Cheap Trek Episode 1 (a cheap attempt at mimicking the legendary *Physics of Star Trek*).

Dear Cheap Astronomy – How does warp drive work?

Lawrence Krauss, who wrote the Physics of Star Trek and Miguel Alcubierre, who most people think has developed the best on-paper version of warp drive, both agree that our current understanding of the Universe precludes any likelihood of warp drive being possible. At the same time, both agree that there's no harm in thinking about it.

So, in leaving you to think about it, let's instead turn the question of how the USS Enterprise works – because, as fictional spacecraft go, the Enterprise really is quite well designed for space travel and might well be the sort of ship that we do eventually explore the Universe with, even if it's not at warp speed.

A major issue with spacecraft design is heat. Sure it's cold in space, but really it's mostly vacuum in space. If you step out of a spacecraft into a vacuum and you are not quickly rotating in strong sunlight, you can expect to *eventually* freeze as your body radiates away its warmth. But you would freeze much quicker in the middle of the Antarctic with a howling gale around you, as each air molecule that streaks past you takes some of your intrinsic heat with it by conduction.

In a vacuum your only way of losing heat is by radiation and when you have a spacecraft full of people running computers and other gadgets, you will make quite a lot of heat – and make it continuously. And if you can't lose that heat as fast as you make it, it's going to get unpleasantly, even dangerously, hot.

When the Space Shuttle orbiter flew in orbit, it always opened its bay doors, to maximise the surface area from which heat could radiate. In basic math terms, what matters is the *surface area to volume ratio*. A flat spacecraft that is ten metres in width and a hundred metres in diameter has a good surface area to volume ratio and won't retain too much heat. So, it turns out that a flying saucer is an example of sensible spacecraft design.

An example of terrible spacecraft design is the Death Star out of Star Wars – since a sphere has the lowest possible surface area to volume ratio that you can achieve in 3 dimensional geometry. It might just manage with a circulating coolant system which constantly conducted heat from the inside to the outside, but that coolant can only stay cool to the extent that it can lose heat from the surface of the sphere by radiation. Otherwise, you could try constantly venting passively-warmed gas away into space, presumably via a series of small thermal exhaust ports – but this is only going to work for so long as you have a ready supply of gas that is initially cooler than the areas of the spacecraft that you are wanting to cool down.

So, after considering these engineering challenges, you might just conclude that building the Empire's most powerful battle station in the form of a sphere it isn't such a great idea. For the record, a Borg cube has only a slightly higher surface area to volume ratio than a sphere does, so the Star Trek universe also has a few daft engineering ideas.

But then there's the USS Enterprise. It is built from a flat disk and a number of slim, inter-connecting cylinders – all being shapes that have high surface area to volume ratios. The nacelles, which hold

the ship's (let's just say) *plot development* drive coils, would be major heat sources and are hence sensibly positioned a good distance away from the rest of the ship.

Another sensible feature of the Enterprise, which is not commonly seen in other fictional spacecraft outside of Star Fleet, is the main deflector. This parabolic dish is thought to be capable of projecting a beam, presumably a kind of reverse tractor beam, which can deflect dust and debris out of the path of the speeding ship.

Of course, it would defeat the whole purpose of the deflector if the Enterprise was able to travel faster than light since it would also then be travelling faster than the deflector beam. But if light speed can't be reached (and let's face it, it can't), a deflector beam might be a genuinely useful thing to have beaming out ahead of you while you are travelling at 90% of the speed of light – since, at that speed, one wayward dust grain in your path might be enough to destroy your spacecraft.

And if anyone wants to know how you could generate such a deflector beam – well, remember, this is Dear Cheap Astronomy.

Dear Cheap Astronomy – How do you think a photon torpedo works?

Star Trek lore has it that photon torpedoes are projectiles filled with anti-matter, which needs to be held in some kind of containment field, as well as in a vacuum – since the whole idea is produce an very energetic explosion by bring the antimatter into sudden contact with an equivalent amount of matter.

There are some fundamental designs issue to overcome if this process is going to work. Contact between the *surface* of a chunk of anti-matter and the surface of a chunk of matter would be enough to explosively separate those two chunks long before their constituent particles and anti-particles had been able to interact.

So, to even get close to a 100% efficient reaction you will need some kind of pre-detonation mixing process, or some kind of matrix field whereby single particles of matter and antimatter are each encapsulated in their own tiny containment field pocket. Then,once the isolation field matrix is switched off, all the particles will be able to inter-mingle with all the anti-particles at the same moment, thus producing an efficiently-destructive blast.

Indeed the matrix field idea may be the only way to go. Another tricky issue to deal with, when you are designing matter- antimatter weapons, is *particle charge*. While you can theoretically achieve an effective detonation by bringing a collection of electrons instantaneously together with a collection of positrons – containing these separated collections prior to detonation is difficult, since the negatively-charged electrons will strongly resist being bunched together, as will the positively-charged positrons.

If this charge problem isn't easily overcome, you might have to look at filling your warhead with hydrogen and anti-hydrogen – which are one proton (or one anti-proton) joined with one bound electron (or one bound positron). However, while an electron and a positron neatly annihilate to form one gamma ray photon, other particles and antiparticles follow more complex annihilation

pathways, which may prolong the reaction and lead to a less-efficient and less-destructive photon energy output.

But, there is still an even bigger problem to face. The large majority of the Universe is made of matter. Using current technologies, you would have quite a job on your hands to gather together even a teaspoon-full of anti-matter, let alone a whole warhead's worth. Most Star Trek background texts suggest that you will need about 1.5 kilograms of antimatter to load a single photon torpedo.

Creating antimatter artificially can be achieved in particle accelerators, but this requires about as much energy input as you are ever likely to get back from a matter-anti-matter explosion. So this is probably not the way to go.

Instead, it's probably better to try and harvest anti-particles from natural sources. Within the solar system, reasonably abundant sources of anti-particles exist above the planets, including the Earth. When a high-energy cosmic ray collides with an atmospheric particle, the kinetic energy of the collision often produces a particle and antiparticle pair. The anti-particle that is produced is ephemeral, since it can only exist as long as it avoids colliding with an equivalent particle. But, in the upper reaches of a planet's exosphere, an anti-particle can exist for quite a while before it meets a particle.

Apparently one of the best planets for such sustained antimatter production is Saturn, since its thin rings present a large surface area for cosmic ray collision and any anti-matter particles produced are shot out the other side of the ring-plane into fairly-empty space.

So… if we could deploy a fleet of robotic scourers, orbiting Saturn's rings and collecting antimatter particles within a matrix containment field, arming Star Fleet does start sounding at least *a tiny bit* possible.