How expensive would building the Death Star be?

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1. Start with the big picture problem & 2. Define problem so a clear numerical answer can be obtained

[1] Image of DS-1 MBS

[2] Image of an incomplete DS-2 MBS

In this report, our large-scale problem would be how much would it cost to build the Death Star. Now this large question leaves large room for assumptions so first we will need to define the problem so we can get a clear numerical answer. A key distinction we must make is that we are referring to the Death Star mobile battle station used in Rouge One and in A new Hope [1] and not to the one used in Return of the Jedi [2]. Our new question that we will be using so that we can get a numerical answer would be: How much money in United States Dollar (2024) would it cost to build the Death Star 1 in terms of the materials, equipment and labour.

3. Estimate the magnitude and units of answer

Because of the sheer size of the battle station, we will have to use scientific notation to list the costs. If we are to use scientific notation, we can estimate that it will cost of being that of at least that of the power of 20, 1,000 times the GDP of the world. This is

4. Decide the state of mathematical strategy

The also,h Star would be an astronomical undertaking to build not only the super laser but also the hull and many more. Therefore, to tackle this question we will separate all the costs, then separate out the ones with the highest cost and calculate those since a large majority of the cost would be those. After looking at all the aspects of the Death Star, we can pin these 5 aspects as the most expensive:

- Material cost of the hull – The cost of the main hull would encompass the building of the frame, panels and internal structure of the 160km kilometre battle station.
- Main battery – As seen in a New Hope and in Rouge One, the death star can destroy a planet in about 4 seconds with a massive laser. Currently our lasers can barely burn through steel so this laser would have to be incredibly powerful.

- Power generation – A laser with the power to destroy a planet would take a large amount of energy, therefore we must have an equally large power generator onboard.
- Cost of sending it to space – This will be both the cost of fuel and the production of rockets or other methods of transportation.
- Labour

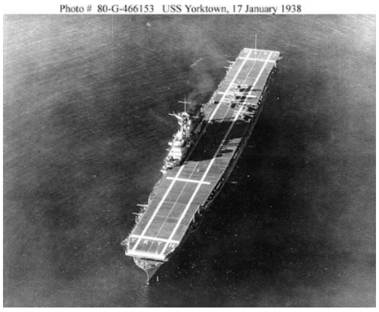
Note: Although these are the biggest aspects some notable others that would either be too hard to calculate or small compared to the total scope will be listed below:

- Secondary batteries – Although we know the amount of them, the cost compared to the main battery will be small. As well as this, the method would be very similar to calculating the main battery and therefore we would not learn much from calculating it individually.
- Research and Development – The cost of this is basically impossible to calculate due to a lot of it being wages but also the development other failed technologies and dead ends.
- Screen Fighters – The cost of the tie fighters and other small craft would have similar steps to this but most with most of the cost coming from R&D. This makes it hard to calculate as although we know the general evolution of the Tie fighter which stem from the V-wing star fighter which was used during the clone wars we have similar dead end issues.
- Any sort of cost based on Imperial credits – Since the economy is driven by supply and demand, the purchasing power of certain goods will change at different rates to others due to supply and demand. I.e. the ratio of the cost of bread

5. Research required information

The Hull:

The hull of Death Star can be described as a metal sphere with a radius of 80km with rooms, walkways and hangars inside. To calculate the tonnage of the hull, we need to calculate the ratio of steel to empty space inside the Death Star. To do this we will use an Aircraft carrier as a reference, like the Death Star, Aircraft carriers have large hangers for aircraft, hallways and rooms for eating, sleeping and control. We know the tonnage of an aircraft carrier, but we do not know the volume. If we use the beam, length and draft we can calculate it by approximating its shape into a triangular prism. For this reason, we will be using the Yorktown class

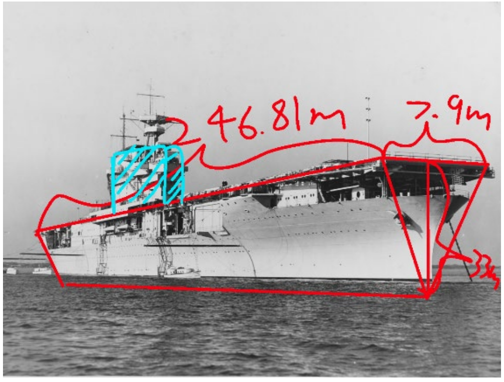


[3] USS Yorktown, 1938

carriers [3] as a model which is an older carrier that does not use an angled flight deck like the Gerald R. Ford class [4].

[4] USS Gerald R. Ford, 2017

With the length being 246.81 meters, the draft being 33m and the beam 7.9m we get a calculation for the total volume. We can also find that the displacement of the Yorktown class is 19,800 long tons [5] which when converted to kilograms is 20,117,729 kgs. To calculate the kilograms per meter cubed we just divide the displacement by the volume



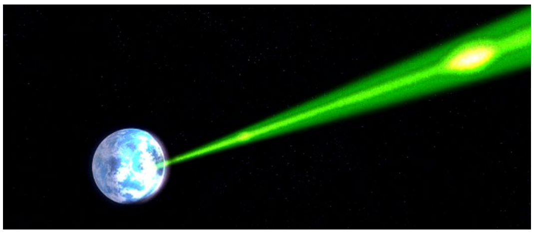
$$Volume = \frac{Beam \times Draft}{2} \times Length$$

$$\frac{Density}{Volume} = kilograms/meters^3$$

As stated earlier the Death Star is essentially a sphere with radius 80km which is equal to 80,000 meters. Since most modern spaceships use stainless steel, we will be using that for our calculations. The cost of Stainless steel 304 is between $0.70 and $1.10 AUD [6], this is equivalent to $0.46 to $0.72 USD [16].

The Super Laser

The main weapon of the Death Star is a super laser that can destroy planets in one blast. As seen in A new Hope, the death star destroys a planet very similar to earth in about 4 seconds [9]. To calculate this, we will need to know the amount of energy required to destroy a planet, then we will need to calculate the cost of a laser capable to performing a feat like that.



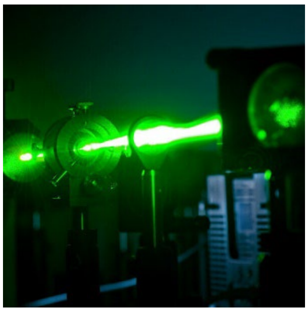
[9] Death Star destroying Alderaan

To destroy a planet, our best assumption is that the laser needs enough energy to destroy the gravitational field of the planet. From Lang (2013, p.p.272), for a solid planet we can get the gravitational binding energy U given by the equation:

$$U = \frac{3GM_p^2}{5R_p} \text{ [10]}$$

Where M_p is the mass of the planet and R_p is the radius of the planet.

Image of the Vulcan 20-20 laser [22]



At the current date, the world's most powerful laser currently is the Vulcan 20-20 [11]. While it is still being upgraded it will be a 20 Petawatt or 2×10^{16} Watt laser. If we assume that laser power scales linearly, we will just have to multiply the cost of the Vulcan 20-20 which would be 82 million GBP or 103.87 million USD by how much more powerful the Mk-1 super laser is than the Vulcan.

Power Generation

We know that the Death Star uses a class 4 hyperdrive engine [12], since this technology does not exist, we will not be calculating the energy required for the propulsion. Additionally, since we don't know the amount of energy shield generators holograms or how many computers are on the vessel we will be excluding them. That will mean we only need to calculate the energy required for the mega laser. According to Paschotta [13], the maximum energy efficiency of a diode laser is above 70%. Therefore, to calculate the energy required to shoot the laser is with the following formula:

$$Energy\ required\ to\ destroy\ planet \times \frac{100\%}{100\% - \ energy\ efficency} = 100\%$$

Now according Wookiepedia [14], the first Death Star takes a day to charge up. This means we need to convert the energy required to kilowatt hours. We will then divide the energy required by 24 since we have 24 hours to charge up the laser

$$\frac{Energy\ required}{3600 \times 24} = watts\ hours\ required$$

Image of Kashiwazaki-Kariwa powerplant, 2007 [17]

Since currently we have no real way of using anti-matter efficiently, we will need to rely on nuclear fission to provide power. Currently the most powerful nuclear powerplant in the world is the Kashiwazaki-Kariwa nuclear powerplant in Japan [15]. The KK-7 reactor in the powerplant is the newest and most powerful reactor so we will use that as a reference. The installation cost per kilowatt is ¥280 JPY or $1.82 USD [16], to convert this to kWh we will multiply it by 24. We will then multiply this by the required amount.

$$kWh\ required \times (24 \times Cost\ per\ kilowatt)$$

Transportation:

Because of the sheer size of the death star, that would mean we need to build an absurd number of sections. If we were to ship them up in the size of passenger aircraft, it would still be very inefficient. Therefore, we can rule out attempting to ship fully manufactured plates up. A better solution would be shipping up raw steel and producing them in space, this would mean we could send it up more efficiently as there would be less space.

SpaceX's newest spacecraft the Starship has become the first spacecraft with both the first and second stages reusable. This means costs are that of only fuel, maintenance and the use of the pad. Currently the price per flight is $10 million USD and $2,540 per kilogram in the hull according to Elon Musk, SpaceX's CEO in the future the costs could be driven down as much as $2 million with the cost per kilogram only $100 per kilogram. Therefore, to calculate the cost of sending the steel into space we will multiply the steel needed in kilograms by 100.

Image of the SpaceX Starship heavy lift launch vehicle [20]

$$kilograms\ of\ steel\ needed\ \times cost\ per\ kilogram\ sent\ up\ to\ space = transportation\ cost$$

If we are using rockets however, we will need to calculate the cost of the rockets used. Since there is no official data online, we will have to base the cost off, currently estimates range from $90 million with a majority of that being from the 39 Raptor engines it uses each costing at least a million [19].

To calculate the number of rockets we need we will base that off the current world steel production which is 1.9 billion metric tons in 2022 [7]. If we are to assume that it takes 1 month for a rocket to fly up, deliver its cargo, return to earth and be ready to fly again this means each rocket can make 12 cycles a year. Since the capacity of a Starship is 150 metric tonnes [20], we can calculate the total cost of the spaceships we need per year with this formula:

$$\frac{Steel\ production\ per\ year}{cargo\ capacity\ per\ ship \times cycles\ per\ year} \times cost\ per\ spaceship = Ships\ needed$$

Labour:

For labour bar calculating how many manhours are needed for the entire thing meticulously, the best option is mealy getting the average of what the percentage of the budget is usually being spent on labour for construction projects.

According to Austin (2021) [21], the percentage of the budget used on labour is generally 20-35% but can go as high as 40% if skilled or specialized workers are needed. Since the death star will most likely require laborers who use spaceships instead of cranes or forklifts that will mean it falls into the second category. Therefore, after we have calculated the costs of the other parts, we will just use the following formula:

$$Cost\ of\ the\ rest \times \frac{100}{60} = total\ cost$$

6. Create and justify assumptions

Assumption	**Reasoning**
We will assume that the internal density is like that of an aircraft carrier	Since an Aircraft carrier is the closest real life equivalent of the Death Star, we must assume the internal density is similar.
We will assume that the ratio of power of lasers and cost of lasers scales lineally	Although technology rarely scales linearly, we can get an estimate if we assume it does.
We will assume advanced technology like tractor beams, shield generators and hyperdrives do not need to be factored into the cost.	Since we don't have anything like any of these technologies or they are straight up sci-fi we can't really turn them into numerical values and therefore can't calculate them.
We will assume any planet the Death Star is firing at has no sort of shield generator or specialized defensive measures	
We will assume that destroying a planet means creating enough energy to destroy the gravitational field of the planet	Due to lack of time, we must assume for this model that destroying a planet means creating enough energy to destroy the gravitational field.
We will assume the planet we are shooting at is a similar size of earth	The only planet we see on camera getting completely destroyed by the Death Star is Alderaan, we must assume the planets we are destroying are that size and are also not a gas giant
We will assume the planet the super laser is firing at is a solid planet	
We will assume that we will not need to worry about cooling of weapon systems	Due to constrains on time for research, we will have to make these assumptions to ease the calculation and research process.
We will assume the Death Star laser is a diode laser	
We will assume that the hull weight will include the weight of the island (The rectangular bridge part sticking out)	Although it would be possible to factor the island in the volume calculation, due to time restrictions we will be excluding it as the size of it is small compared to the rest of the carrier.
We will assume everything goes according to plan and no accidents occur	Although the chance of this occurring is basically zero, the information about

	accident rates is hard to come by on the internet.
We will assume that we don't need to cover the cost of the launch sites.	Calculating the cost of launch sites it harder because unlike vehicles like spaceships or planes each launch site will cost a different amount due to terrain.

7. Carry out calculations

The Hull

Using the calculation for a triangular prism and the dimensions of the Yorktown class we get a calculation for the total volume. After the volume has been found we divide the displacement of the ship by the volume to get kilograms of steel used per meter square.

$$\frac{Beam \times Draft}{2} \times Length = Volume$$

$$\frac{7.9 \times 33}{2} \times 246.81 = 32{,}171.6835 \ \approx 32{,}171$$

We know that the displacement of the Yorktown class is 19,800 long tons [5] which when converted to kilograms is 20,117,729 kgs.

$$\frac{Density}{Volume} = kilograms/meters^3$$

$$\frac{20{,}117{,}729}{32{,}171} \approx 625.337 \ \approx 625$$

We now know the kilograms of steel per meters cubed of the Yorktown class, now we must simply multiply this by the volume of the Death Star which is a sphere with radius 80km or 80,000 meters. Since most modern spaceships use stainless steel, we will be using that for our calculations.

$$\frac{4}{3}\pi \times radius^3 \times Kilograms\ per\ meter\ cubed$$

$$\frac{4}{3}\pi \times 80{,}000^3 \times 625 \approx 5.656 \times 10^{20}$$

The cost of Stainless steel 304 is between \$0.70 and \$1.10 AUD [6], this is equivalent to \$0.46 to \$0.72 USD [16]. Therefore, the cost of the hull would be:

$$\$4.072 \times 10^{20}\ USD$$

The Super Laser

From Lang (2013, p.p.272), for a solid planet we can get the gravitational binding energy U given by the equation:

$$U = \frac{3GM_p^2}{5R_p}\ [10]$$

Where M_p is the mass of the planet and R_p is the radius of the planet. We will find that the energy required to destroy a planet of said size is 2.25×10^{32}J. Since Alderaan is destroyed in 4 seconds and we need a laser with just as much power, we would require a 5.625×10^{31} Watt laser.

Since the Vulcan 20-20 [11] will be a 20 Petawatt or 2×10^{16} Watt laser we need a laser that is:

$$\frac{5.625 \times 10^{31}}{2 \times 10^{16}} = 2.813 \times 10^{15}$$

times more powerful than the Vulcan. If we assume that laser power scales linearly, we will just have to multiply the cost of the Vulcan 20-20 which would be 82 million GBP or 103.87 million USD by 2.813×10^{15}.

$$1.038 \times 5.625 \times 10^{17} = 2.921 \times 10^{17} \text{ or } 2.921 \times 10^{21}$$

Therefore, to build a laser this powerful it would take $\$2.921 \times 10^{21}$ USD.

Power Generation

According to Paschotta [13], the maximum energy efficiency of a diode laser is above 70%. Therefore, to calculate the energy required to shoot the laser is with the following formula:

$$Energy\ required\ to\ destroy\ planet \times \frac{100\%}{100\% - \ energy\ efficency} = 100\%$$

$$2.25 \times 10^{32} \times \frac{10}{7} = 3.21 \times 10^{32}$$

Therefore, to fire the laser once we require 3.21×10^{32} Joules of energy. To convert the energy required to kilowatt hours we will divide it by 3,600. We will then divide this by 24 since we have 24 hours to charge up the laser.

$$\frac{Energy\ required}{3600 \times 24} = watts\ hours\ required$$

$$\frac{3.21 \times 10^{32}}{3600 \times 24} = 3.72 \times 10^{27}\ kWh$$

The installation cost per kilowatt of the KK-7 reactor in the Kashiwazaki-Kariwa powerplant is ¥280 JPY or $1.82 USD [16], to convert this to kWh we will multiply it by 24. We will then multiply this by the required amount.

$$kWh\ required \times (24 \times Cost\ per\ kilowatt)$$

$$3.72 \times 10^{27} \times 24 \times 1.82 = 1.62 \times 10^{29}$$

Therefore, the cost to build all the nuclear reactors is \$$1.625 \times 10^{29}$ USD.

Transportation:

As we calculated earlier the amount of steel we need in kilograms is 5.656×10^{20}, therefore the cost of launching all the steel into space is:

$$5.656 \times 10^{20} \times \$100 = \$5.656 \times 10^{22}\ USD$$

Now for the cost of the rockets, using the formula we came up with we can get a numerical answer:

$$\frac{1.9 \times 10^{9}}{150 \times 12} \times 9 \times 10^{7} = \$9.500 \times 10^{14}\ USD$$

Labour:

If we add up all the sub-costs, then we get the total cost of the Death Star excluding the labour.

$$4.072 \times 10^{20} + 2.921 \times 10^{21} + 1.625 \times 10^{29} + 5.656 \times 10^{22} + 9.500 \times 10^{14}$$
$$= 1.625000598882\ \times\ 1029 \approx 1.625 \times 10^{29}$$

$$Cost\ of\ the\ rest \times \frac{100}{60} = total\ cost$$

$$1.625 \times 10^{29} \times \frac{100}{60} = 2.7083 \times 10^{29}$$

Therefore, the cost of the Death Star is $162.5 Octillion United States Dollars (2024)

8. Check that the answer is in line with estimate and in line with information online

Back in 2013 there was a satirical proposal to the government of the United States of America to build the Death Star. This proposal reached 30,000 signatures and therefore qualified as an actual proposal. The US government responded with a tongue-in-cheek response as well as the Lehigh University doing an estimation of the cost. This came out to \$850 quadrillion or \$$8.5 \times 10^{17}$ USD (2013) which is roughly \$$1.151 \times 10^{18}$ USD (2024). As you can see our estimate is very far off from the one done by Lehigh

University. Some possible explanations for this are: cost of steel at the time and using other real-life examples as a base for their model. As well as this since the biggest cost by overwhelming margin was the power generation, they could've used a different method to create power for the laser.

9. State your answer in a meaningful way

To start with, the cost of the Death Star is 2.7 Sextillion years of the global GDP in 2024 [8]. Even if we exclude the cost of the power generation and labour, the death star would be equivalent to 100 kilometres cubed of pure diamonds [23]. The amount of steel needed would be the world's current steel production [7] for 100,000 years or 3,333 generations. Keep in mind that this is the world's entire steel production, every single bit of it. The number of nuclear reactors needed to power the laser would be roughly 10^{23} nuclear reactors the size and power of the KK-7 reactor of the Kashiwazaki-Kariwa nuclear power plant in Japan. Even the lowest major cost which was creating all the rockets would still almost be the cost of one kilometer cubed of pure 24-carat gold.

10. Conclusion

In conclusion, based off the methods used in this model at the current technological level, it would be astronomically expensive in both money and raw materials to build the death star. With our current industrial capacity, Thousands of years' worth of materials would have to be used to fund the project. The Death Star project would dwarf any projects preceding it. Anyone considering building it would need a method that is at least a Quintillion times more efficient for it to even be feasible.

There are many areas that this model could be improved. First among these is fleshing out some of the simple calculations made like factoring the island into the calculation for the volume of the aircraft carrier. Another major area that could be improved is the power generation, mostly looking into using antimatter as an energy source and storage. As seen in this report a large majority of the cost was the power generation. The main reason that was forgone in this report was due to make the research easier as this is a mathematical modelling task, not a science one. If I were to redo only one part of the report, it would be the power generation.

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