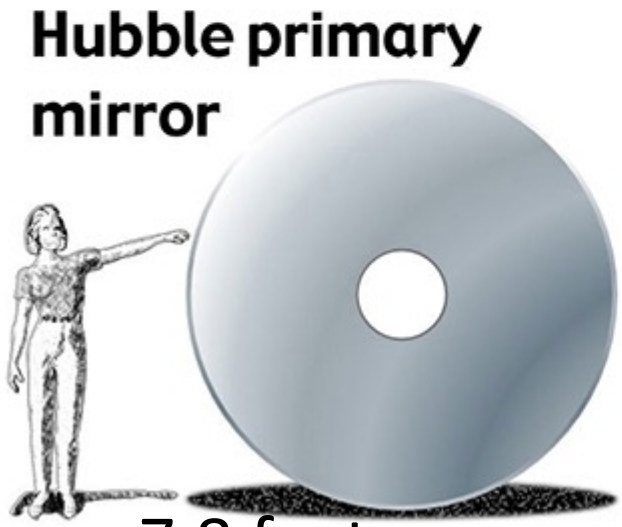
In low Earth orbit, launched from the space shuttle Discovery in1990 and still taking photos from ultraviolet to visible to infrared light!



- Initial flawed lens required a spacewalk!
- Over 1.5 million observations
- 19,000 peer-reviewed science papers
- Looked back more than 13.4 billion light-years
- 5 servicing missions
- Still operating!

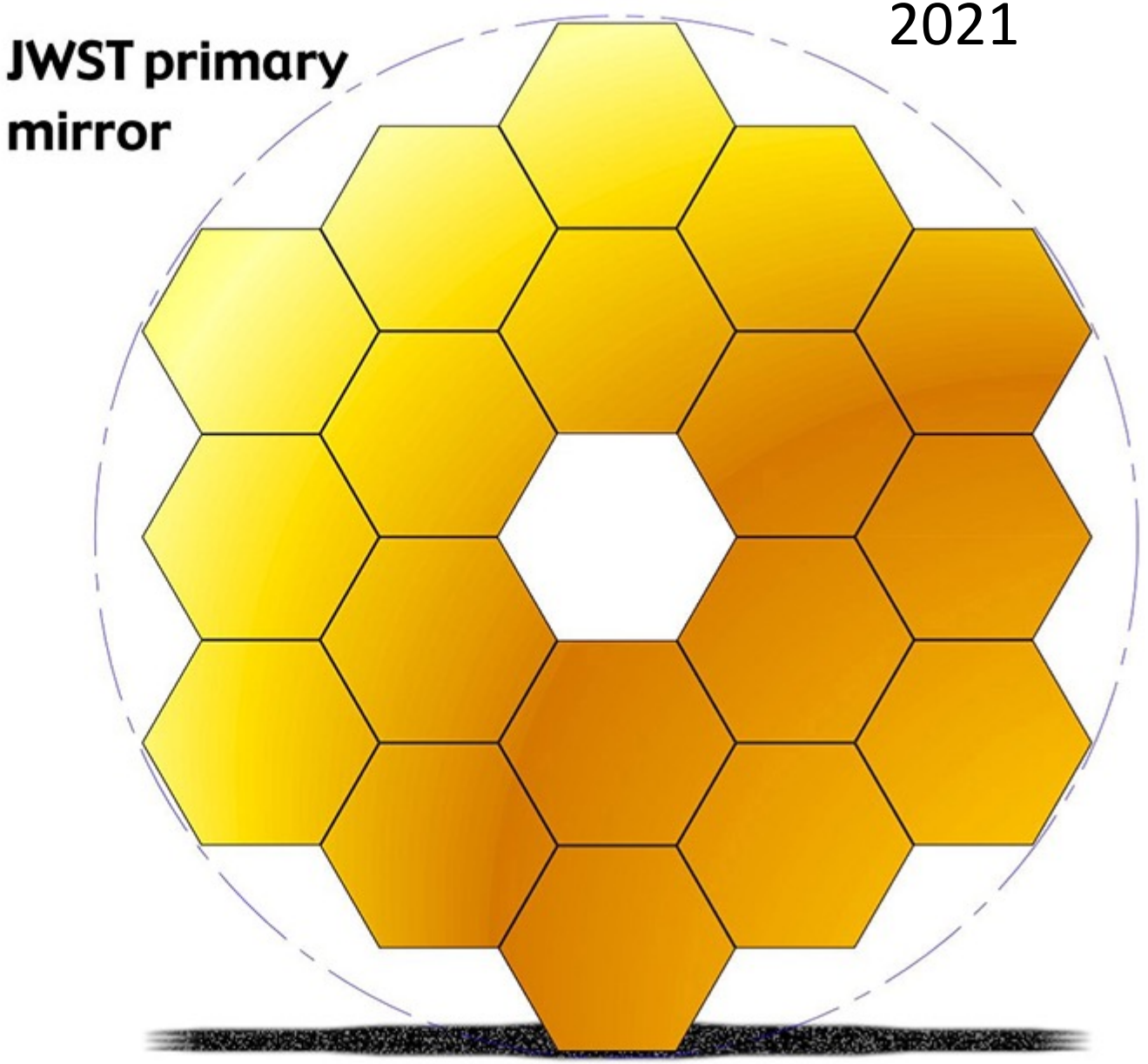
Two Space Telescope Primary Mirrors

1990



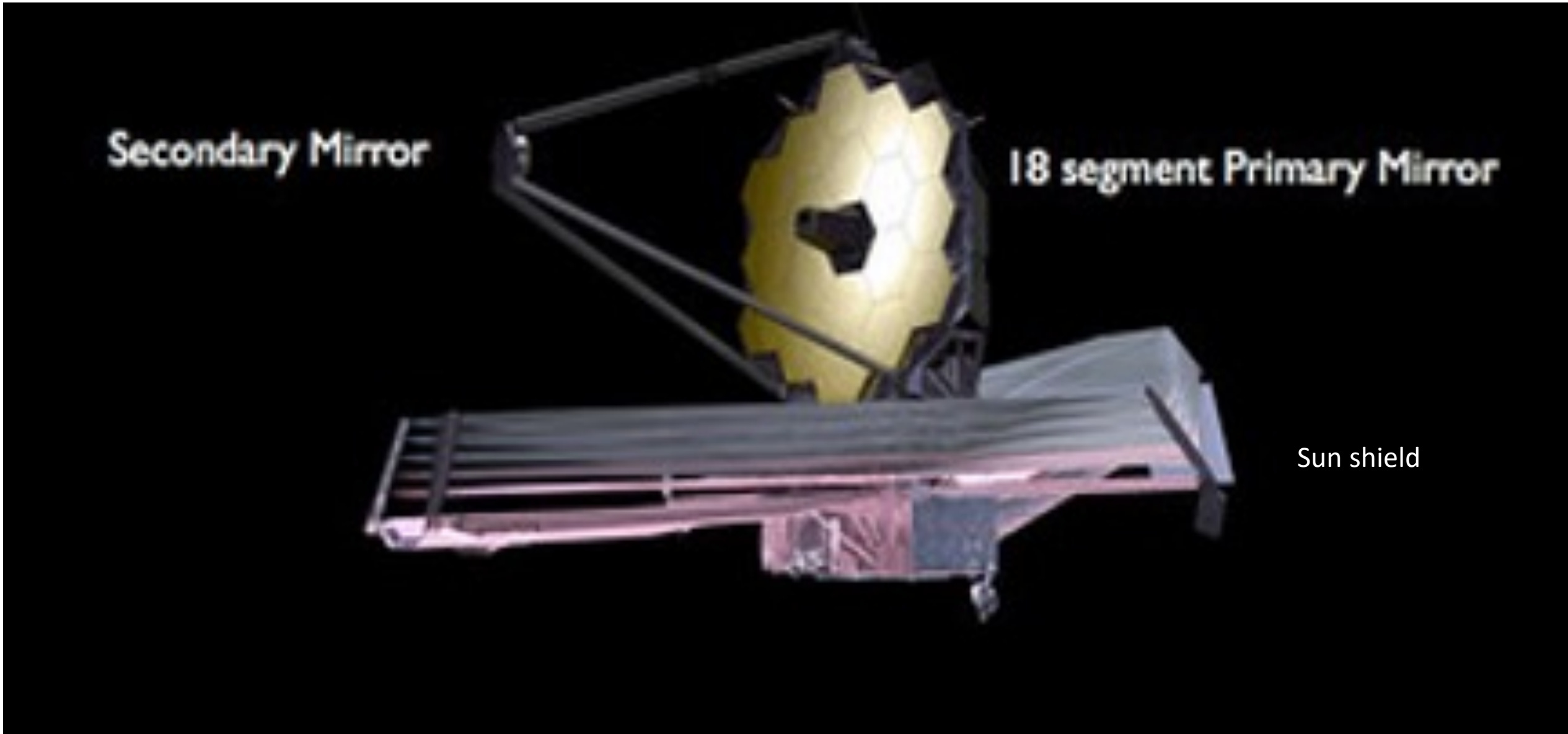
7.8 feet

2021



21.3 feet

Artist Illustration of the JWST



Key to JWST: Mirror Alignment

To produce a sharp focus 18 mirrors must align almost perfectly

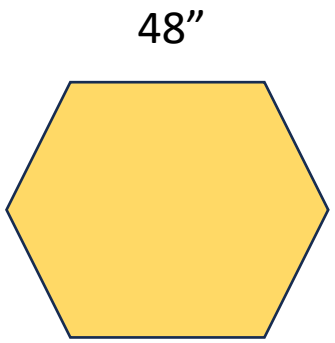
7 Actuators on each segment, tiny, precise mechanical motors

- Six actuators on the back of each mirror for alignment
- One actuator at its center of each mirror to adjust its curvature.

Actuators align each mirror to 1/10,000th the thickness of a human hair

18 Primary Mirrors made of Beryllium

- Beryllium is a strong, light metallic element that holds form in deep cold
- Mined in Utah, pressed from powder into **blanks**
- **Back** was cut away into an **egg crate-looking structure;** much lighter than if solid
- **Front** of each mirror was **highly-polished**

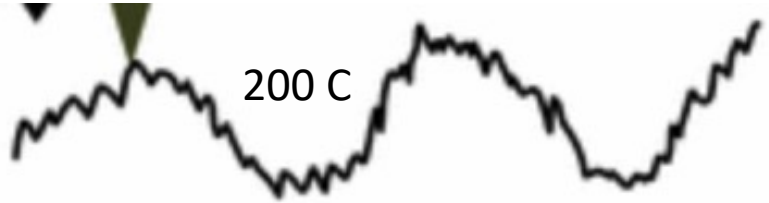


44 pounds, 88 with actuators & Controls

2” thick

Polish the mirrors: the critical step

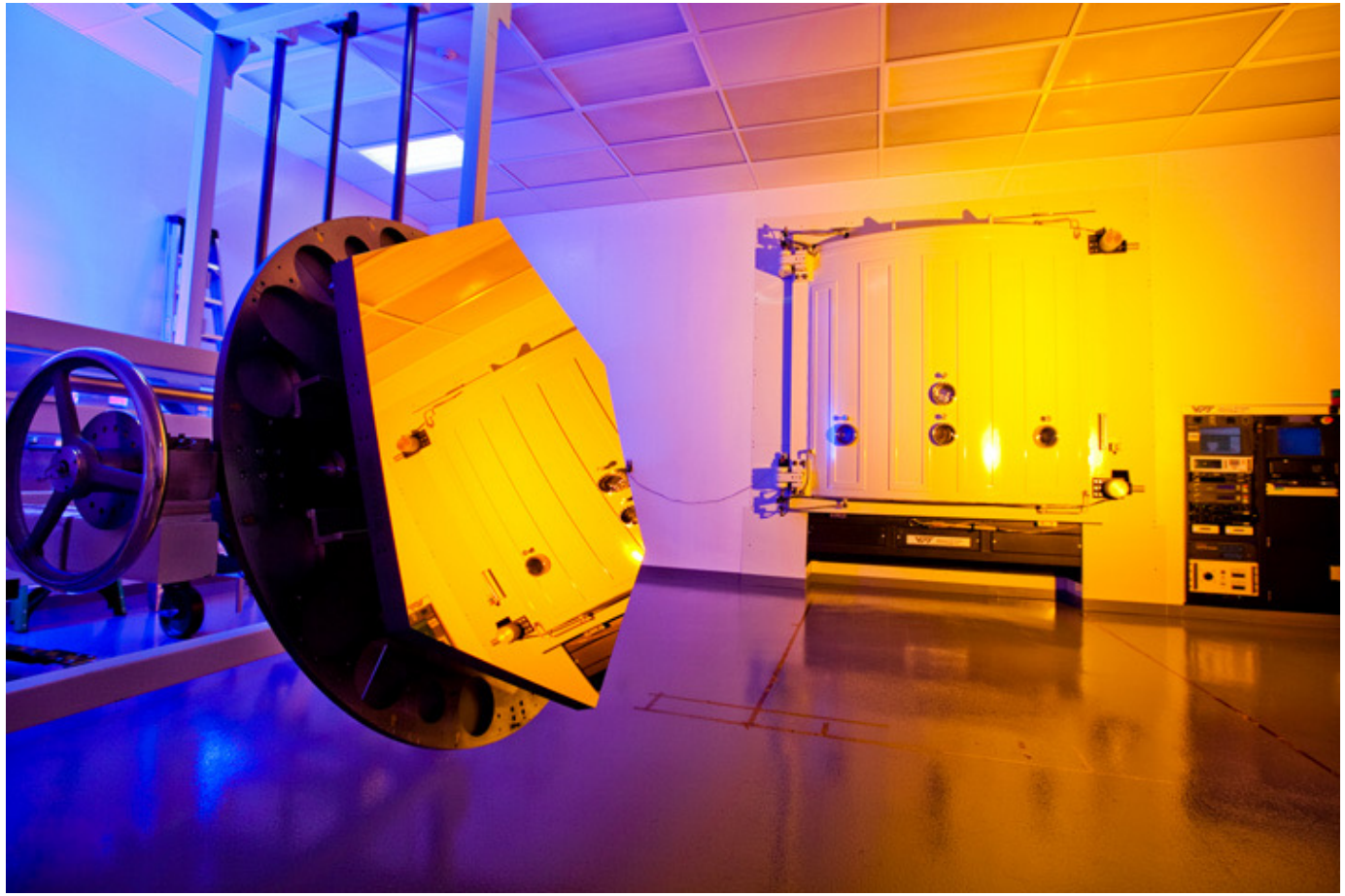
1. Grind the surface near the final shape
2. Smooth and polish the mirrors **to be exquisitely smooth**
   - Polish to an average peak-to-valley roughness of 20 nanometers
     - = 200 carbon atoms versus paper is 100,000 nanometers
3. Cryogenic testing of integrity
   - Deep space is -450 degrees Fahrenheit



Surface roughness of a substrate

https://youtu.be/TFjJ6SZmpTM

Gold-coating the primary mirrors

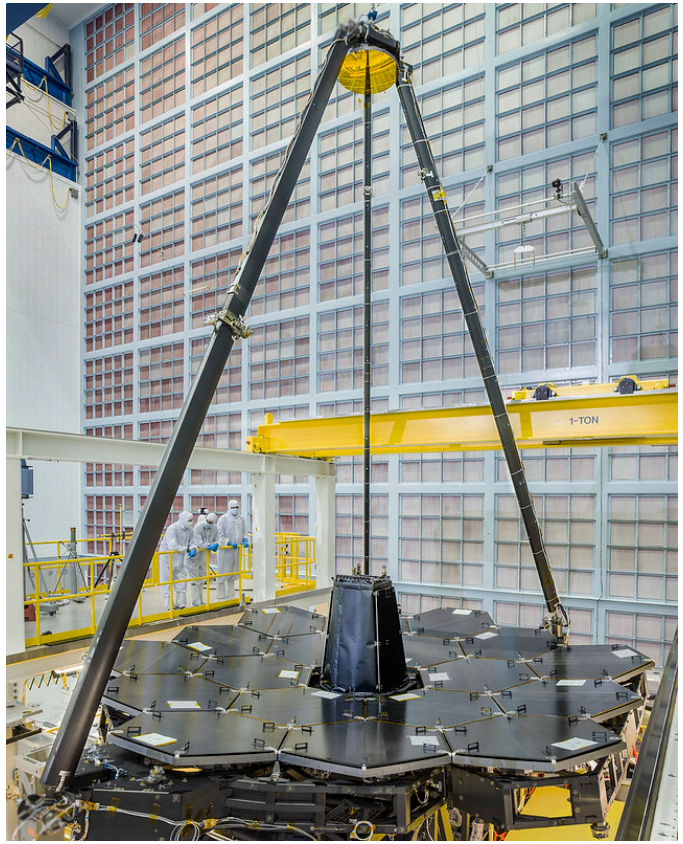


A thin **coating of gold** 100 nanometers thick is deposited in a vacuum

- Gold reflects **infrared** light

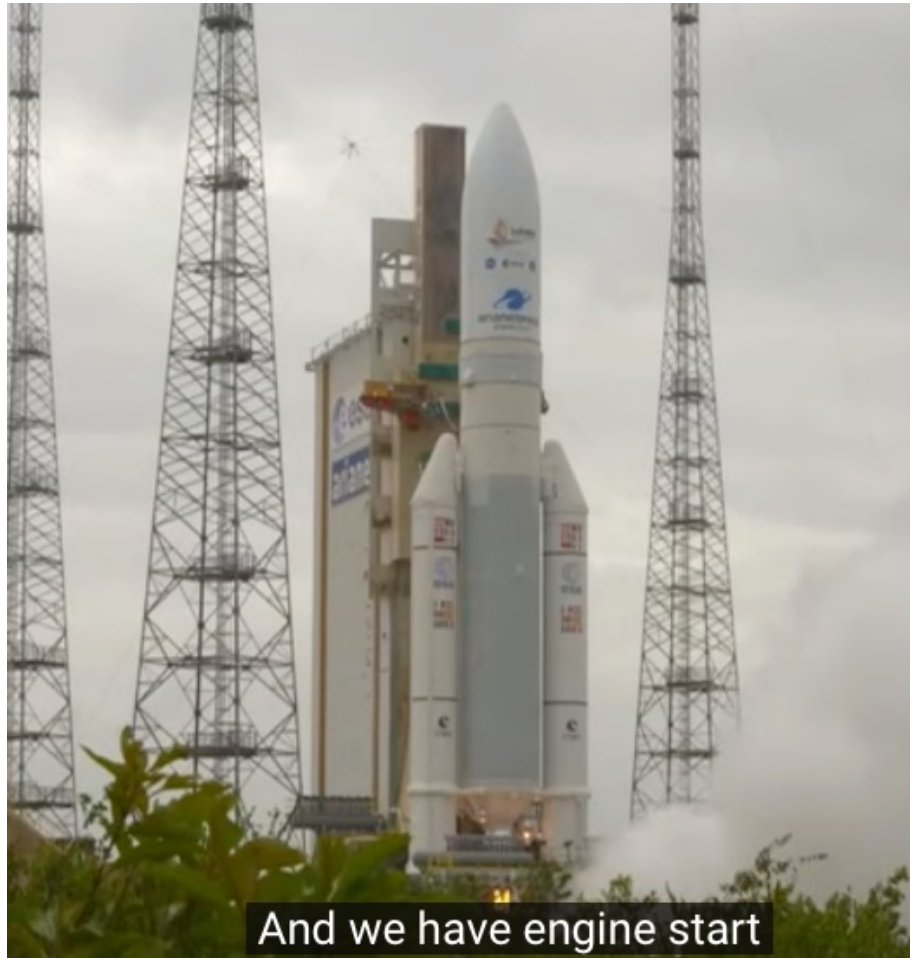
A thin layer of **Quartz** protects it from scratches

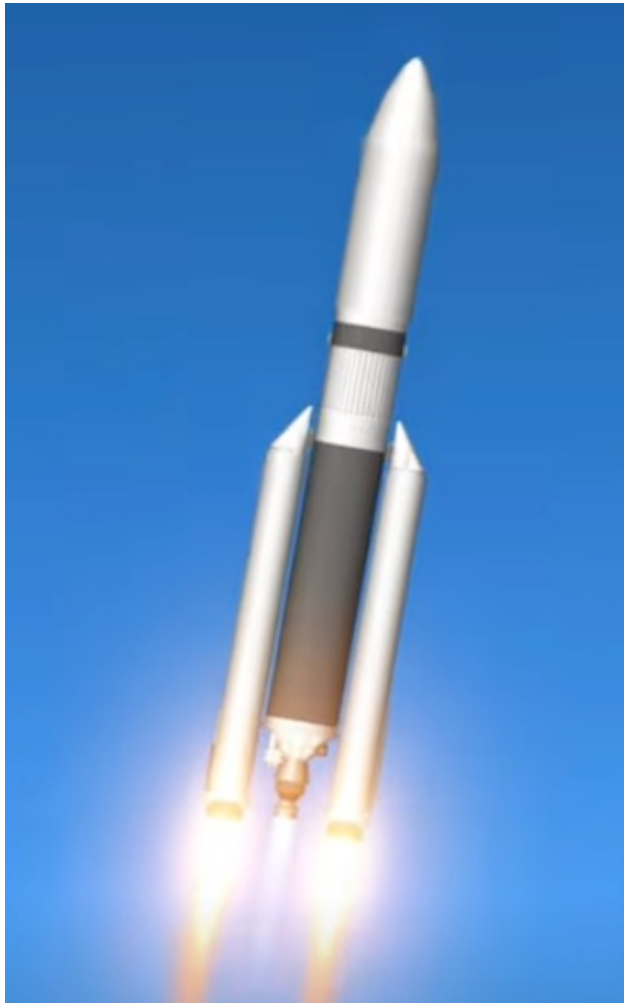
Assembly & Test



F□NAL Testing & alignment

JWST Launch December 25, 2021





JWST image of Star Birth: The Carina Nebula

Previously unseen