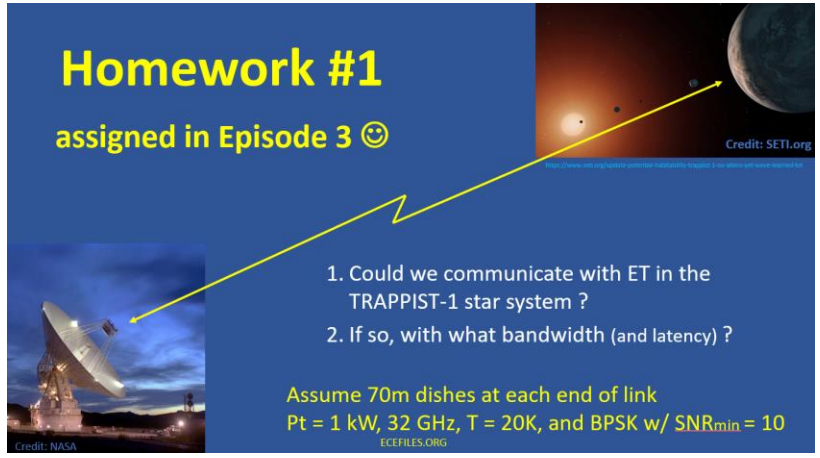
Antenna Briefs #4 -- Interstellar Communication and SETI (Revised)

Slides downloaded from: https://ecefiles.org/rf-design/

Companion video at: https://www.youtube.com/watch?v=fuOVn2YgWRA

This episode looks at communicating across distances of several light-years, and at the big antennas and very large power levels needed. In this revised episode, we start with an errata (list of changes) to the previous Episode 4 video. We then proceed, as before, to the solution to the "homework" problem assigned in episode 3 and apply the results to the Search for Extraterrestrial Intelligence (SETI). The goal is to determine the power levels that must be used, the antenna's needed, and the narrow bandwidths that may be required by “ET” to ‘talk’ to us, very slowly … ;-)



Antenna Briefs #4A


Credit: SETI.org

Interstellar Comm and SETI

(Revised)


Credit: NASA

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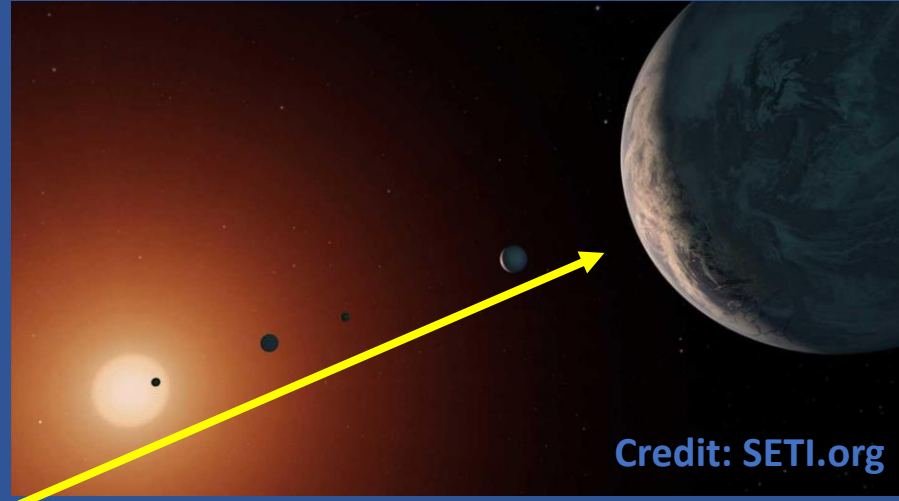
Homework #1

assigned in Episode 3 ☺



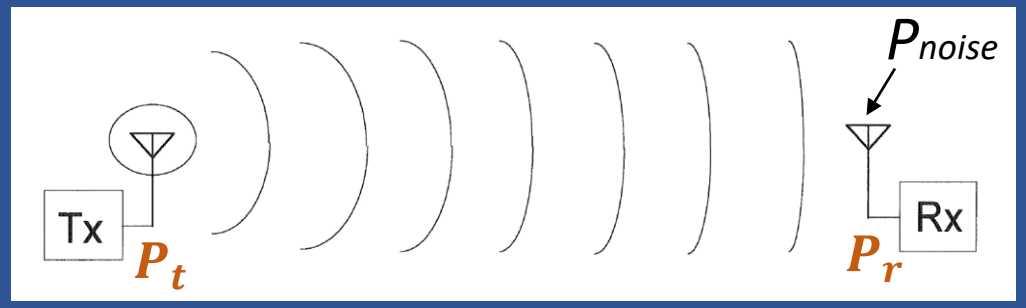
https://www.seti.org/update-potential-habitability-trappist-1-no-aliens-yet-weve-learned-lot

1. Could we communicate with ET in the TRAPPIST-1 star system ?
2. If so, with what bandwidth (and latency) ?

Assume 70m dishes at each end of link

Pt = 1 kW, 32 GHz, T = 20K, and BPSK w/ SNR_{min} = 10

Key Equations from Episode 3



$$P_{density} = \frac{P_t G_t}{4\pi d^2}$$

$$P_r = P_{density}\, A_{eff}$$

$$G_t = \frac{4\pi A_{eff}}{\lambda^2}$$

$$A_{eff} \approx \pi \left(\frac{dia}{2}\right)^2$$

Make this big enough: i.e. $P_r > P_{noise}$, where

$$P_{noise} = k\,T\,B$$

k=1.38E-23 W/Hz.K,

T is temperature in Kelvin

B is bandwidth in Hz

$$P_r = P_t\, G_t\, \frac{1}{4\,\pi\, d^2}\, A_{eff}$$

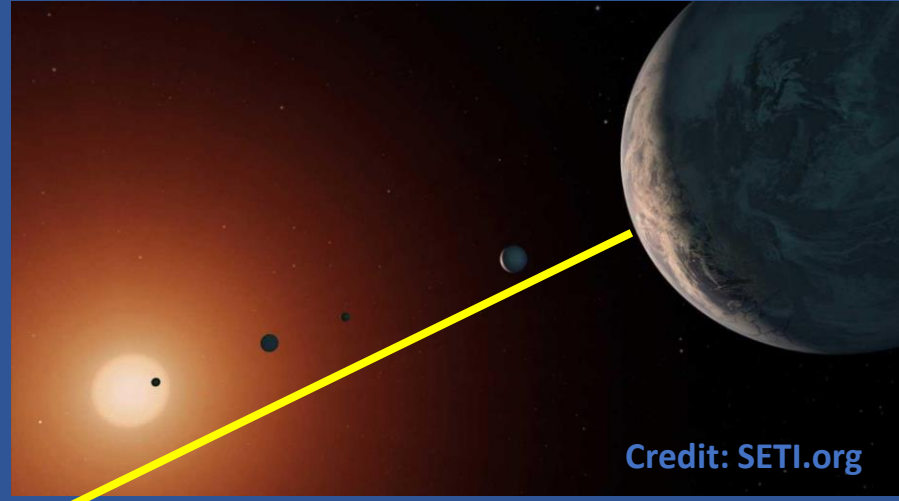
(Revised) Homework Solution

Need: $P_r = P_t \frac{G_t}{4\pi d^2} A_{eff} > (k\,T\,B)\,SNR_{min}$

Given:

Pt = 1000 W
Frequency 32 GHz
Earth-Trappist-1 distance: 39.5LY = 3.7E17 m
Transmit dish diameter: 70 m
Receiver dish diameter: 70 m
T = 20K, SNRmin = 10

Try: bandwidth = 1 Hz ...



https://www.seti.org/update-potential-habitability-trappist-1-no-aliens-yet-weve-learned-lot

229 trillion Miles

Some (approx.) intermediate values:

$\lambda = \frac{c}{f} = 0.0094\ m$

Gt=5.5E8

Aeff=3800 m^2

Then:

P_r = 1.2E-21 (-179 dBm)

kTB = 2.8E-22 W (-186 dBm)

$SNR = 4.3$ $(+6\ dB)$

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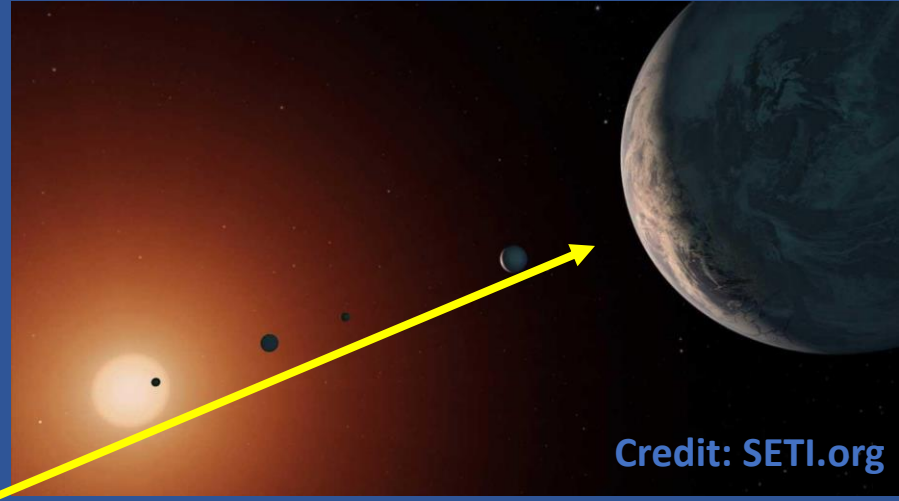
Scaling to get the answer...

Recall SNR needs to be 10 or higher.

So we need to drop bandwidth by a factor of 10/4.3 = 2.3, to **0.4Hz**

Latency is 2 x 39.5 years ☹

Implications for SETI



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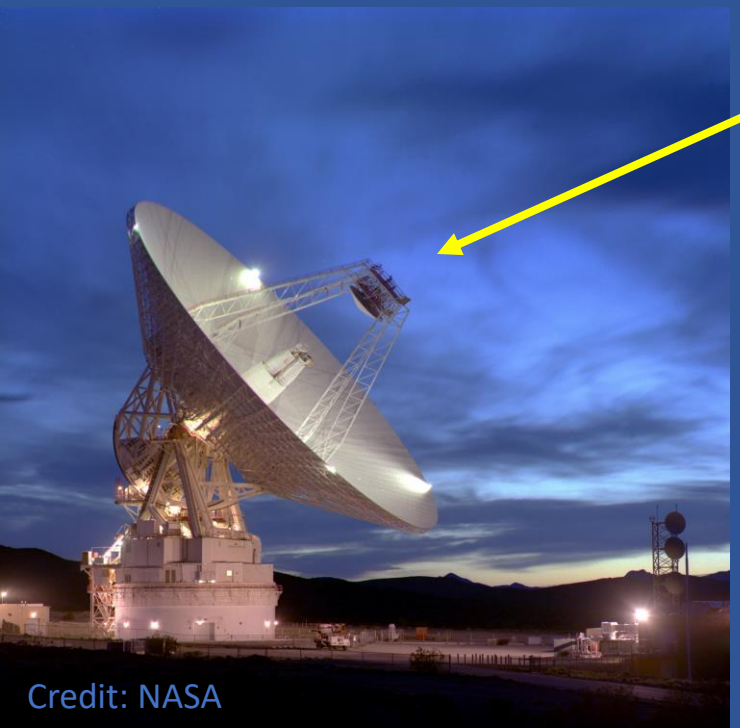


- No “conversations”, at least within a human lifetime
- A bandwidth of 0.4 Hz is a little hard to achieve at 32 GHz (requires oscillator stability of 1E-11)
- 32 GHz is not the ‘right’ frequency for SETI anyway.

So How Can ET Reach Us ?

We Need: $$P_r = P_t\, G_t \frac{1}{4\,\pi\, d^2} A_{eff} > (k\,T\,B)\, SNR_{min}$$

Recall homework result:

- SNR was 4.3 at B=1Hz with 70m dishes at each end, but we wanted SNR >= 10

Pt Gt used by ET needs to increase by…

- 2.3x if we use 1 Hz bandwidth in our search
- 500x more to use the 1420 MHz magic frequency

ET's Options:

- Increase *Pt* from 1 kW to **1.2 MW**, or
- Increase transmit antenna from 70m to **2.3 km diameter** (and point it really well !), or
- Use some combination thereof, or
- Wait till we make our antenna a lot bigger (and/or use much lower bandwidth…)

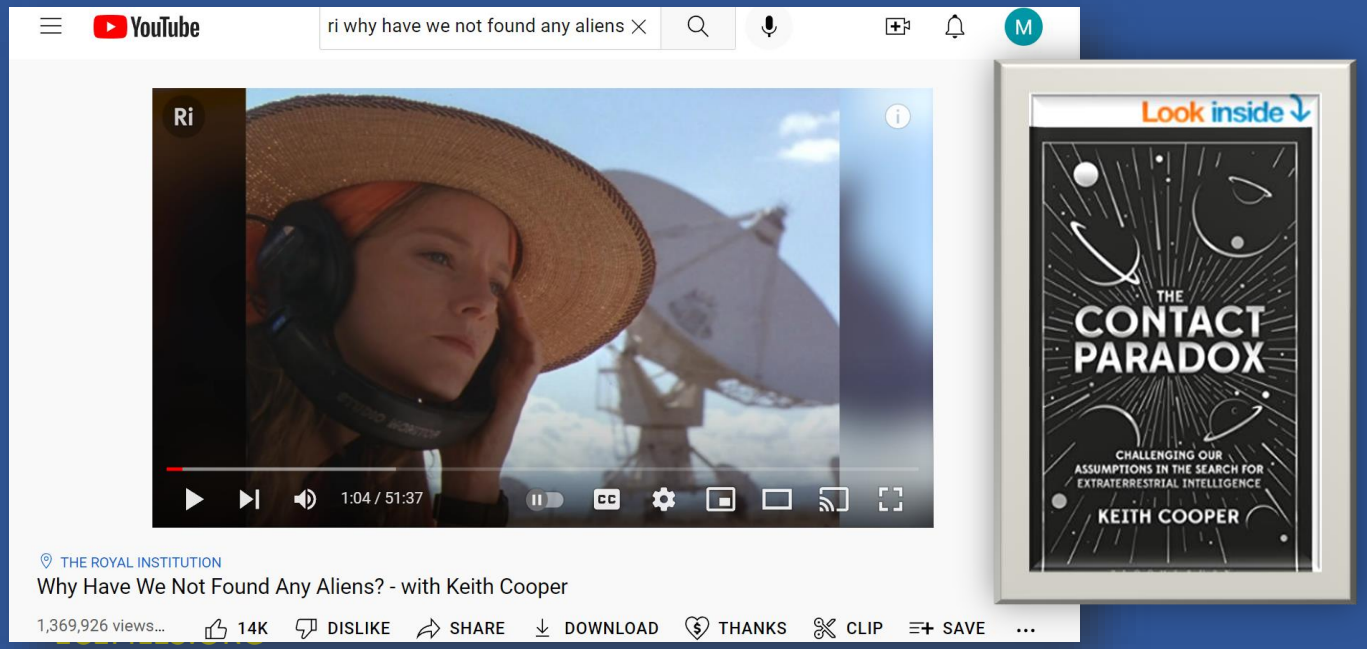
NOTE:

- This is for Trappist-1 at 39.5 LY
- To reach to around 400 LY (for more candidate stars), we need another factor of 100x in Pt Gt or *Aeff*

Things to Ponder …

- At 1.2 MW with 70m dish at 1.42 GHz, ET needs to point at us with accuracy of 0.15°
  Or, do an omnidirectional broadcast with Pt = EIRP = (1 kW)(5.5E8) = **500 GW !**
- They don't know when we're listening - so they need to transmit for years/decades
- **Why would they do all of this ?**
  (Maybe they have emotional intelligence too, and want to be helpful/nice…)
- **Other possibilities**

THE ROYAL INSTITUTION
Why Have We Not Found Any Aliens? - with Keith Cooper



Some Technical References


Credit: JWST


Credit: NASA

- Giuseppe Cocconi, and Philip Morrison, "Searching for Interstellar Communications", Nature, 1959.
- Bruce Murray, Samuel Gulkis and Robert E. Edelson, "Extraterrestrial intelligence - An observational approach", Science, 1978.
- Cordes and Woodruff, "Astrophysical coding: A new approach to SETI signals. I. Signal design and wave propagation", ASP Conf., 1995.
- Sheikh, et.al, "Choosing a Maximum Drift Rate in a SETI Search: Astrophysical Considerations", 2019. https://arxiv.org/pdf/1910.01148.pdf

Future “Antenna Briefs” Episodes

Back to Earth in Episode 5:

Electric (E) and magnetic (B) fields

Power and impedance

Far-field pattern calculation

Antenna simulation

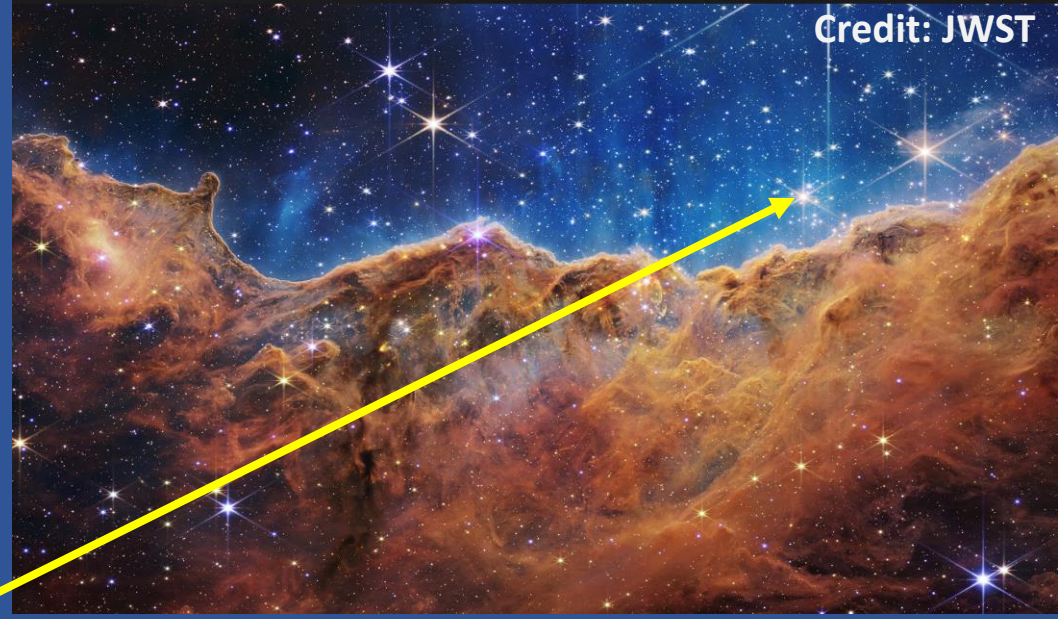
What “are” E, B and EM fields ?

Additional episodes

- Antenna counterpoise, baluns, and chokes
- Reflection of E and H fields
- Design of some basic antenna types
- Phase, superposition, and beamforming…

Thanks for Watching

- Traditionally the Hydrogen line frequency of 1.42 GHz is targeted (assumed most likely to be used by ET ☺)
- Implies less transmit antenna gain by factor of (32/1.42)^2 = 500 ☹
- Solutions include significantly increasing dish diameter(s) and/or assumed transmitter power.
- Dish surface accuracy, pointing requirements, and resulting dwell and scan times are also potentially problematic …



https://en.wikipedia.org/wiki/Arecibo_Telescope


Arecibo Observatory, aerial view, 2012

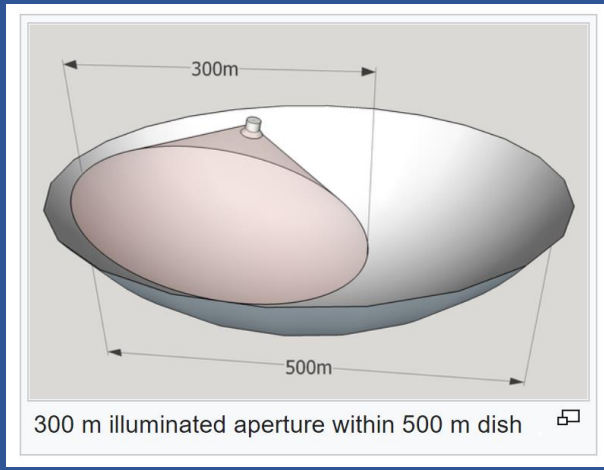
https://en.wikipedia.org/wiki/Five-hundred-meter_Aperture_Spherical_Telescope

Five-hundred-meter Aperture Spherical Telescope

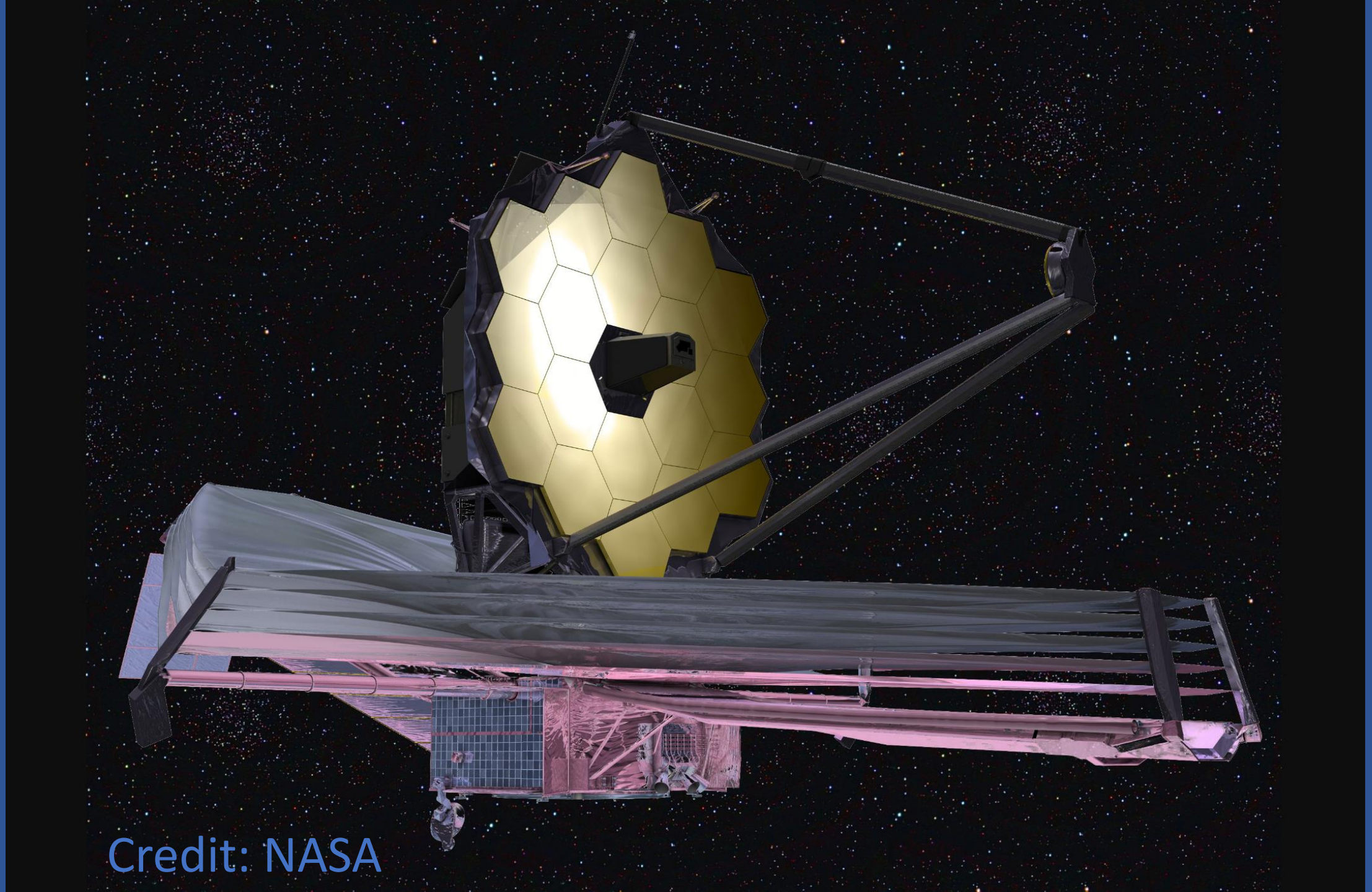

The telescope as seen from above in 2020

Alternative names Tianyan

Effective aperture is 200 to 300 m
Maximum frequency is 3 GHz



300 m illuminated aperture within 500 m dish



Credit: NASA