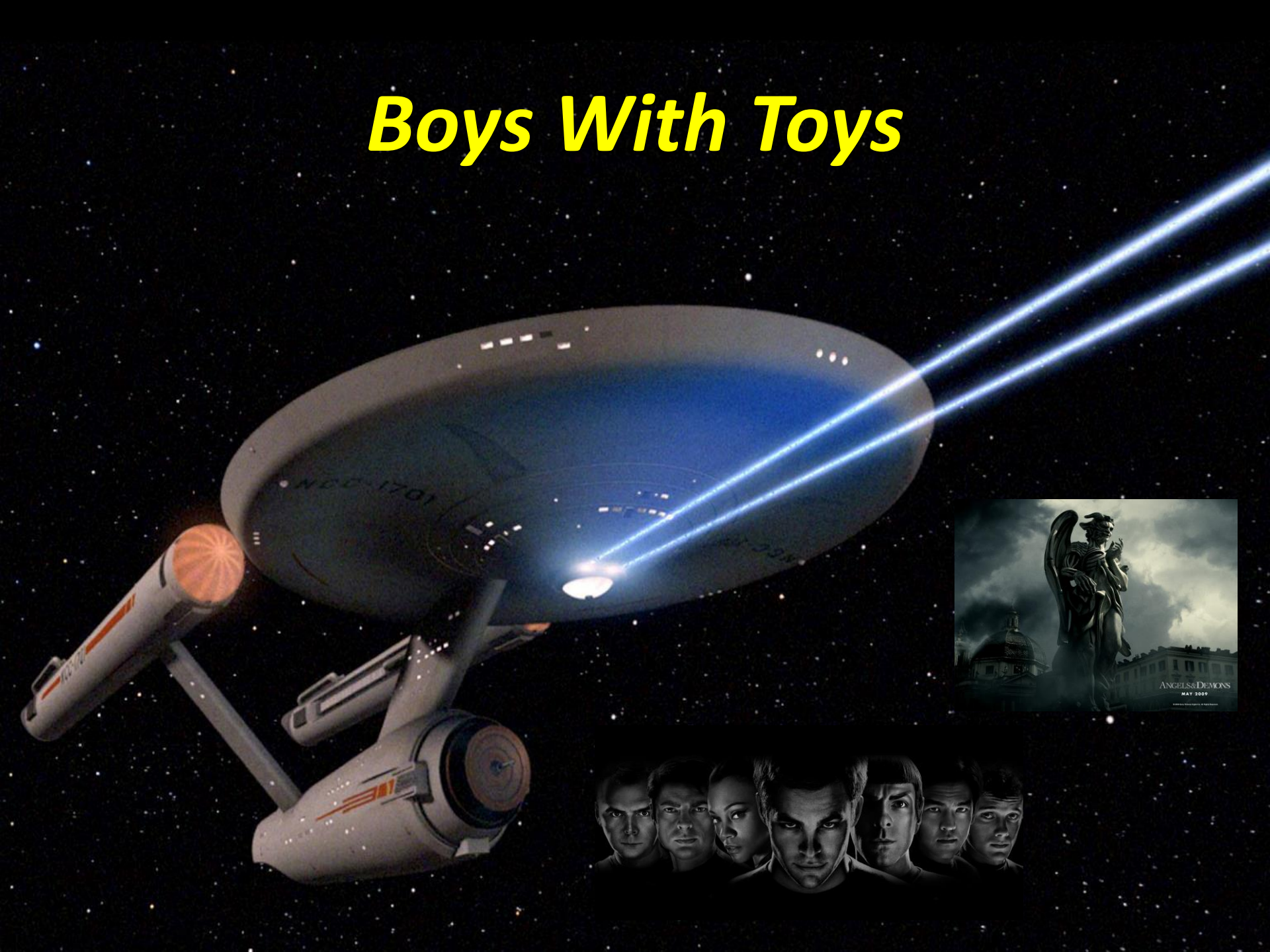
Boys With Toys



Note to the teacher:

In order to achieve a heightened realism (and accuracy), as well as to hold to the aim of injecting more modern physics at an earlier level in the curriculum, the calculations involving the kinetic energy of the starship Enterprise have been treated relativistically using the formula $E_k = (\gamma - 1)mc^2$ *. The formula has been fully explained in the Background Materials section entitled "Oh No!! Formulas!" in a manner that should be fully understandable to students at the* 9^{th} *and* 10^{th} *form levels.*

The teacher can, of course, choose to do a non-relativistic treatment using $E_k = \frac{1}{2}mv^2$*. In the first example, where the speed of the ship is 0.5c, the non-relativistic treatment can be used without a significant loss in accuracy. However, this is not the case for the second example where the ship is given a speed of 0.995c.*


Antimatter-driven spacecraft!

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"…Of all the ship's systems, warp drive is the one which does most to allow the ship to fulfill its purpose…The warp drive provides the means to warp space, allowing the ship to cross distances at speeds far in excess of the speed of light, the universal 'natural' top speed of Einstein's theories…"

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…The power is provided by mixing matter with antimatter together in the warp core…The reaction results in a massive release of plasma energy which is then fed to the warp engines, housed in the two cigar-shaped nacelles, typically located on either side of the ship…"

(from Star Trek: The Original Series Season 3 DVD Collection brochure, © 2004 Paramount Pictures)

As devout fans of the science-fiction series “Star Trek”…

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…the TV series and all of the movies…

..my partner and I eagerly await the day when matter-antimatter reactors are used to drive spacecraft.

…the TV series and all of the movies…

OK, let's see what we can do…

A STARSHIP TO SIRIUS!

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ENTERPRISE 1701-D

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Let's find out how much antimatter we would need for what would surely be a trip around the block for the Enterprise: a voyage to Sirius, a nearby star just 8.6 light years away.

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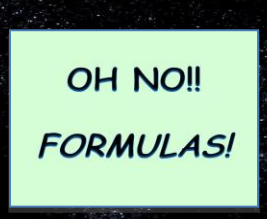
ENTERPRISE 1701-D

Let's find out how much antimatter we would need for what would surely be a trip around the block for the Enterprise: a voyage to Sirius, a nearby star just 8.6 light years away.

As it is not yet well-understood how to warp space, we'll take it easy and travel at sub-light speed, say one-half the speed of light (0.5c).

To find out how much energy is required, we shall use the formula $E_k = (\gamma - 1)mc^2$,

You will find a tutorial on this formula in "Oh No!! Formulas!" in the Background Materials:



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For our purposes, this represents the energy required to ***move*** *the ship to Sirius.*

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We will take the mass (m) of the Enterprise 1701-D to be 190,000 tons = 1.9×10^8 *kg. **

By calculating directly (or using the table/graph provided in "Oh No!! Formulas!"), we find that $\gamma = 1.1547$ *for a speed v = 0.5c.*

**according to the "Memory-Alpha" website* http://memory-alpha.org/en/wiki/Starship_class

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So, an amount $E_k = (1.1547 - 1) \times 1.9 \times 10^8 \text{ kg} \times (3.0 \times 10^8)^2$

$= 2.6 \times 10^{24}$ J *of energy is required.*

Note to the teacher:
This question can be treated in a non-relativistically without a significant loss of accuracy.
If $E_k = \frac{1}{2}mv^2$ *is used instead of* $E_k = (\gamma - 1)mc^2$, *the energy required would be*
$E_k = \frac{1}{2} \times 1.9 \times 10^8 \times (0.5 \times 3.0 \times 10^8)^2 = 2.1 \times 10^{24}$ J

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That will take $15{,}000{,}000{,}000 \div 5 \times 10^{-10} = 3 \times 10^{19}$ years
*That's 30,000,000,000,000,000,000 years**

**(please keep in mind that the universe has not yet reached its 15,000,000,000th birthday yet)*

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Antimatter production is presently highly inefficient.
Only around 0.0000001 % of the energy we put in comes out as antimatter.
So come to think of it, we will need 2.6 × 10^{33} J of energy (sorry).

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So, the cost of making this antimatter will be about € 7.2 × 10^{25} .

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(That's almost $100,000,000,000,000,000,000,000,000 for our friends in the USA).

And, at the leisurely pace of only half the speed of light it will,
unfortunately, take us 17.2 years to travel the 8.6 light years to Sirius.
(Without the warping of space we have had to actually travel the entire distance).


Honey, are we being made fun of?


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EXCUSE me.
My partner said he "awaits the day".
Of course this won't work with today's technology!
But in the 24th century…


That's right!
EXCUSE me.
My partner said he
"awaits the day".
Of course this won't work
with today's technology!
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OK, let's pretend that it's the year 2310.

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As an exercise, calculate how long it will take, using the 2310 production rate, to make enough antimatter to travel to Sirius on the Enterprise at 0.995c. (you can use $\gamma = 10$).

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[Answer: 1.7×10^{-4} years ≈ 5400 seconds = 90 minutes]


I knew that answer…


I knew that answer…
AHA!
You see? Only 90 minutes!


Revenge is a dish best served cold, isn't it dear?
AHA! You see? Only 90 minutes!

Indeed it is.

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But please remember this:

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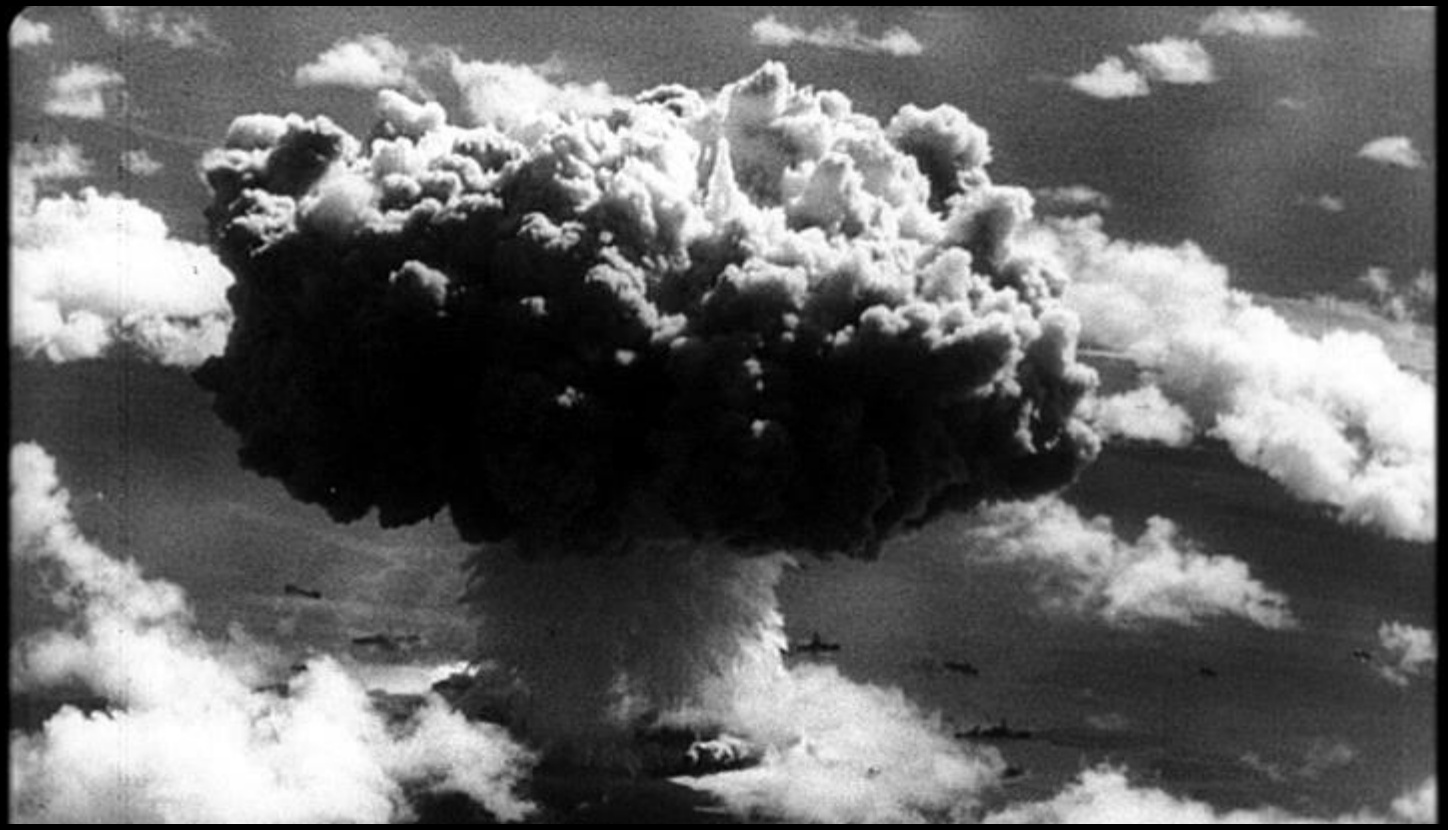
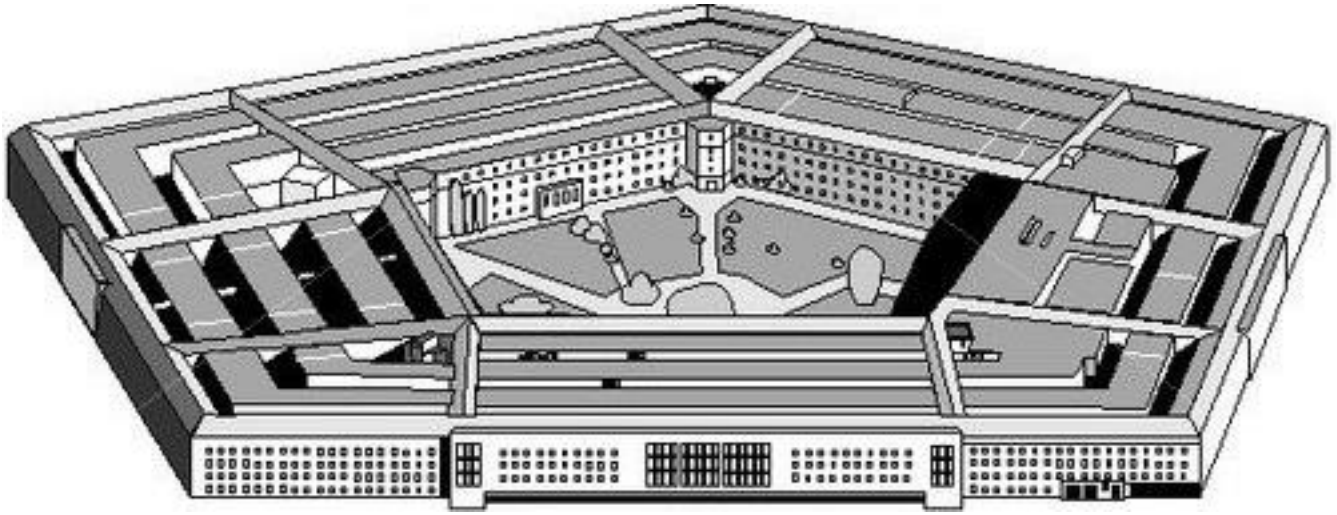
(On a less crucial note, you may have seen in your calculations that around 860,000,000 kg of antimatter was required for the 0.995c trip to Sirius. That means that the ship would need to carry that plus another 860,000,000 kg of matter to react with it. That's about 1,700,000,000 kg of fuel for the matter-antimatter reactor, which is almost nine times the mass of the ship itself).

Today is a GOOD day to die!

Antimatter Weapons??



One day, somewhere in the Pentagon…



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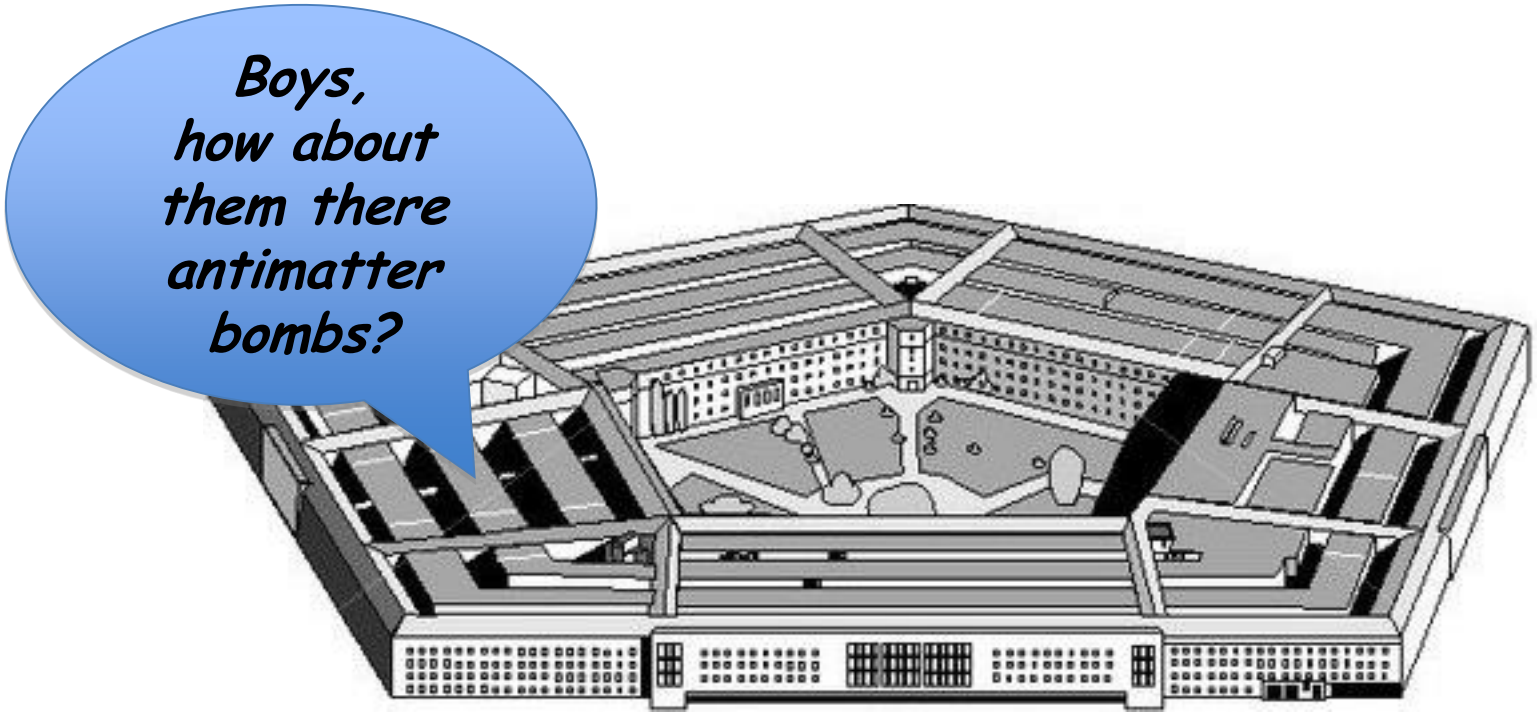

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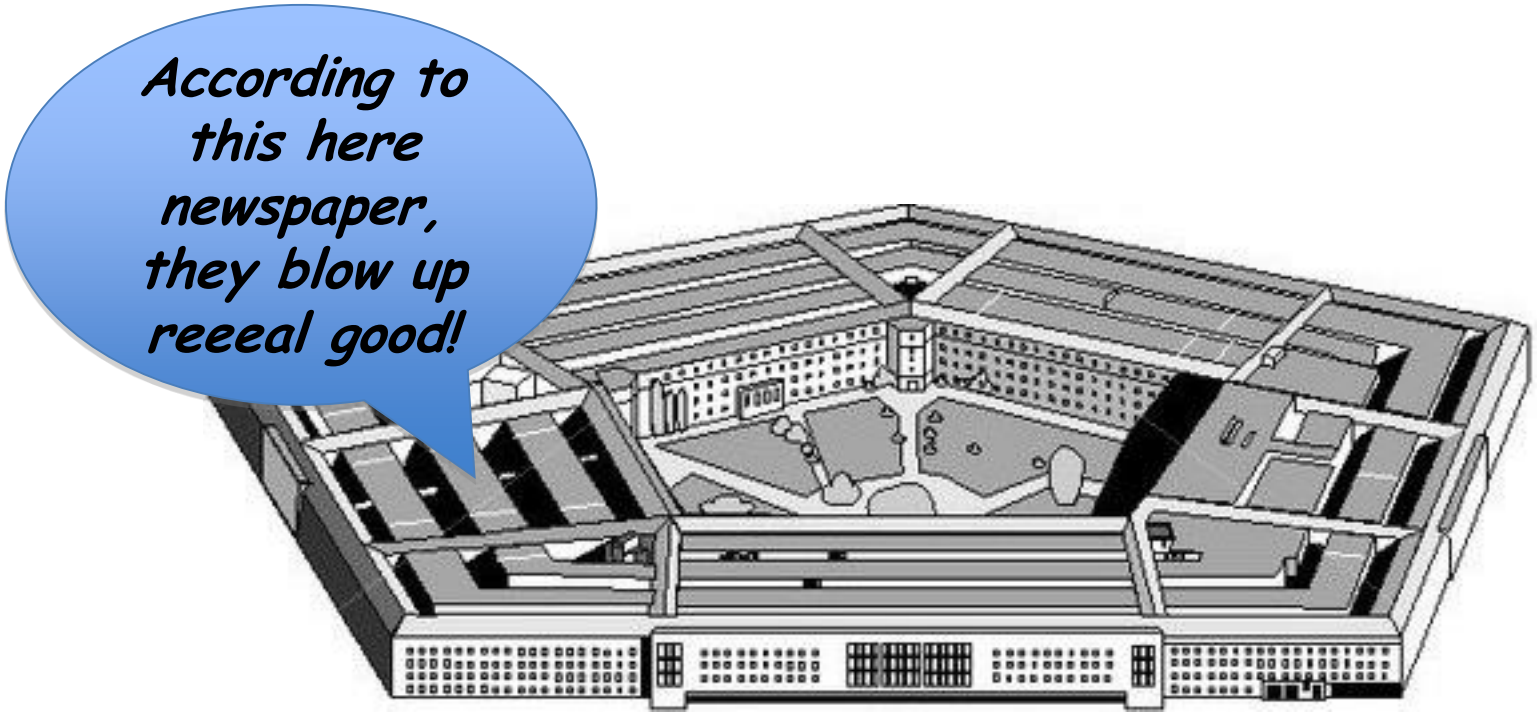


San Francisco Chronicle
NORTHERN CALIFORNIA'S LARGEST NEWSPAPER
MONDAY, OCTOBER 4, 2004

Air Force pursuing antimatter weapons

Program was touted publicly, then came official gag order

Keay Davidson, Chronicle Science Writer

The most powerful potential energy source presently thought to be available to humanity, antimatter is a term normally heard in science-fiction films and TV shows, whose heroes fly "antimatter-powered spaceships" and do battle with "antimatter guns."

But antimatter itself isn't fiction; it actually exists and has been intensively studied by physicists since the 1930s. In a sense, matter and antimatter are the yin and yang of reality: Every type of subatomic particle has its antimatter counterpart. But when matter and antimatter collide, they annihilate each other in an immense burst of energy.

During the Cold War, the Air Force funded numerous scientific studies of the basic physics of antimatter. With the knowledge gained, some Air Force insiders are beginning to think seriously about potential military uses -- for example, antimatter bombs small enough to hold in one's hand, and antimatter engines for 24/7 surveillance aircraft.

More cataclysmic possible uses include a new generation of super weapons -- either pure antimatter bombs or antimatter-triggered nuclear weapons; the former wouldn't emit radioactive fallout. Another possibility is antimatter- powered "electromagnetic pulse" weapons that could fry an enemy's electric power grid and communications networks, leaving him literally in the dark and unable to operate his society and armed forces.

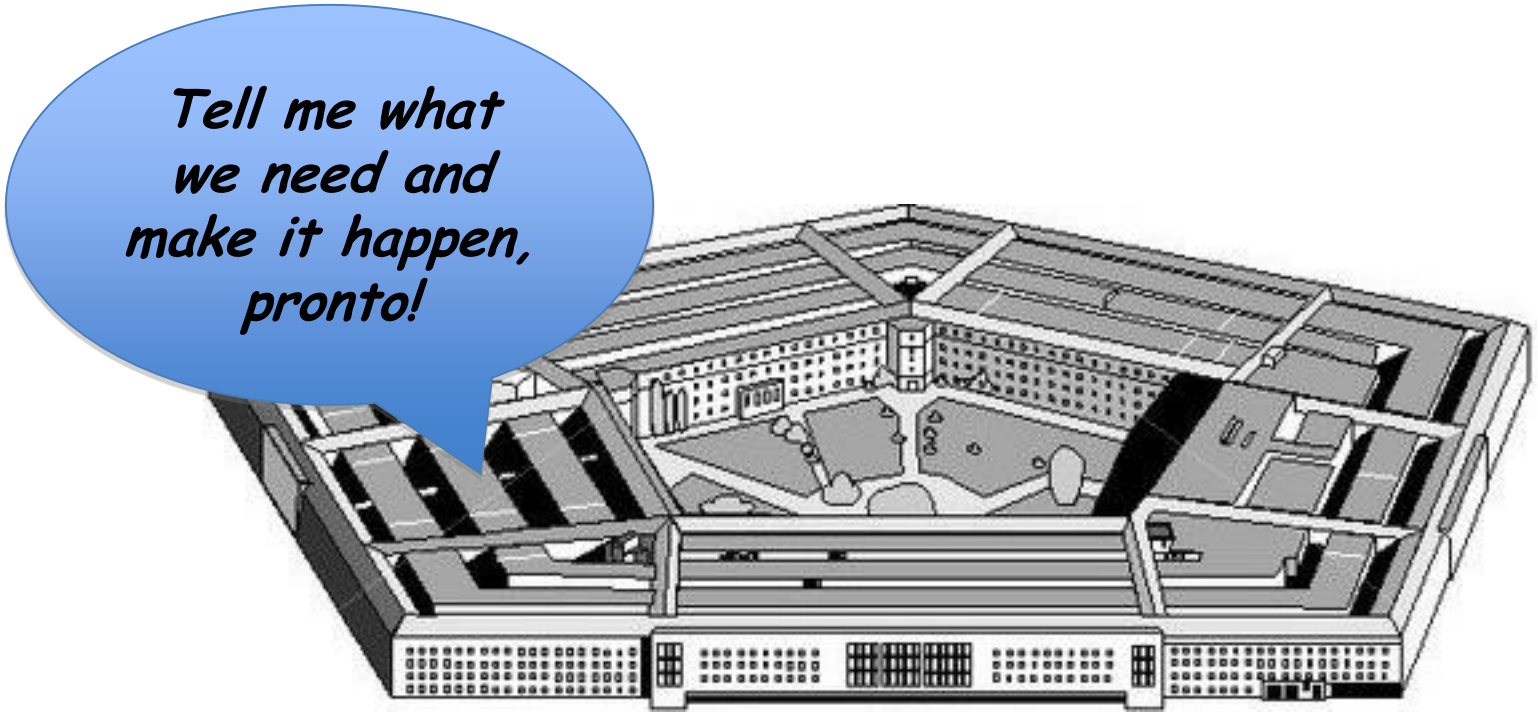
Following an initial inquiry from The Chronicle this summer, the Air Force forbade its employees from publicly discussing the antimatter research program. Still, details on the program appear in numerous Air Force documents distributed over the Internet prior to the ban.

These include an outline of a March 2004 speech by an Air Force official who, in effect, spilled the beans about the Air Force's high hopes for antimatter weapons. On March 24, Kenneth Edwards, director of the "revolutionary munitions" team at the Munitions Directorate at Eglin Air Force Base in Florida was keynote speaker at the NASA Institute for Advanced Concepts (NIAC) conference in Arlington, Va.

For the full text of this article, click on the following link:

http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2004/10/04/MNGM393GPK1.DTL

One day, somewhere in the Pentagon…



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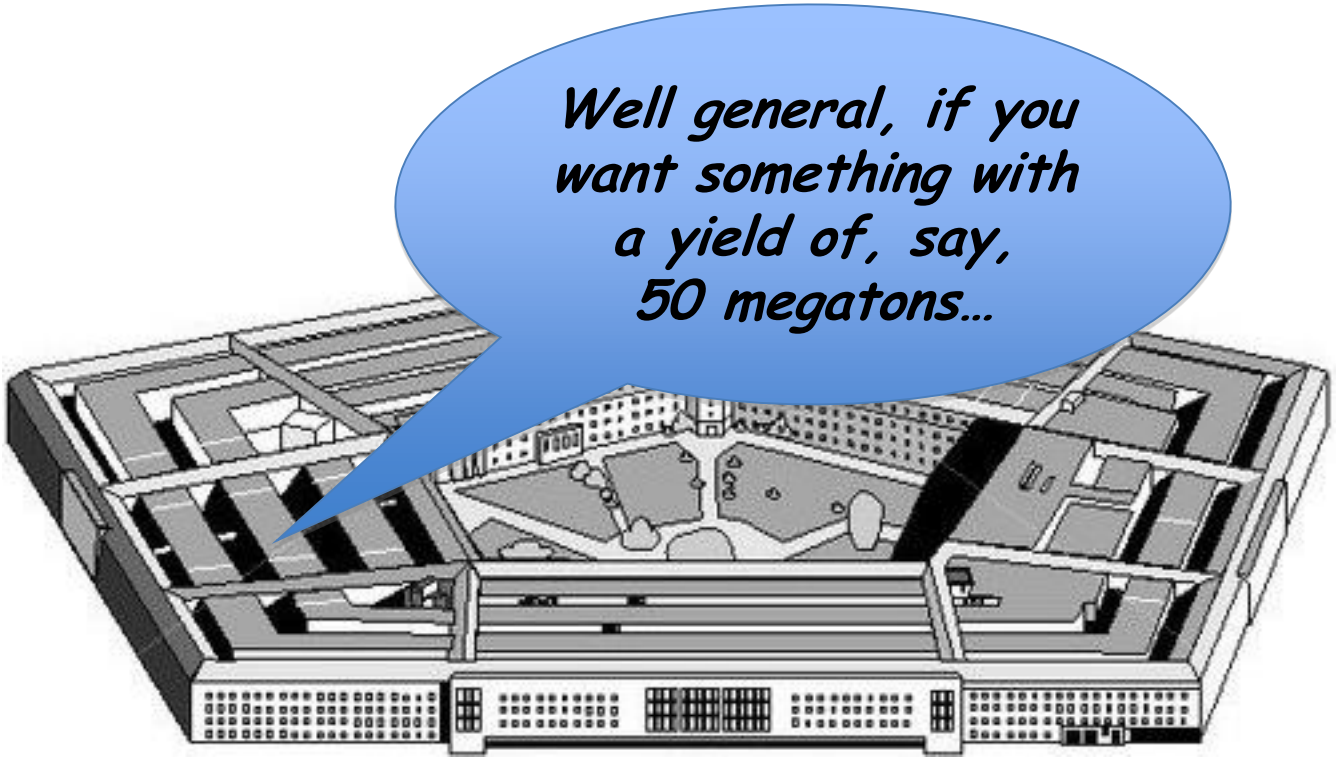

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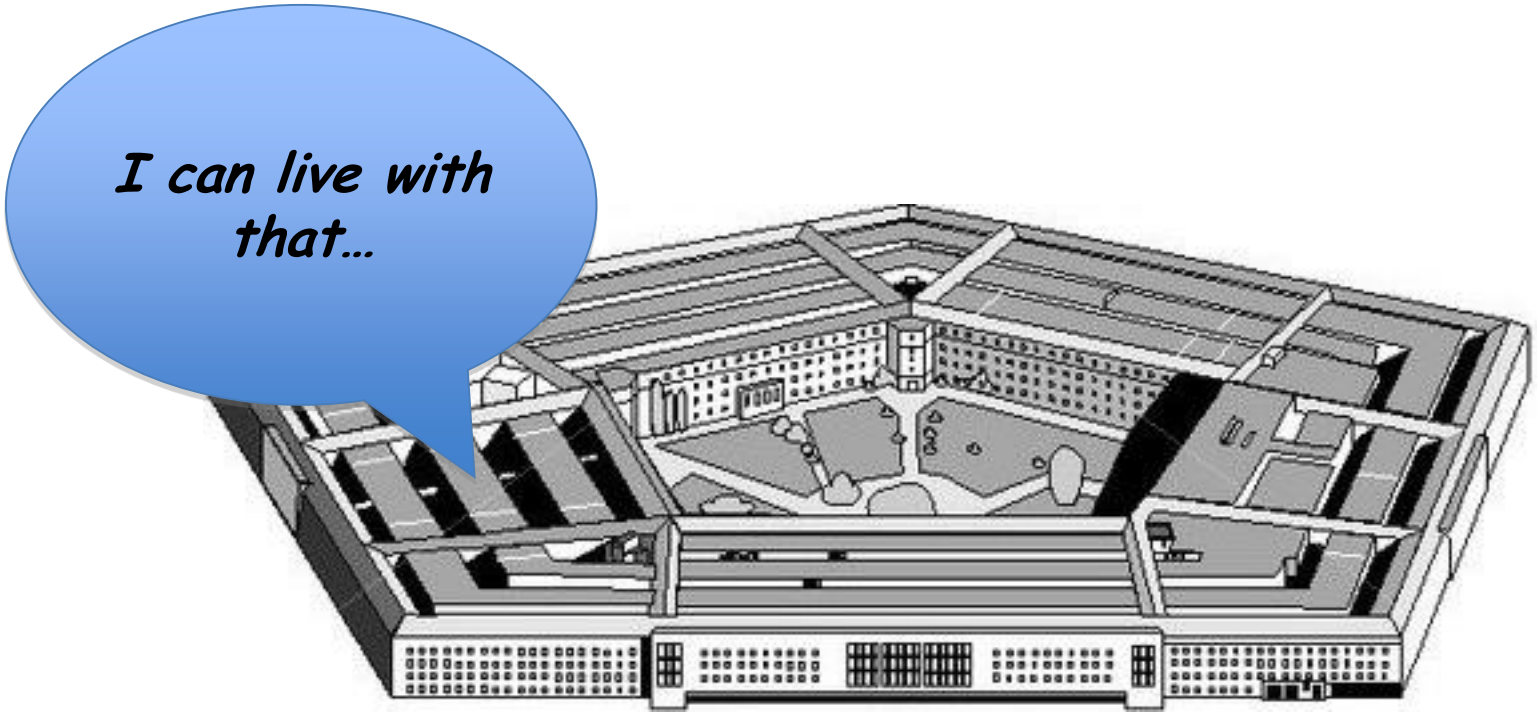

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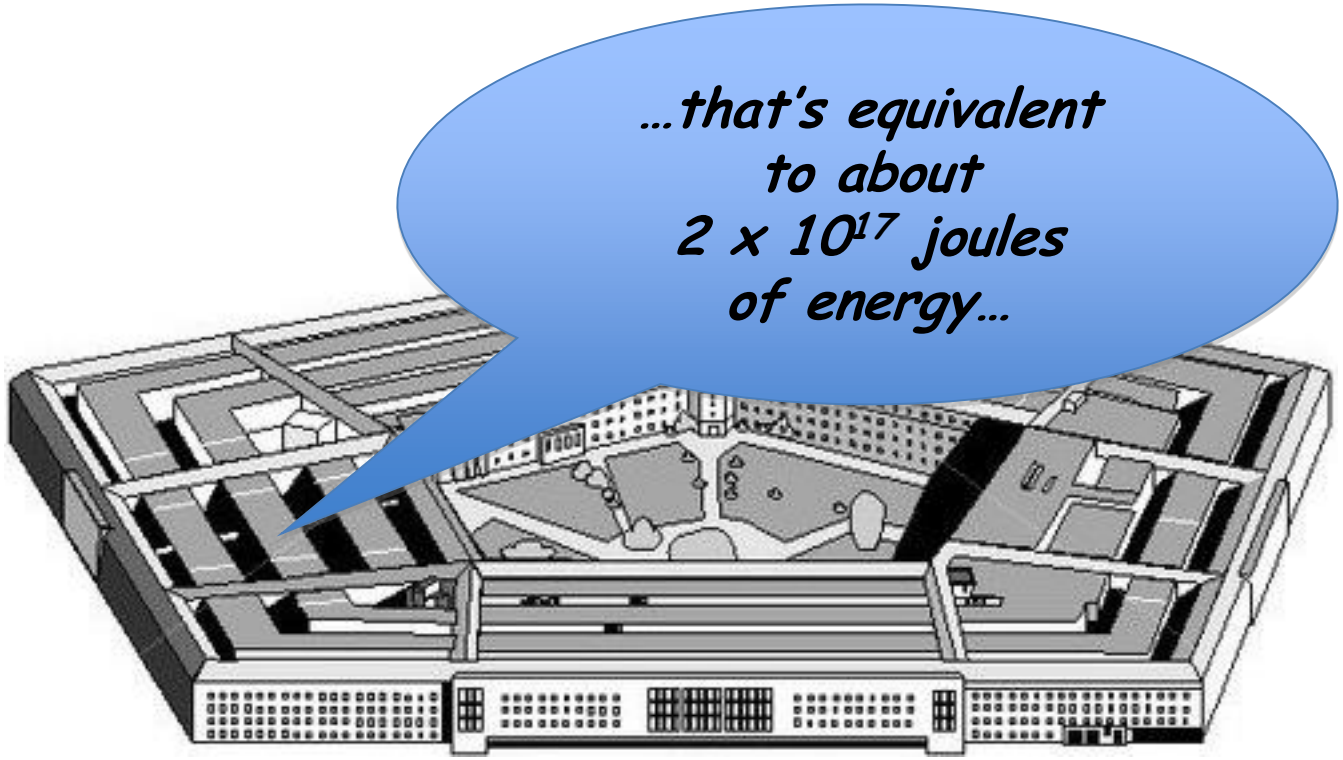

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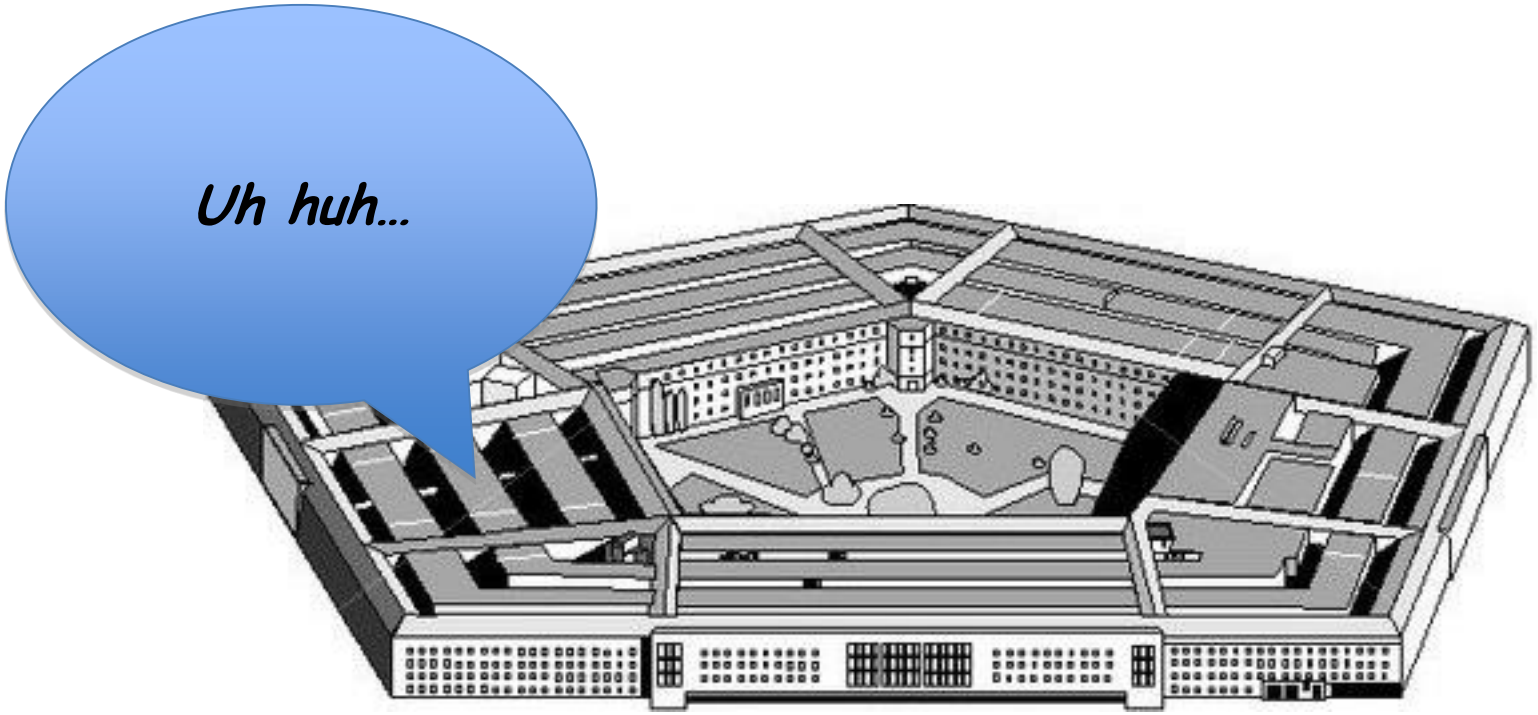

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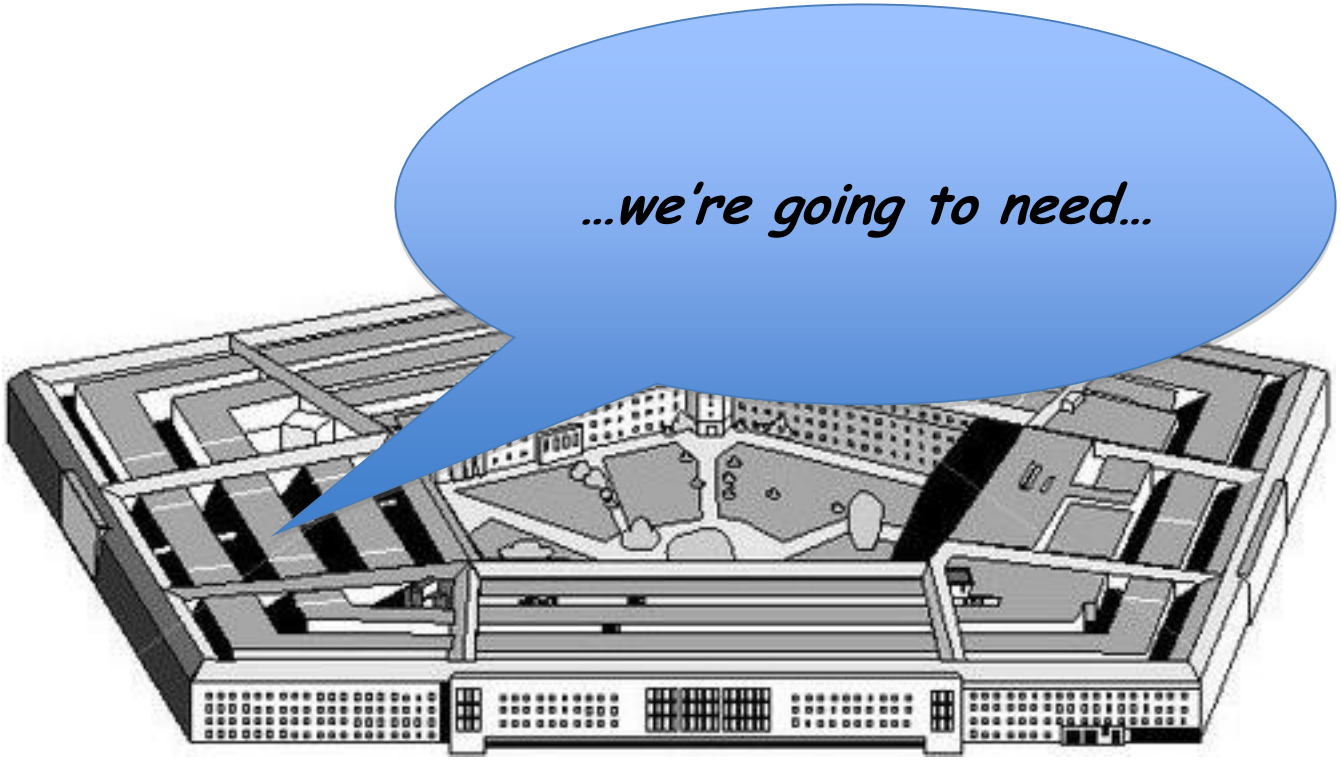

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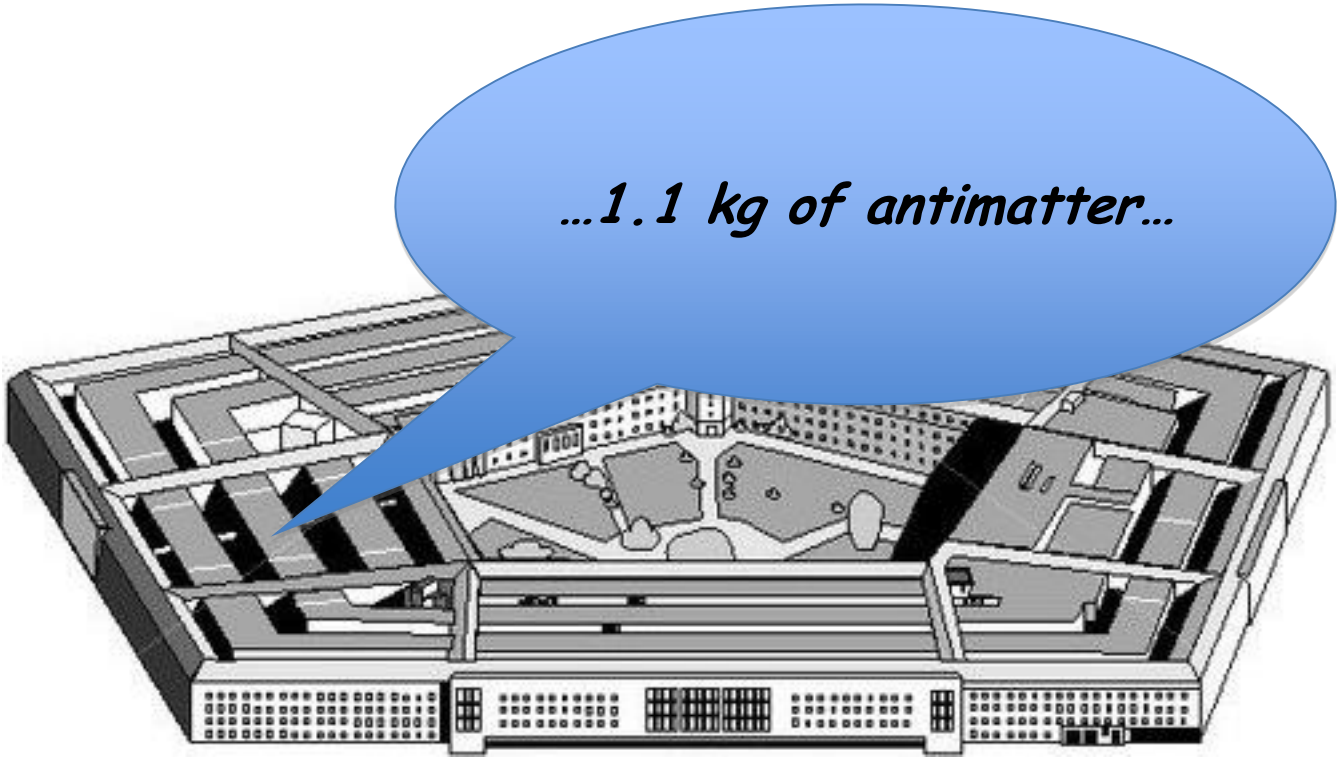

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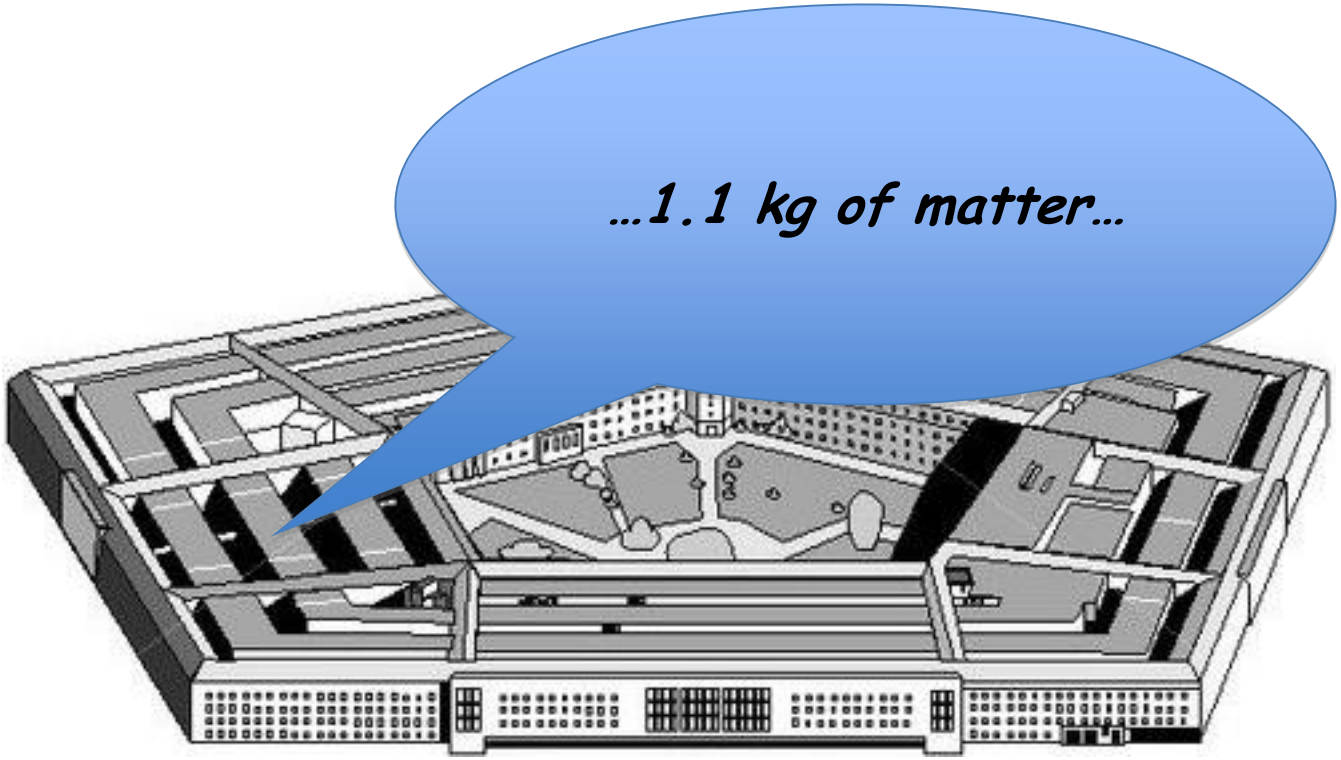

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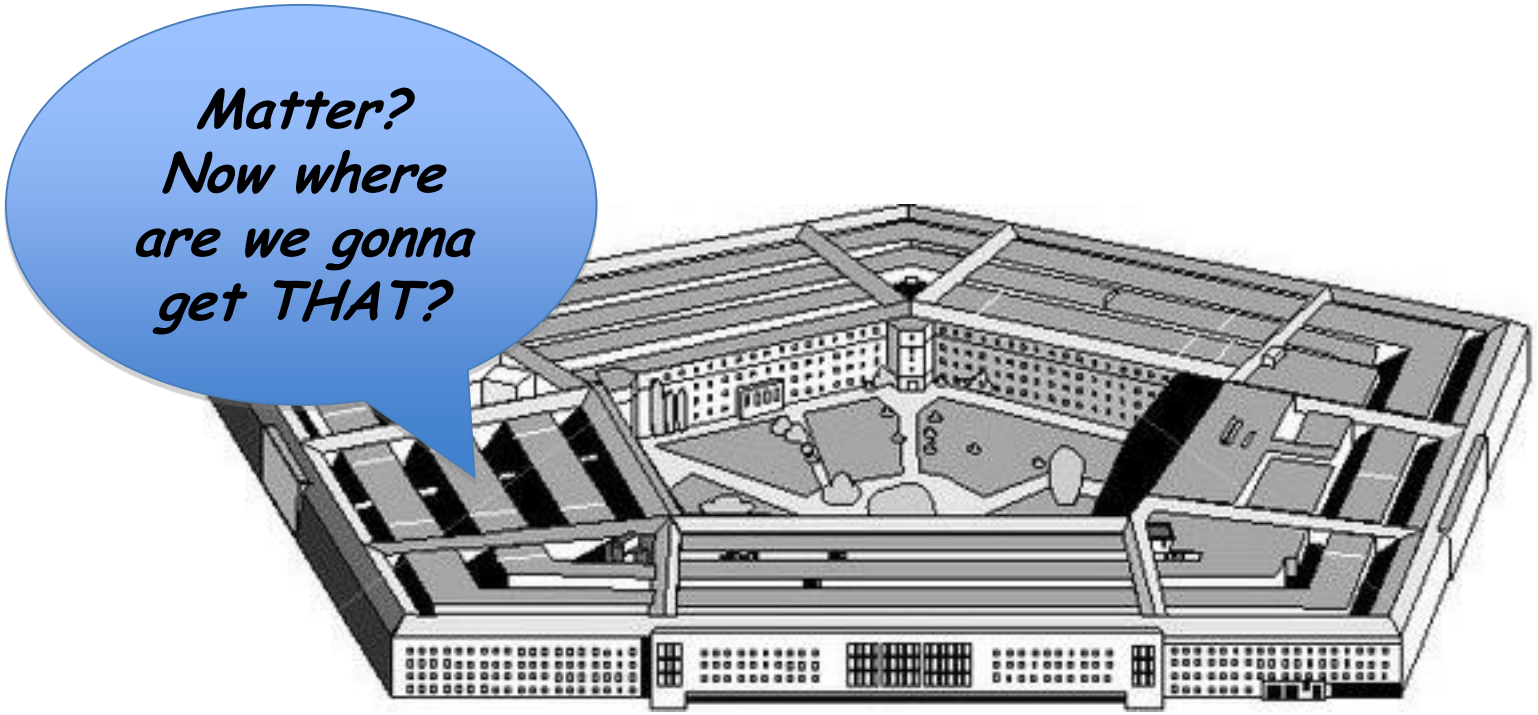

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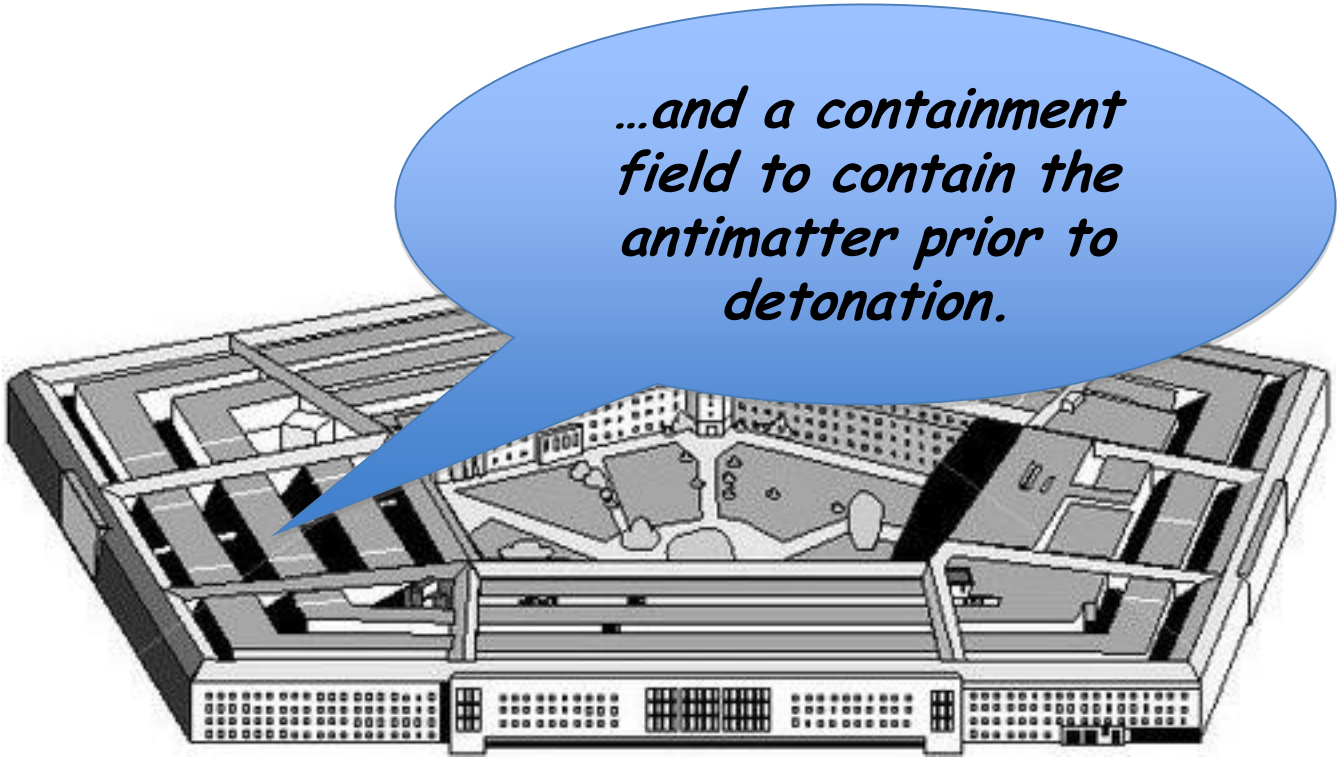

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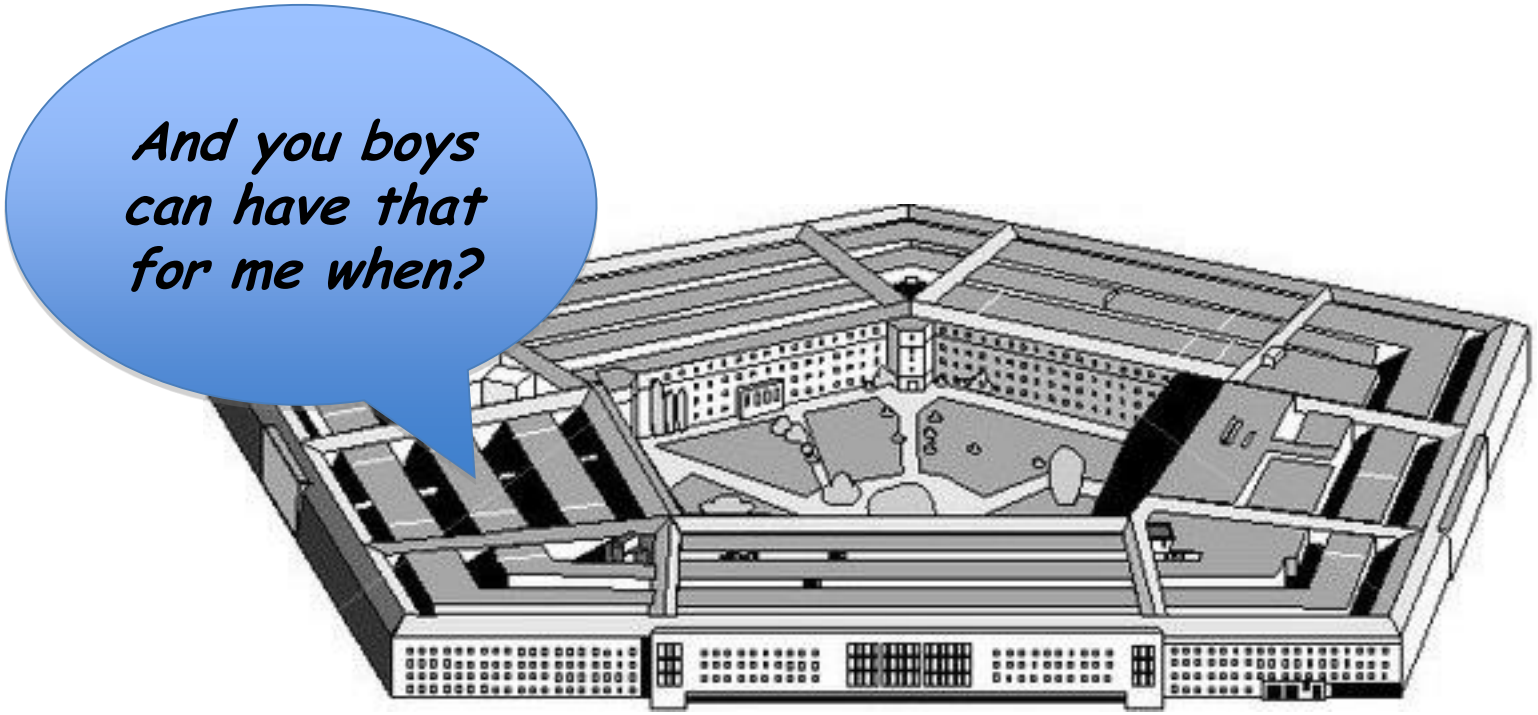

If we assume that the Pentagon rate of antimatter production is similar to that of CERN (10^7 antiprotons per second), calculate the time required to produce 1.1 kg of antimatter.

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[Answer: 2,200,000,000,000 years]

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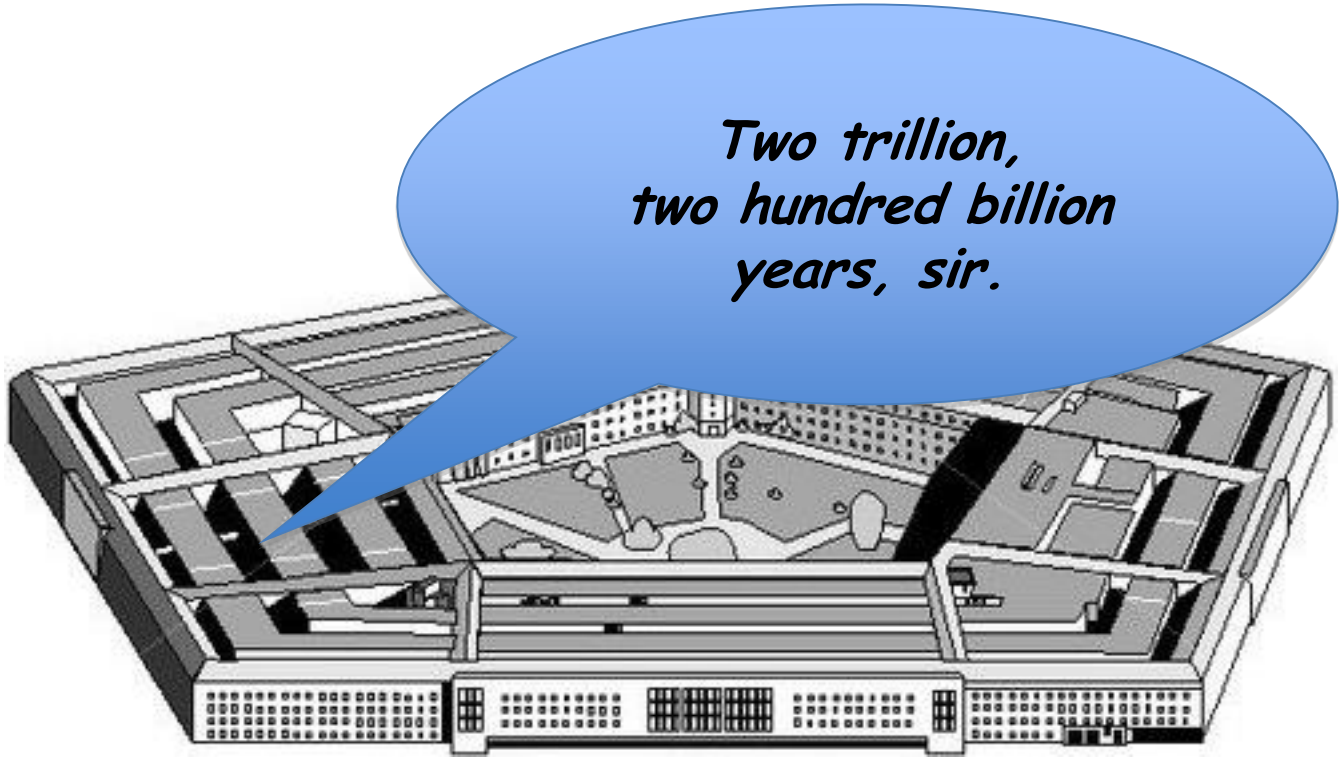

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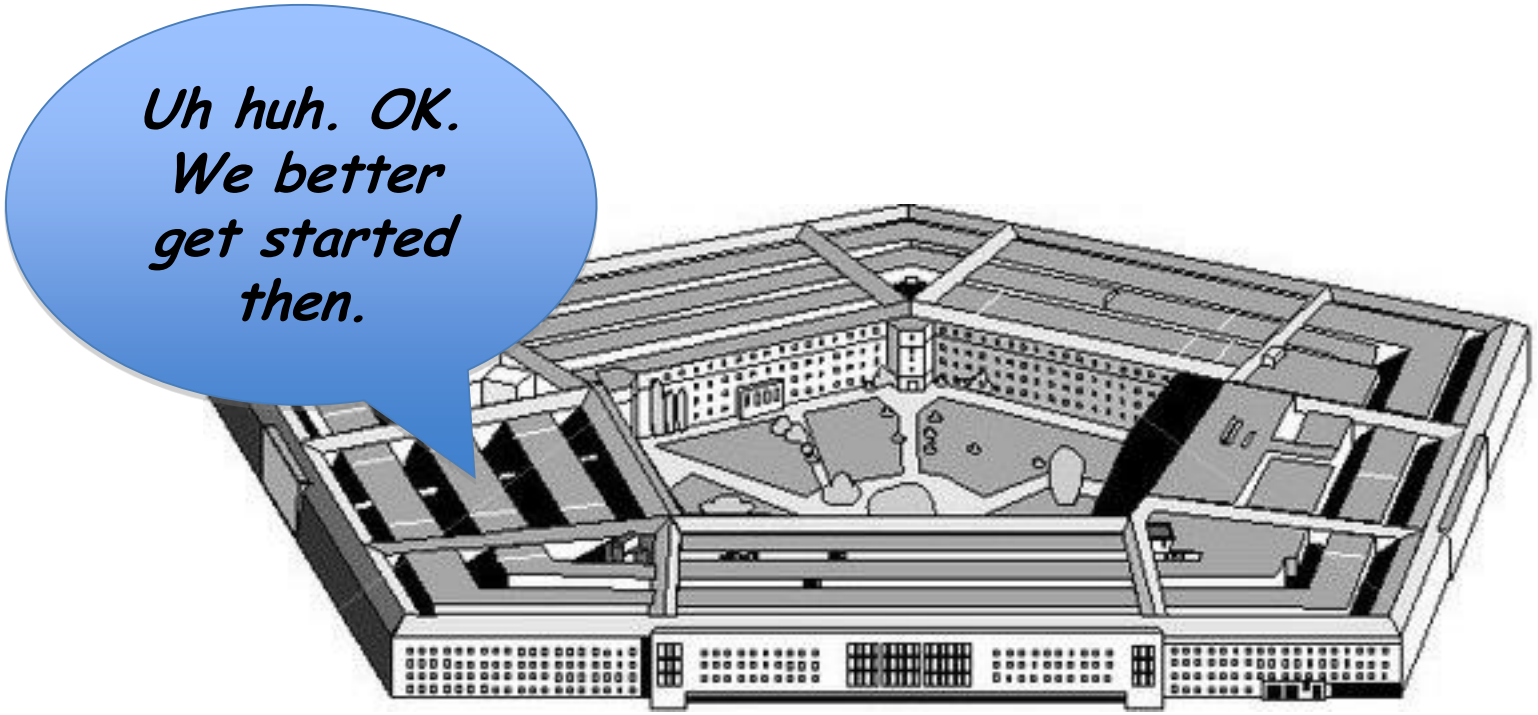


I WANT YOU
TO MAKE
ANTIMATTER

One final note:

There is one aspect to the feasibility of using antimatter in the way described in this lesson that we have not yet discussed: the question of *antimatter containment.*

If you would like to know more about this topic, see the Extension Lesson *"Containing Antimatter".*