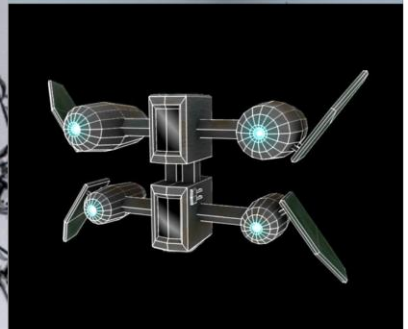
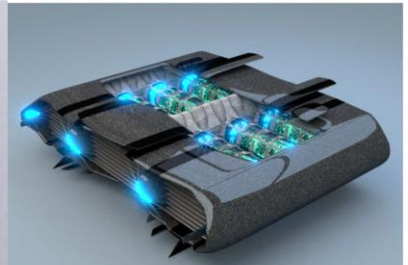
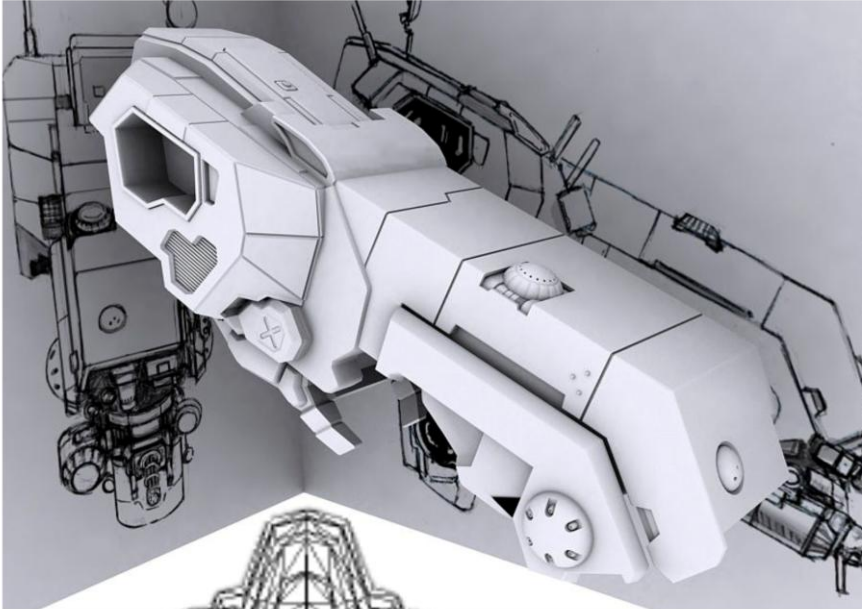
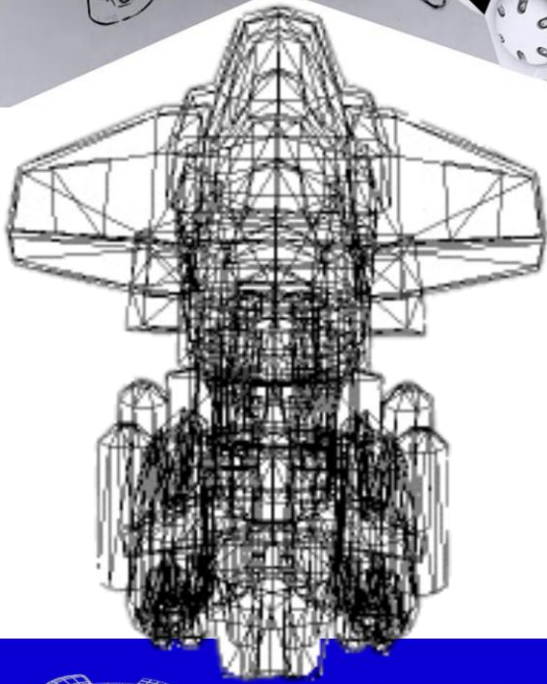


The Authorised Evochron Mercenaries' Technical Guide

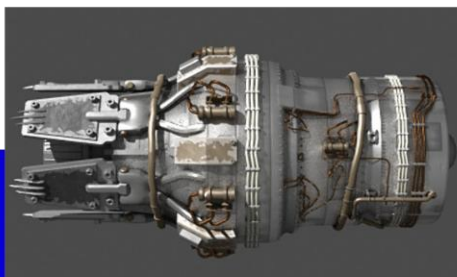
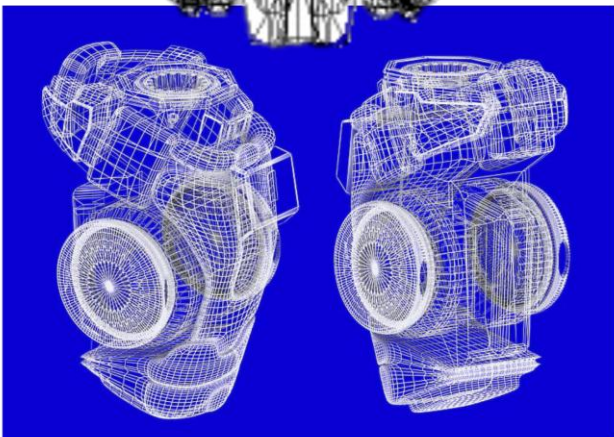
(or "How your equipment works")



created by DaveK
(aka Incoming)



Expansion Edition



REVISED
NOVEMBER
2013



Users who would like a deeper explanation of the underlying physics outlined here can use on-line sources in the **omninet** knowledge bases:

Grammatically Organised Online General Language Expert AI system

Wisdom Intelligence Knowledge & Information AI system (that became self aware in 2394)

Start in the 20th/21st Century physics, nanotechnology and cosmology sections and work from there.

This manual has been written because information explaining how the technology that we depend on for survival has not been clearly explained elsewhere - or at least not in readily accessible places. A great deal, in fact the vast majority, of the technology we take for granted today was developed from theories and discoveries in twentieth and twenty-first century fundamental physics.

Subsequent centuries lead to the slow development of technology that could turn the theoretical constructs of relativity and quantum theory (primarily) into the reliable and practical equipment we often take for granted today.

Notes about the Revised Expansion Edition

I have taken the opportunity of the recent expansion to completely rewrite this manual. There has been a substantial addition of new material and the role of nanotechnology integrated where appropriate;

- **new equipment is covered (e.g. Terrain Walkers, various emergency packs, several new cannon and missile types)**
- **the Weapon Laboratory available at all trade stations. The variety of particle cannon and missile warhead types now available have been described and explained in detail**
- **The opportunity has been taken to rewrite and expand many sections using the latest released information. Many more diagrams have been included.**
- **The section on sub-light engine performance has been extensively expanded and a glaring error corrected - my sincere thanks to [splosives](#) who pointed out that acceleration does differ for engine class and for different frames with the same engines - details below!**

In this revision, many typo's have been sorted and some sections edited or rewritten to make them clearer and more accessible. Some diagrams have been changed and a few others added to improve clarity

(our thanks is offered to [Marvin](#) for numerous tutorials, the technical data in the Appendices on ship frames, engines, wings and weapons and his support)

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Key to abbreviations

AI - Artificial Intelligence

BH - Black Hole

CDM - Cold Dark Matter

DE - Dark Energy

FaF - Fire and Forget missiles allows pilots to concentrate on staying alive in combat after launching missiles

FT - Fulcrum Torpedo

FtL - faster than light (applied to travel through space)

IFF - Identify Friend or Foe; a transmitter receiver that identifies you to other spacecraft and stations as friendly or hostile

NT - nanotechnology

SIF - structural integrity field

SoL - speed of light (c in the Einstein mass energy equivalence equation - $E=mc^2$)

QVee - Quantum Vacuum Energy Extraction (technology or unit) - also able to extract antimatter and normal matter from the vacuum of space

WH - Wormhole

Layout of the Manual

We recognise that not every pilot will be interested in the background theories underlying the technology she/he/it uses. Consequently all the back ground theory is presented in the first section of the manual. The technology that uses it is listed with active links so that readers can jump straight to the items that interest them

The various technologies are given a section of their own and the underlying supporting theories are identified again with active links so that any pilot wishing for more understanding can jump directly to the appropriate theory section

It is hoped that this allows pilots to jump between technological specifics and background theory as and when (and if) they want to in an efficient, quick and simple way

A word of warning

. . . the following explanations and descriptions are inevitably simplified. The details of some aspects are Top Secret. If you begin to struggle with your understanding then remember Arthur C Clarke's 3rd Law of Technology.

'Any sufficiently advanced technology is indistinguishable from magic'

Professor Gehm's Corollary to Clarke's Third Law says that

'Any technology distinguishable from magic is insufficiently advanced'

I think that this manual bears out these laws!

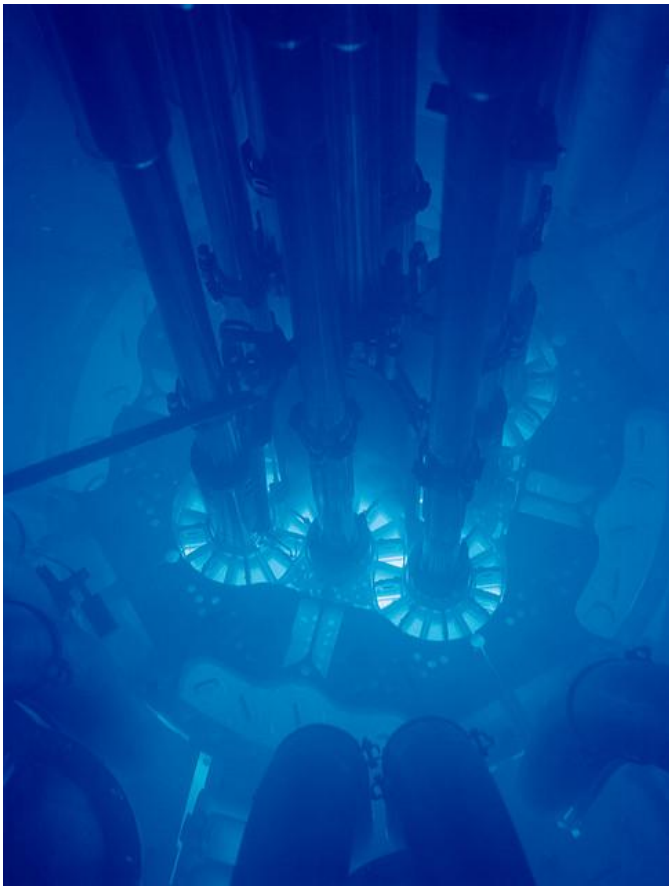
Part 1: The Background Theories

Relativity

Classical physics was overturned at the end of the 19th century. Most of our technology has been developed from the theories and laws that replaced the earlier paradigms.

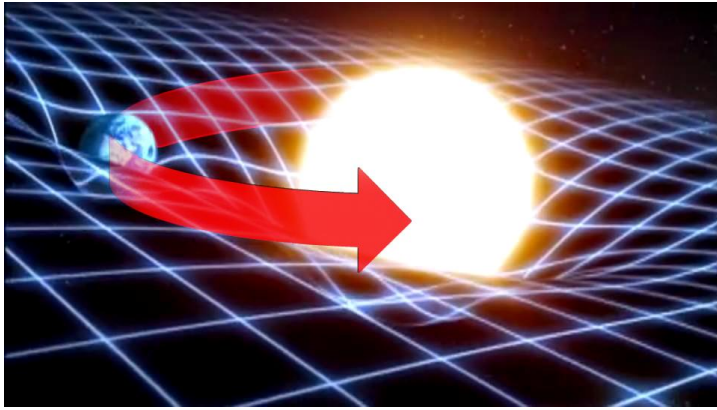
In early 20th century on Earth (in the Sol system), Albert Einstein developed his theories of special and then general relativity. Amongst many other consequences this put a 'speed limit' on the universe - the speed of light (SoL), or more properly the speed of all electromagnetic radiation. The SoL also applies to material objects as well.

Tachyons are the only particles not constrained by the SoL limit - in fact they cannot travel slower than SoL. Actually Einstein's equations don't say FtL travel is impossible, just that you can't accelerate an object up to the speed of light. Photons are born, live and die at the speed of light. Tachyons never slow down to the speed of light.



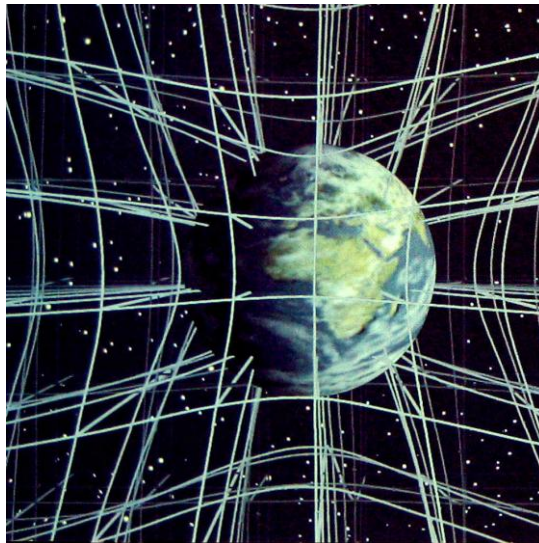
A neat illustration of this speed limit is seen in the nuclear pile at the centre of a nuclear power generator. As a result of beta decay, electrons are born in the nucleus and leave it travelling faster than the SoL. They instantly have to slow down. As they do so they emit their excess kinetic energy as blue light - this is the origin of **Cerenkov radiation** - the blue glow seen in the pile of an old fashioned nuclear power station, still used on some frontier worlds!

Relativity explained gravity in terms of four dimensional space-time. Thus to define where a particle is you need to specify three physical dimensions (the familiar X, Y and Z coordinates) plus the 'when' ie the time that you are talking about.

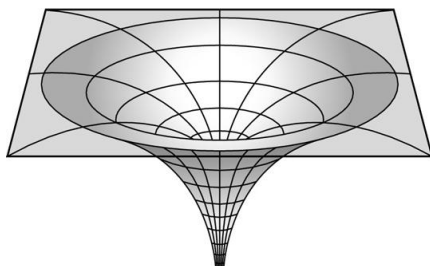


Mass 'bends' space-time like a bowling ball on a rubber sheet - the bigger the mass the greater the bending. Objects move across the sheet and like a marble passing near the bowling ball, curve around due to the dent in the sheet. Gravity is just the curve in space time causing planets to orbit their star or objects to fall downwards.

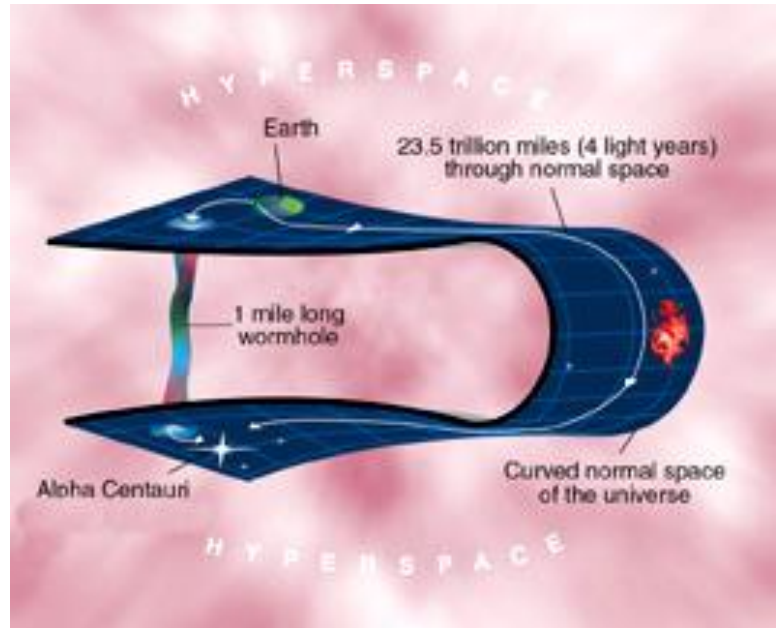
Spacetime has, of course, three physical dimensions and so the distortion is more complex than the illustration above suggests!



A second important consequence is that if the mass of an object is large enough the gravity causing it to contract can overcome all the forces of repulsion between sub-atomic particles (mainly proton - protons and electron - electrons) causing the object shrinks to zero size - a singularity. There is a distance outside the singularity within which no object travelling at less than the speed of light can escape. This is the 'event horizon'. Within an event horizon even light cannot move fast enough to achieve 'escape velocity' and hence can't escape - hence the name 'blackhole'!



A blackhole has a massive distortion effect on the surrounding space-time and if large enough is able to create and stabilise a wormhole event horizon in it centre. Careful and skilful piloting allows a pilot to jump into the event horizon of the WH before being destroyed by the BH singularity. Even the smallest miscalculation results in complete destruction of the ship. Some BH's don't have WH's in the centre. Wise pilots would use a probe to check out any unmapped BH they come across before venturing in since the only way back out is via a WH!

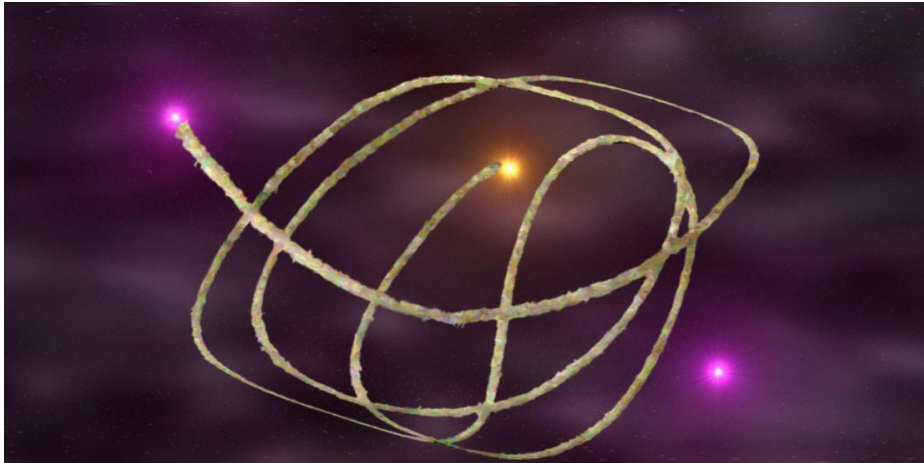


A wormhole is, fundamentally, a 'shortcut' through space-time. For a simple visual explanation of a wormhole, consider space-time as a two-dimensional (2D) surface. If this surface is folded along a third dimension, it allows one to picture a wormhole 'bridge' between the two sides of the fold.

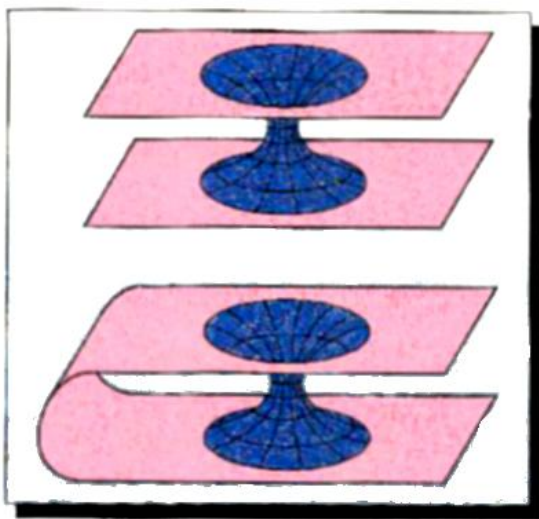
This is merely an image to convey an essentially unimaginable structure existing in 4 or more dimensions.



The parts of the wormhole are higher-dimensional analogues for the parts of the curved 2D surface; for example, instead of mouths which are circular holes in a 2D plane, a real wormhole's mouth is a sphere in 3D space. A wormhole is much like a tunnel with two ends each in separate points in space-time. In normal space a wormhole mouth appears as a sphere.



Only one wormhole has been fully mapped to date (in Olympus). As might be expected the complexity of such a distortion of space time does not resemble a smooth tube!



Lorentzian Traversable Wormholes (to give them their full name!) allow travel from one part of the universe to another part of that same universe very quickly. (previous page and upper left picture)

They also, in theory allow travel between universes in the multiverse (lower left picture). Some people offer this as an explanation for at least some of the ships that go missing every year. The possibility of traversable wormholes in general relativity was first demonstrated by Kip Thorne in his famed 1988 paper. The type of traversable wormhole he proposed, has a mouth held open by a spherical shell of 'Exotic Matter' (material that has negative mass/energy).

It is ironic that despite the universal furore generated when neutrino's were shown to exceed the speed of light in the middle 21st Century (after a false alarm half a century earlier), none of our technology actually uses faster than light travel. The impossibility of accelerating a ship to light speed only applies locally. Wormholes allow the perception of faster-than-light travel by ensuring that the speed of light is not exceeded *locally* at any time. While travelling through a wormhole, slower-than-light speeds are used. If two points are connected by a wormhole, the time taken to traverse it would be less than the time it would take a light beam to make the journey if it took a path through space outside the wormhole. However, a light beam travelling through the wormhole would always beat the traveller. As an analogy, running around to the opposite side of a mountain at maximum speed takes longer than walking through a tunnel through it.

A decade after Einstein published his work on relativity, quantum theory was developed. Until the middle of the 21st century it only explained the behaviour of particles at the atomic and sub-atomic level. Our technology developed out of our deeper and deeper understanding of relativity and quantum theory and how they were finally melded into a **Grand Unified Theory (GUT)** aka **Theory of Everything (ToE)**.

Background - Rewriting how the universe works

In the late 20th and early 21st century several major developments in cosmology, and quantum theory undermined the standard physics descriptions of the universe. Galaxies were found to have insufficient mass/matter in them to hold together at the rate they were spinning. The Universe was shown, not only to be expanding but that the rate of expansion was accelerating. Black holes were shown to 'evaporate' by emitting Hawking radiation, as a result of Quantum Uncertainty (in an extension of Heisenberg's famous principle). The result was a traumatic and radical rewrite of fundamental physics comparable with the impact of relativity and quantum theory on 'classical physics' at the start of the twentieth century.

Visible matter plus photons plus neutrinos in the universe could only account for 10% of the mass required to explain the movement of galaxies and clusters of galaxies. 30% of the mass of the universe (called *Cold Dark Matter* or *CDM*) permeates space and couldn't be seen, felt or measured but provided the mass required to create the gravity holding galaxies together.

The cause of the acceleration of the rate of expansion of the universe (effectively the increased rate of stretching of the fabric of space and time) was attributed to a (then) undetected new energy which appeared to have negative gravity. It was named *Dark Energy (DE)*. As shown by Einstein, mass and energy are equivalent. The mass equivalence of the Dark Energy accounted for the remaining 60% of the missing mass.

One outstanding discovery was that gravity has negative energy. Summing all the gravitational interactions in the universe and calculating their (negative) mass equivalence lead to an awesome discovery: the mass of matter, CDM, DE, photons and neutrinos exactly balances the negative mass of gravity - the two sum (add up) to zero! At a stroke the philosophical conundrum about how the universe can have come out of nothing was solved!

Treasured theories were modified or replaced. Nanotechnology was incorporated into engineering technology and AI systems developed to stabilise the intrinsically unstable technology being developed. The result was jump gates, jump drives, shield technology, particle weapons and the ability of small ships to travel across the universe without having to carry all their own fuel. Even stations could be created and delivered through WH's across vast distances to develop new star systems. Ships could carry equipment (Constructors) that 'projected' created real equipment that could create fuel or repair ships or extract energy rapidly from the vacuum energy permeating all of space.

Humankind left its nest, the Solar System, and moved out to the stars; Evochron was born
All of our commerce, space travel and offensive and defensive combat equipment depends on the technology coming from these new discoveries

Quantum Theory

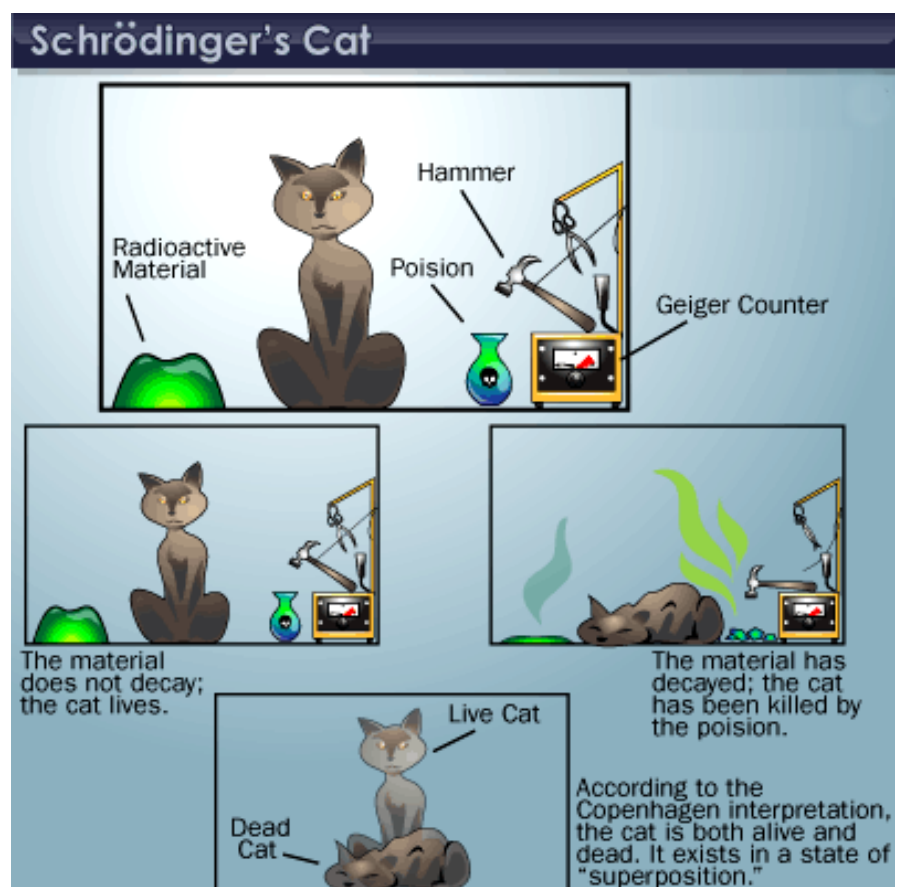
The standard explanation of what takes place at the quantum level is known as the Copenhagen-interpretation. This is because much of the pioneering work was carried out by the Danish physicist Niles Bohr, who worked in Copenhagen. Quantum theory describes the behaviour of very small objects, generally speaking the size of atoms or smaller, in much the same way as relativity describes the laws of larger everyday objects, including galaxies. There are two sets of rules because atomic and sub-atomic particles do not behave in the same way as larger everyday objects, such as billiard balls. We can, for example, say precisely where a billiard ball is, what it is doing, and where it will be in the future. The same cannot be said for particles. They are, quite literally, a law unto themselves

Of the theories that drive our technology Quantum Theory is probably the hardest to understand - it is the least commonsensical. Common sense is the result of our (often sub conscious) learning from a lifetime of direct experience. Quantum theory describes the behaviour of atomic sized particles and smaller. We live in a macroscopic world, hence the mismatch with the quantum world.

However, our technology is underpinned by a couple of fundamental outcomes from the quantum world - probability and entanglement. Although these are very hard to accept as occurring they are relatively easy to follow. Entanglement is at the cutting edge of FtL communications research; the probabilistic behaviour of particles underpins electronics (via quantum tunnelling), QVee technology, many practical aspects of nanotechnology and enzyme function and our sense of smell!

Entanglement - FtL communication

Schrodinger's cat-in-the-box thought experiment's original purpose was to expose the impossibility of the Copenhagen-interpretation of Quantum Theory:

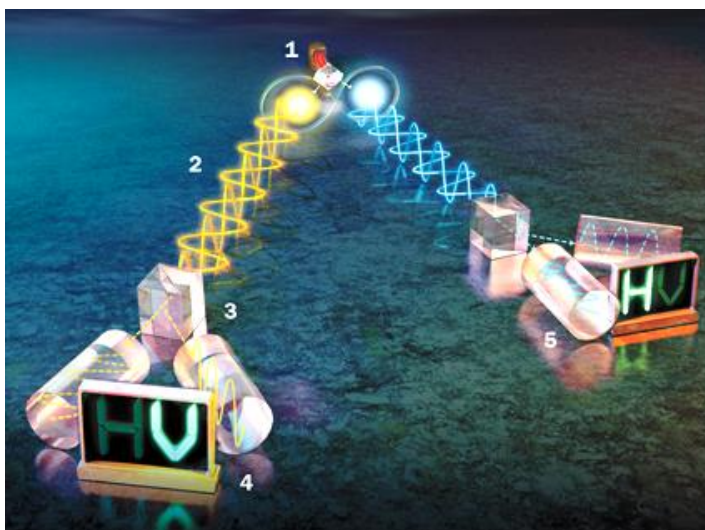


The EPR Paradox is so named because it was a thought experiment devised by Albert Einstein, Boris Podolsky and Nathan Rosen. As with Schrodinger's cat-in-the-box thought experiment's it was devised to expose the 'foolishness' of the Copenhagen-interpretation. The experiment focuses on the phenomenon of 'non-locality', which concerns 'communication' between sub-atomic particles. A pair of protons, for example, associated with one another have equal and opposite amounts of 'spin' - one spins clockwise and the other anticlockwise. Experiments show that the protons do not collapse their probability wave and 'decide' which spin to adopt, until they have been observed. If you measure the spin of one proton, according to quantum theory, the other proton instantly 'knows' and adopts the opposite spin. So far so good, we have come to expect this sort of behaviour from particles, so what is the problem with this particular experiment?

Until you make the observation the two protons are 'entangled' and both have both spins at the same time - like kitty being both dead and alive. It is easy to split the protons apart and send them in opposite directions and then measure the spin of one of them. The instant it is measured the other proton adopts the opposite spin. The time interval is zero, the event takes place instantaneously, even though the particles are separated by a distance measured in light years. Remember this was a thought experiment. This theoretical behaviour is what upset Einstein, the implication that particles could communicate at faster than light speed, as it is impossible for this to happen according to his theory of relativity.

When this thought experiment was proposed, in the early 1930's - around the time of Schrodinger's cat-in-the-box thought experiment, it was not possible to physically carry out the experiment. Einstein did not live to see the experiment actually carried out, which is probably just as well in light of the results produced - they confirmed the theory. Research is now focussed on finding a way to create sufficient entangled particle clusters and transport them to communication centres across Evochron to make universe wide instantaneous communications practical.

Albert Einstein coined the phrase 'spooky action at a distance' to describe the counterintuitive phenomenon in which particles appear to instantaneously influence each other even when they are kilometers apart. Today, our scientists call it quantum entanglement, and it forms a cornerstone of the quantum world.



1. Connection created

One way to create entangled photons is to shine a laser at a particular type of crystal. The crystal will split some of the photons in two — leaving two photons whose combined energy and momentum match that of the original photon. The two are now linked even if they travel far apart.

2. Fuzzy states

Depending on their techniques, scientists can entangle photons in numerous ways and make the particles' properties match or differ. One property that can exhibit the phenomenon is polarization, the direction of

oscillations of the light waves. Until measured, both linked photons are in a superposition of states — horizontally and vertically polarized at the same time.

3. Making a choice

Passing one of the photons through a cube that bends light with a certain polarization allows scientists to measure the property. A detector placed directly in front of the cube will register horizontally polarized light, and a detector to the side will register vertically polarized light.

4. Double detection

If the detector records a vertical measurement for one photon, then it will be instantly known that the partner photon is horizontally polarized. The very act of measuring one seems to determine what the other will be, even though the two are so far apart that information couldn't travel between them.

5. Distant influence

When passed through a similar cube, the partner photon does indeed register as having a horizontal polarization. The findings may make it look as if one measurement caused the other to come out a certain way, **but that is not the case**. Suppose the second photon was measured in a different reference frame, say speeding along on a rocket ship, it could look as if the second measurement came first. Explaining this was one step in combining relativity and quantum theory into the GUT. Scientists

Technology has proved Einstein wrong; faster than light speed, at least in the quantum world, is a reality. However, in classical physics - at sizes above that of atoms - relativity still remains unchallenged, nothing has been detected at faster than light speed.

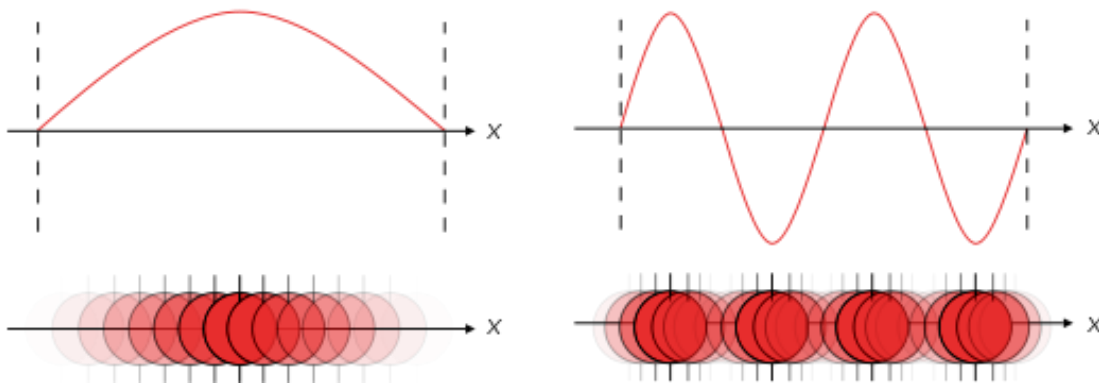
Heisenberg's Uncertainty Principle

There is one last thing we need to know about quantum theory, and that is that we cannot know everything about a particle. The more accurately we measure a particle's position the less accurately we know its velocity and vice versa. This is **not** a result of inadequate apparatus - it is a fundamental property of our universe. Heisenberg said that the electron was a particle, but a particle which yields only limited information. It is possible to specify where an electron is at a given moment, but we cannot then measure its specific speed and direction at that time. Or conversely, if you fire it at a known speed in a certain direction and so know its momentum accurately, then you are unable to specify exactly where it is. The information that an electron 'carries' is limited in total.



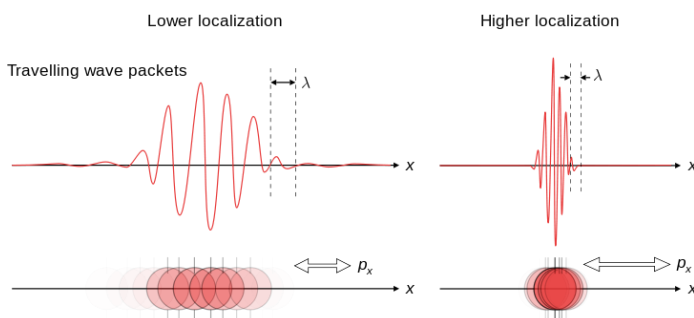
The principle of Uncertainty showed that all knowledge is limited, that there is no such thing as absolute certainty. This leads to some extraordinary outcomes. At an atomic level particles have wave-like properties and waves (like light) have particle like properties - particle-wave duality. Hence light exists as chunks of waves - photons.

The amplitude (height) of the waves is a measure of how likely you are to find the wave at that point. We can't say exactly where, but we can calculate the probability of it being at a certain place.



In this diagram we see a single particle imprisoned in an energy box - the particle doesn't have enough energy to escape. It isn't shooting around like a pea in a can - if you look into the box it will appear at a point (the probability function 'collapses') - Each time you look it will be in a different place. It will appear in places that have a greater probability - where the amplitude of its wave is higher more often. In the first illustration the particle is more likely to be found in the centre of the box - in the second diagram it is likely to appear at the energy walls or a quarter or three quarters of the way across the box. Not hard to follow - just very hard to accept as reality!

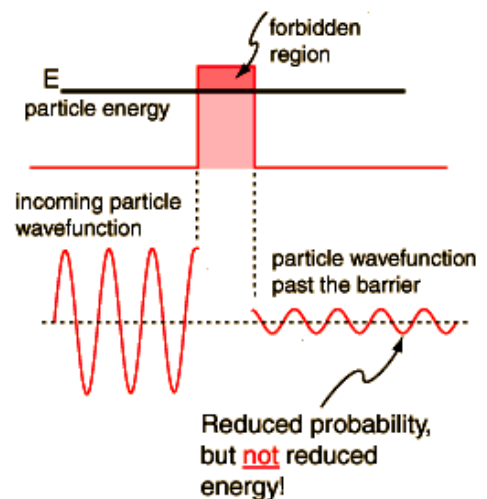
If we have a travelling wave/particle packet, for example an electron we get:



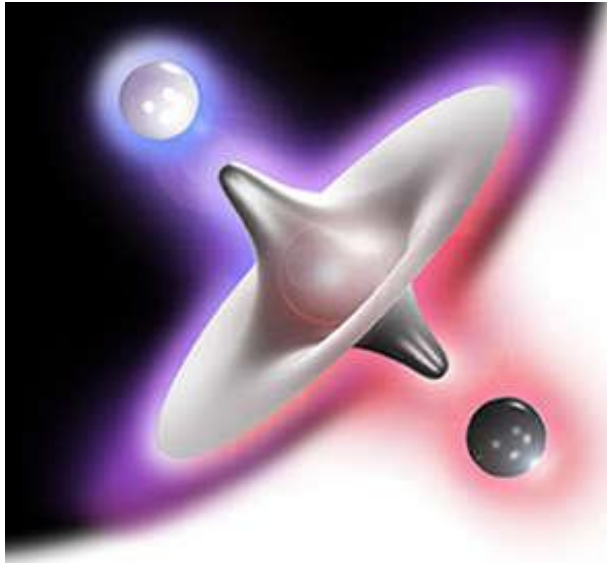
In the **first case** we have chosen to measure its velocity and the act of measuring causes the wave packet to smear out - we lose detail of where it is - its position. In the **second illustration** we have chosen to measure where it is and as a result we lose information about how fast it is travelling and in what direction, ie its velocity

Now the applications bit! If we trap an electron in an energy trap it can't escape - it simply doesn't have, nor can it get, enough energy to get over the energy barrier. When we calculate the probability of where it is in the trap you might expect it to be 100% certain that it will be somewhere inside! - common sense! However when we do the calculation we see that there is a small (but real) probability that the electron can be found outside the trap:

The red rectangle shows the energy barrier - it is higher than the energy of the particle. The sine waves show the probability of finding the electron in any particular place. Inside the trap the electron has an equal chance of being anywhere inside when you look - but (and it's a vital but!) there is a small probability that you can find the electron outside the trap. It still has the same energy (still less than the trap's energy).



Our energy harvesting technology based on this property is pathetically inefficient, but given the sheer quantity of energy available Quantum Vacuum Energy Extraction technology (QVee's) can still supply sufficient energy to power a capital ship. They can now also be made small enough to power the typical frame sizes used by mercenaries in Evochron.



Quantum vacuum fluctuations are always created as particle/antiparticle pairs.

Professor Stephen Hawking (late 20th Century/early 21st Century) realised that the creation of these virtual particles near the 'event horizon' of a Black Hole (or later a laboratory-created singularity) would have some very significant consequences. The image on the left is simulation of the moment the pair of particles is created.

It is how 'Hawking radiation' is created. The net energy of the Universe remains zero so long as the particle pairs annihilate each other within 'Planck Time' (10^{-43} second).

Steve postulated that if one of the pair is pulled through the event horizon into the black hole before this, then the other particle becomes 'real' and energy/mass is essentially radiated into space from the black hole. This loss is cumulative and results in the black hole's evaporation over time. The time required is dependent on the mass of the black hole. This explains why natural WH's of Type I and Type II can be found both be found - the former inside a black hole and the latter free in space.

Later, when it became possible to create small captive 'singularities' in the lab it was realised that the energy radiated was even easier to manage than fusion generators (that mimic the centre of a star!). This diagram shows the containment field generator for holding a singularity

The quantum fluctuations occur in a vacuum formed by joining the singularity confinement chamber of the QVee with the vacuum space outside the ship. - these can be seen on the side of the chamber.



The virtual particles produced are manipulated so that either matter or antimatter is collected. The type of particles not required are ejected into space and , if they are antimatter particles, gradually annihilate particle by particle as they interact with the hydrogen atoms in the vacuum. If both leaked out it would lead to a mutual annihilation and the ship would explode spectacularly! - See **Fulcrum Torpedo** below.

Anti matter can be collected for use in FT's; it is also possibly the explosive mechanism in Excalibur missile pack warheads, whilst matter particles can be converted into (storable) fuel or pure energy (described by Einstein's famous equation $E=mc^2$) or used to create new hull material, electronics and machinery etc used by the auto-repair systems fitted to most ships.

The amount of energy available from empty space is almost beyond human comprehension.

Using Einstein's equation $E=mc^2$ we can calculate that if one gram of matter is converted into energy it releases 10^{11} MJ (100 billion MJ). This corresponds to the release by half a gram of antimatter and half a gram of matter mixed together or to put it another way, if we extract 1g of 'particle pairs' from the quantum vacuum foam we could use them to create this amount of energy. Using the traditional historical equivalence to the explosive TNT - **a 1g matter/antimatter explosion = 43 000 tonnes of TNT.** The nuclear bomb dropped on Hiroshima (during the first nuclear world war on Earth in the twentieth century) = 15 000 tonnes TNT. **More peacefully, the energy contained in 1 gram of matter/antimatter is enough power the average household module for 4500 years. 1 kg of matter would create the same energy release as a 10 Mtonne nuclear bomb.**

The efficiency of the particle extraction depends on the mass of the black hole and the size of its corresponding event horizon. Our technology only needs to use a tiny singularity to extract sufficient energy to power stations and ships.

Gravity Particles and close up protection!

Shield generation employs a two component system. The first involves gravitons. Gravitons are part of the great success of quantum field theory at modelling the behaviour of all the known forces of nature as being mediated by elementary particles. All forces are 'transmitted' between objects by fundamental particles - electromagnetism by photons (this means that photons carry the electromagnetic force from object to object). Put simple, when two magnets attract each other, photons travel between them to carry the force - this is the source of the 'spooky action at a distance' that freaked out Einstein right up to his death. 'Gluons' mediate the strong nuclear forces, 'W&Z bosons' the weak nuclear force, these forces holding atomic nuclei together..

Gravity is transmitted by an elementary particle, dubbed the 'graviton'. When the quantum description of gravity is translated to the General Relativity view it agrees with Newton's law of gravitation. Basically gravity hasn't changed (the Earth still sucks!) but our description of it has become more complex, and subtle and as a result, far more useful.

To summarise, the importance of the graviton (as well as keeping planets in orbit and us stuck to our planets, and also being a major component of the defensive shield field matrix and tractor beams) is its role in linking quantum gravity (Quantum Theory) with relativistic gravity (Relativity Theory) and our everyday experiences (Classical gravity) into the **Grand Unified Theory**, aka the **Theory of Everything**. This was the Holy Grail of physicists in the 20th and 21st centuries finally achieved in the 22nd century.

The four forces of nature - a summary of 'spooky action at a distance'

Shortly after the 'big bang', when the era of symmetry breaches came to an end there were four forces, and those four identified all the various differences between the existing fundamental force carrying particles:

Force	Particles that 'carry' the force (bosons)	Function	Range
Gravity	Graviton	Gravity curves space. And it always attracts, never repels. Gravity is the only force to which all particles are subjected.	Indefinite
Strong Force	Gluon (8 kinds)	The strong force binds quarks into nucleons and nucleons into nuclei.	Limited to the atomic nucleus
Electromagnetism	Photon	Electromagnetism binds electrons to the nucleus. By doing so electromagnetism allows all physical and chemical processes to happen.	Indefinite
Weak Force	Weak bosons (3 kinds)	The weak force causes unstable particles and nuclei to decay.	Limited to the atomic nucleus

All four of the fundamental forces involve the exchange of one or more particles. Such 'exchange forces' may be either attractive or repulsive, but are limited in range by the nature of the exchange force. The maximum range of an exchange force is dictated by the Uncertainty Principle since the particles involved are created and exist only in the exchange process - they are called 'virtual' particles.

The diagrams are organized into six panels:

- Leptons:** Shows Tau, Muon, and Electron, each with its corresponding neutrino. Electric charges are listed as -1 for the charged leptons and 0 for the neutrinos.
- Strong:** Shows 8 Gluons, Quarks (forming Mesons and Baryons), and Nuclei.
- Electromagnetic:** Shows a Photon and its effects on Atoms, Light, Chemistry, and Electronics.
- Quarks:** Shows Bottom, Strange, and Down quarks, each with its corresponding Top, Charm, and Up quark. Electric charges are listed as -1/3 and 2/3. A note indicates 'each quark: R, B, G 3 colours'.
- Gravitational:** Shows a Graviton (represented by a purple wave) and its effects on the Solar system, Galaxies, and Black holes.
- Weak:** Shows Bosons (W, Z) and their effects on Neutron decay, Beta radioactivity, Neutrino interactions, and the Burning of the sun.

The particles

As stated above, material particles can be divided into three fundamental groups:

- (1) **bosons**, which are bits of force, not real particles; They are the *graviton*, *gluon*, *photon* and *weak boson*
- (2) **quarks**, which are electrically charged, either positive or negative, and which appear as triplets to form atomic nucleons (protons and neutrons) that contains most of the mass of the **visible** universe (ie excluding Dark Matter and Dark Energy);
- (3) **leptons** which either have a negative electrical charge (*electrons*) or no charge at all (in which case they are called *neutrinos*, and which make the universe a lively place in which a lot more happens than simply bumping into each other.

Multiverse Theory

Relativity showed that wormholes are possible and can exist between two points in our universe, traversing extra dimensions. String Theory (actually Superstring Theory (SST) that developed from it) showed that ours isn't the only universe. SST equations describe reality as existing in eleven dimensions (rather than the four we are familiar with). The theory suggested that there might be several different models for the multiverse. Eventually research identified which of the models was correct. We live in one universe within a Level II multiverse. The most significant property of such a multiverse is that each universe within it has different fundamental physical constants. When relativity and superstring theories are melded they show that wormholes can link our universe with parallel universes - the Brane Multiverse - tunnelling through the higher dimensions to link universes together



The membrane universes are stacked side by side like a pile of plates - every disk is a sheet universe in multidimensional multiverse and has physical constants that are different from our universe and different from each other; our universe is just one of the plates!

Linde and Vanchurin calculated the number of these universes to be on the order of $10^{10^{10,000,000}}$. Other researcher believe the number to be infinite. Most mortals think that since there are only about 10^{80} atoms in the whole of our universe, the argument is a little pointless!

The various parallel universes bears no 'historical relationship' to each other - there isn't an alternative 'you' living an alternative 'life' in a parallel universe. Instead, the laws of nature are simply different than those in our own. In one universe examined the value of the Gravitational Constant is much larger than in our universe. The universe consisted of blackholes of various sizes and hydrogen and helium gas in the process of condensing. The internal gravitation attraction of any condensing cloud of interstellar gases was too large for the nuclear fusion reactions in any potential stars to balance it out. Gas clouds condensed and continued to contract to create black holes!

In another, the strong nuclear force was too weak to overcome proton-proton repulsion and thus atomic nuclei couldn't form so the universe was filled with a low temperature plasma - a soup of protons, electrons, neutrinos and photons - that had formed as the universe expanded like ours after the big bang, but even when it had cooled significantly (when our universe was able to form atoms of hydrogen and helium) no atomic matter had formed.

Nanotechnology

Unlike relativity and quantum theory which gave us new and deeper models of the universe, nanotechnology resulted from a blending of engineering and chemistry.

In the 21st Century chemists began to explore nanoscale materials. Nanomaterials are made of particles between 80 - 100 nm in size. A nanometre is one billionth of a metre! At this scale many common materials have very unusual properties. The early outcomes were graphene, carbon nanotubes and bucky balls (buckminsterfullerene). These materials have found application in 'battery' technology for storing electrical charge in a very concentrated form improving charge storage by several orders of magnitude. Examples of their use include shield boosters and charge packs, cannon relay systems and the creation of lightweight materials of outstanding strength and stiffness as well as materials that can self repair.


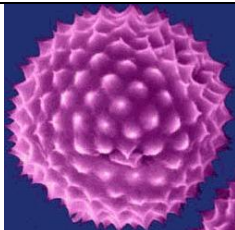
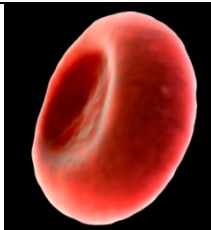
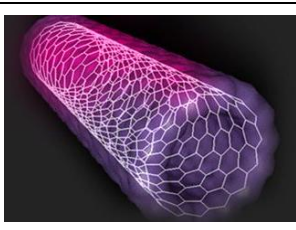
At the boundary between chemistry and physics, research focussed on the creation of ever smaller machine parts, for example gear wheels one ten billionth of a metre across. Engineering technologists were able to develop complex machinery at microscopic and molecular scales.

Another outcome was the ability to manufacture materials and equipment atom by atom allowing an unprecedented manipulation and fine tuning of properties, behaviour and performance. Materials were manufactured in this way that couldn't be produced in any other way.

Nanotechnology joined relativity and quantum theory as the foundation of the technology we now take for granted only a couple of centuries later.

1: Dimensions

In order to understand the unusual world of nanotechnology, we need to get an idea of the units of measure involved. A centimetre is one-hundredth of a meter, a millimetre is one-thousandth of a meter, and a micrometer is one-millionth of a meter, but all of these are still huge compared to the nanoscale. A **nanometre (nm)** is one-billionth of a meter, smaller than the wavelength of visible light and a hundred-thousandth the width of a human hair

head of a pin	ragweed pollen	red blood cell	carbon nanotube
			
1 000 000 nanometres (diameter)	20 000 nanometres (diameter)	2 500 nanometres (diameter)	2 nanometres (diameter)

As small as a nanometre is, it's still large compared to the atomic scale. Atoms are the building blocks for all matter in our universe. An atom has a diameter of about 0.1 nm. An atom's nucleus is much smaller -- about 0.00001 nm.

Nature has perfected the science of manufacturing matter molecularly. For instance, our bodies are assembled in a specific manner from millions of living cells. Cells are nature's nanomachines. At the atomic scale, elements are at their most basic level. On the nanoscale, we can potentially put atoms together to make almost anything.

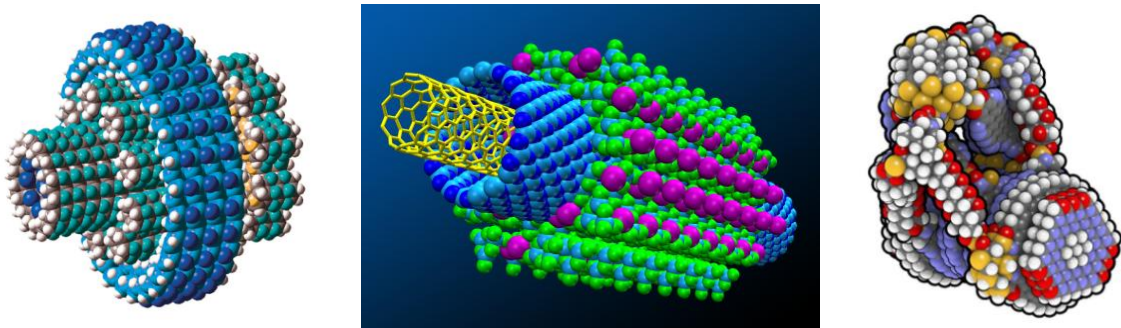
2: Molecular Manufacturing

Basic electronic components such as transistors and amplifiers have been reduced to single, (if somewhat complex) molecules. The goal of molecular manufacturing is to manipulate atoms individually and place them in a pattern to produce any desired structure.

The first step was to develop nanoscopic machines, called **nanobots**, that are programmed to manipulate atoms and molecules at will. In order for it to be practical, molecular manufacturing needs trillions of them working together simultaneously. Only a few nanobots plus a supply of raw materials are required to kick start the process. The nanobots first replicate themselves, building others. Each generation would build another, resulting in exponential growth. Once sufficient nanobots have been created they can be used to do other jobs.

There are two sizes of microscopic robots required. The smallest are called nanobots and the larger ones microbots. These two types work together and work with assemblers/fabricators to automatically construct products, vastly decreasing manufacturing costs and increasing quality, thereby making goods (including stations and cities and ships) plentiful, cheaper and stronger.

Nanobots (and certainly microbots) might contain moving parts like the nanogears (left & right illustrations) or a motor (centre). The individual spheres you can see are individual atoms

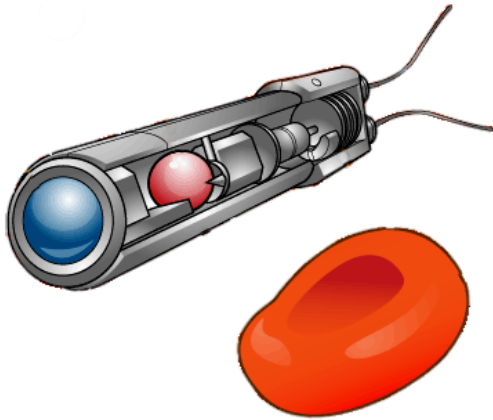


Many conventional designs for basic mechanical parts like gears can be scaled down to the molecular size range (if some care is taken in the design). Other than their small size, it's rather unremarkable. The gears and motor above would be encased in a strained silicon shell with predominantly sulphur termination to provide protection, dimensional stability and stiffness.

Trillions of assemblers and replicators fill a volume smaller than a cubic millimetre, and are still too small for us to see with the naked eye.

Since their invention, computers and robots have been reduced to extraordinarily small sizes. To take two practical uses: In mining one type of nanobot is tasked with breaking the raw material structure into its component atoms. A second uses an onboard digital camera and spectrographic analyser to identify specific atoms. The third type is tasked with picking up and storing the atom, guided by the signal from the second nanobot.

Nanobots can gather materials and 'weld' them into microcircuits, as well as use an onboard atomic force microscope probe to feel its way along a patterned surface, locating itself with an accuracy of two nanometres, which is less than the width of a DNA molecule. The probe is used to measure electronic or mechanical properties to ensure that the electronics function correctly.



Nanobots (also called nanites) are programmed to repeat one task (though the task can be quite sophisticated). The illustration shows one of the three main types of mining nanobot. It is shown next to a (human) red blood cell to give some idea of how small it is.

Microbots are typically a thousand times or so larger than a nanobot (but still incredibly small). They are more complex in design and are able to carry out a greater variety of functions within one programme sequence.

They work with nanobots in molecular manufacturing and raw material mining and processing. Teams of such robots automate work on the molecular scale for the collection of pure raw materials for industrial applications including fabricating the structural sub-systems for building stations and city buildings.

The main advantages of such automated manufacture is firstly cost reduction and secondly the ability of the fabricating factories to be located in extreme locations where humans couldn't survive. More detail is available in the section on Trade Station manufacture, below.



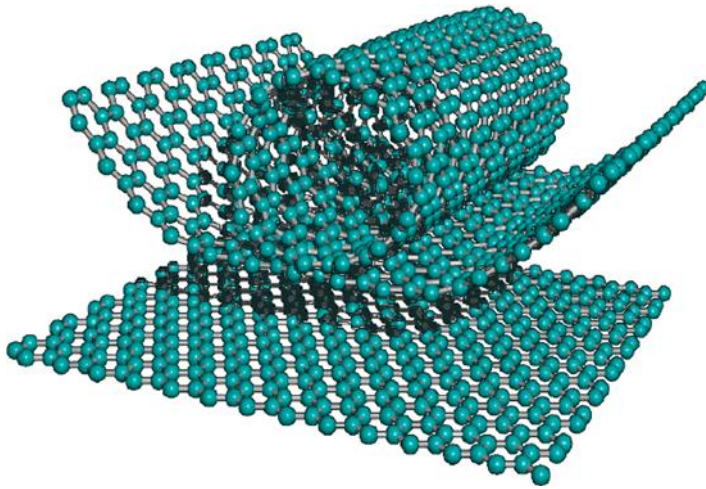
3: Types of nanomaterials commonly used

The main raw material for manufacture is carbon; carbon can be used to make synthetic diamond and diamondoid materials, graphene as well as fullerene nanotubes. Structural components for stations, electronics, armour and most manufactured products are wholly or mainly made from these materials. Metals are now secondary in terms of volume required, though are still vital constituents in small quantities, especially for electronic components.

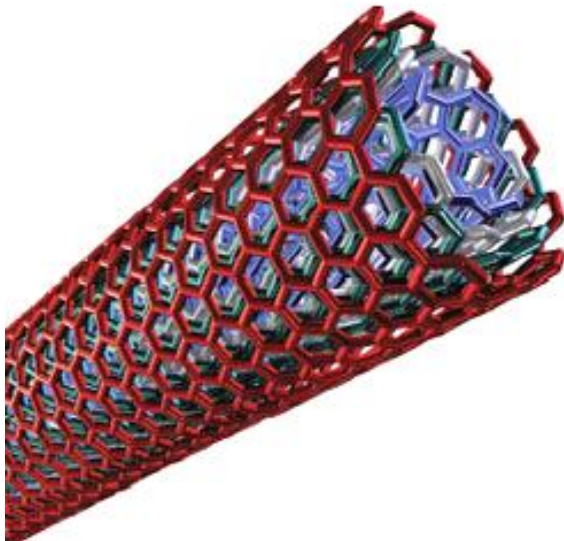
Nanowires and Fullerene (Carbon) Nanotubes

Two nano-size structures are of particular interest: nanowires and fullerene nanotubes. Nanowires are wires with a very small diameter, sometimes as small as 1 nanometer. They are used in the manufacture of tiny transistors for computer chips and other electronic devices. Smaller = faster!

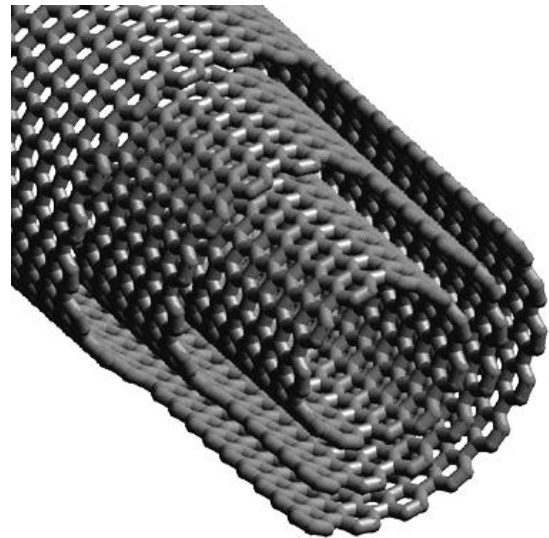
In terms of bulk use, nanotubes have overshadowed nanowires.



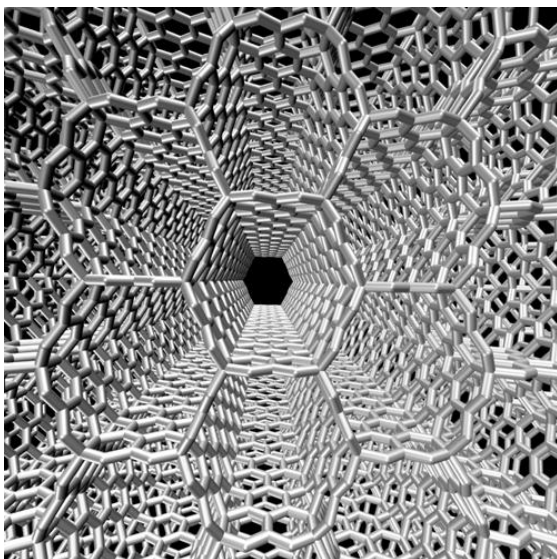
A nanotube is a nano-size cylinder of carbon atoms. Imagine a graphene sheet of carbon atoms, which would look like a sheet of hexagons. If you roll that sheet into a tube, you'd have a nanotube. Fullerene nanotube properties depend on how you roll the sheet. In other words, even though all carbon nanotubes are made of carbon, they can be very different from one another based on how you align the atoms, how many layers of graphene are rolled together and whether they are concentric or in a spiral.



multi-layer concentric 'tube within a tube'

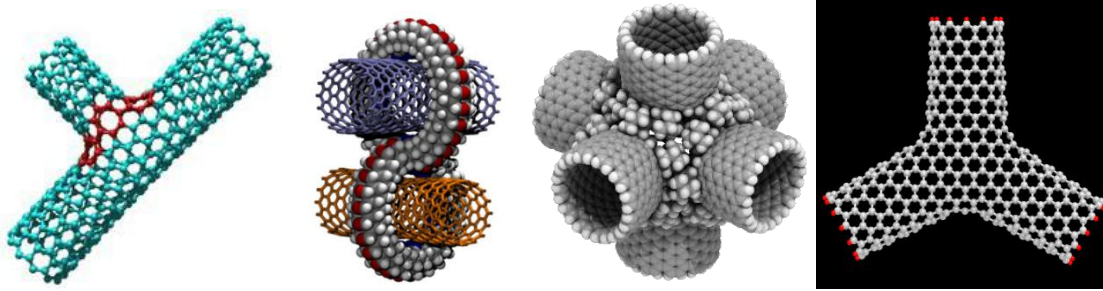


'spirally wrapped from several single sheets'

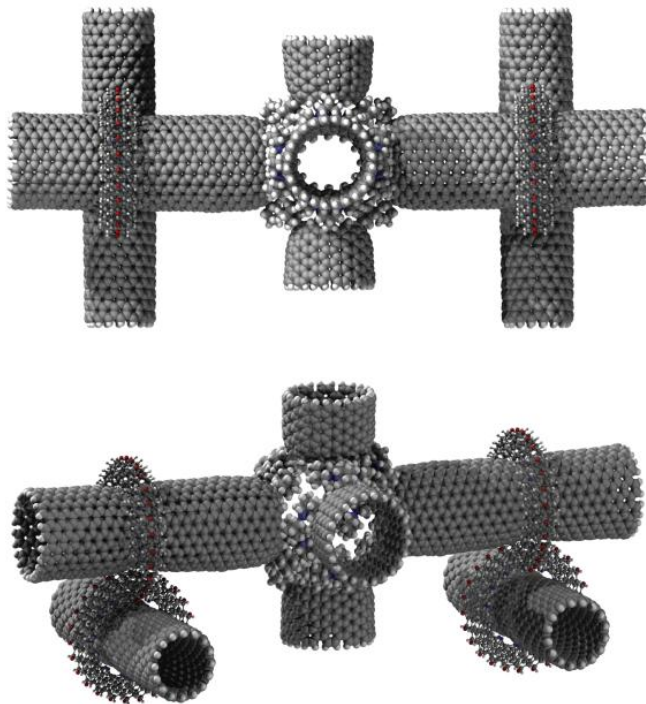


Fullerene tubes can also be manufactured into a 3D structure with tubes joined together along their lengths.

Complex microstructures can also be built using fullerene tubes using molecular sized connectors which are also made of fullerene nanotubes

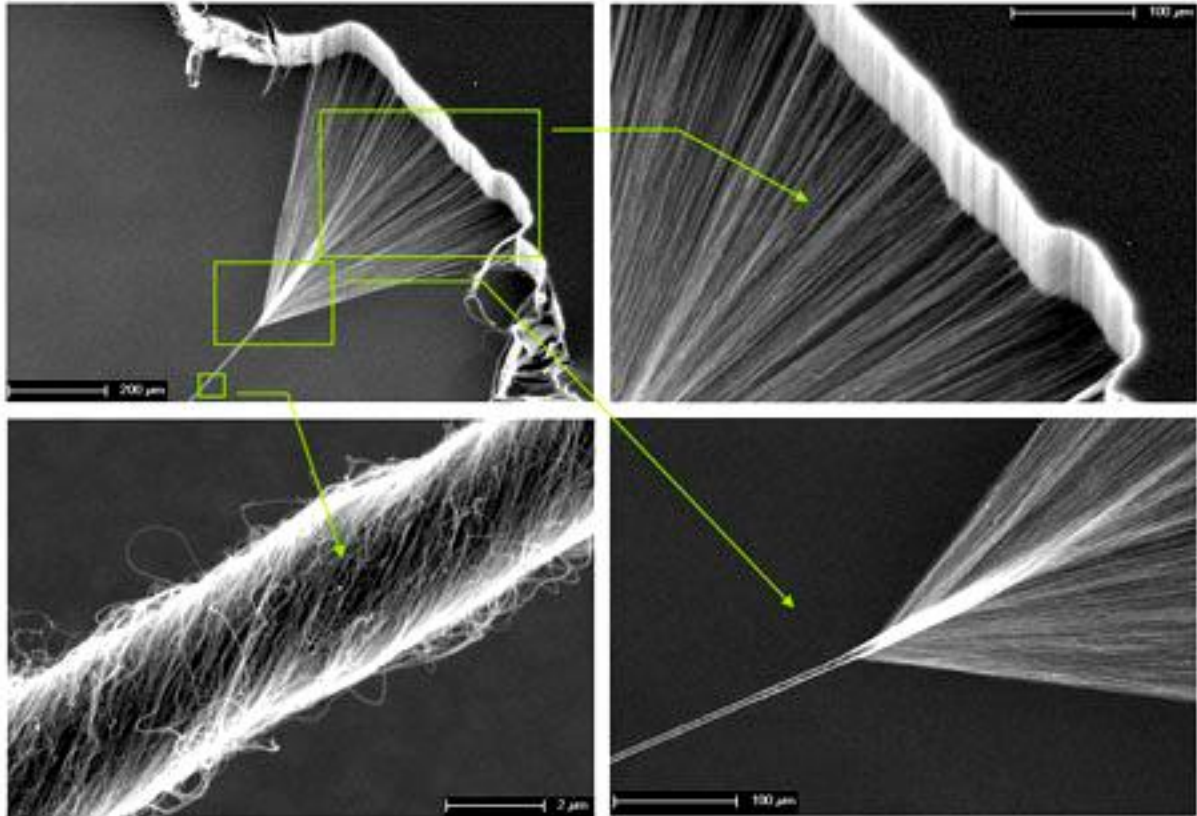


These basic connectors can be used to create very specific complex structures which are especially useful in electronic applications;

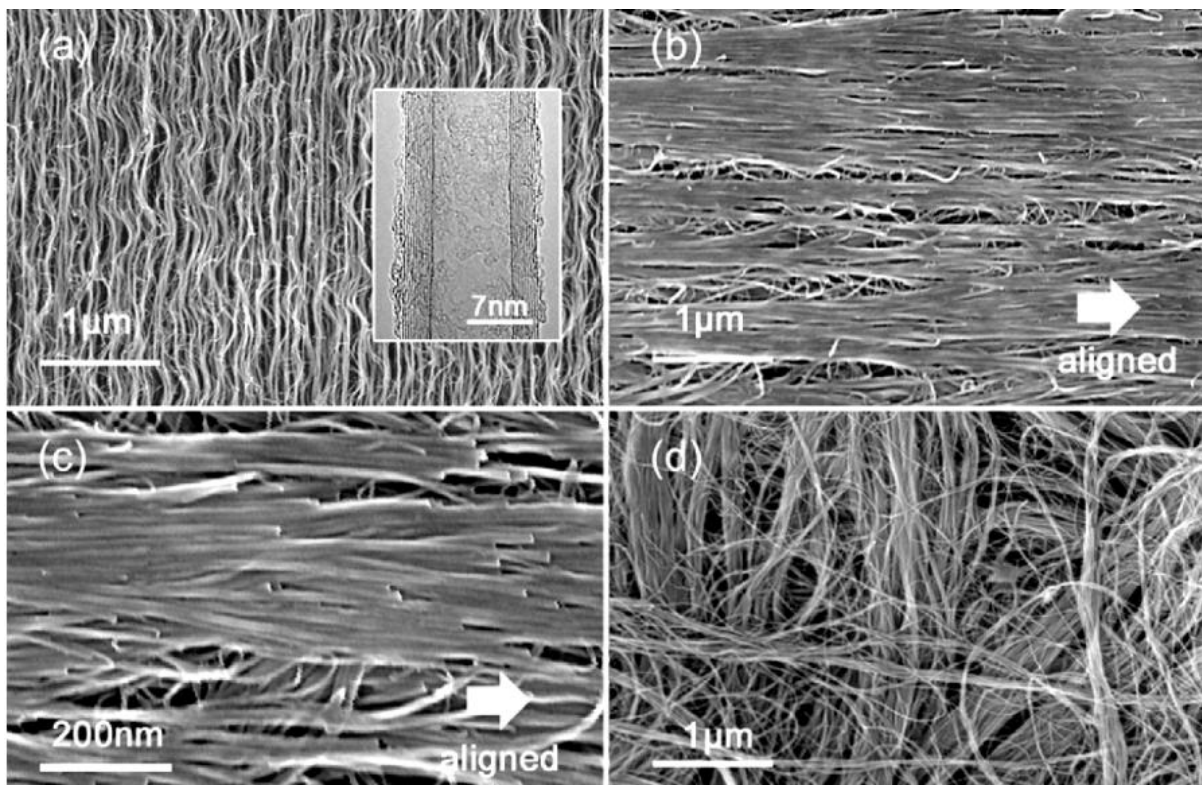


The fine tuning of molecular and macroscopic properties made possible by nanotechnology appears to be unlimited!

Nanotubes can be 'spun' and resulting fibres woven or layered to create macroscopic cloth-like materials.



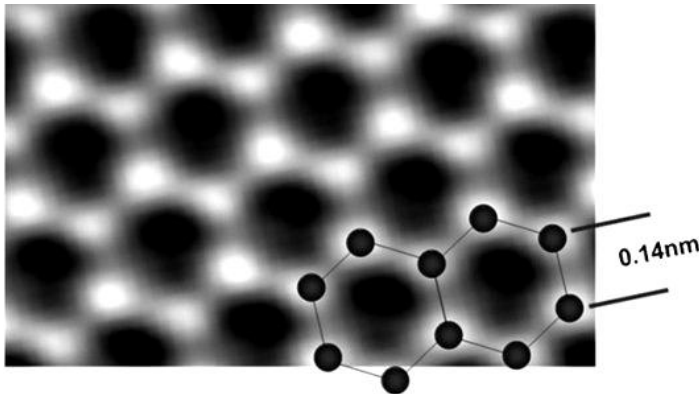
The fibres that can be woven or layered into very strong sheets to more easily create more complex shaped structural units



Fullerene nanotubes are the basic building block for structural components in stations, city buildings and many structural parts of ship. With the right arrangement of atoms, nanotube structures can be created that are very stiff and hundreds of times stronger than steel, but ten times lighter. Lighter ships mean better fuel efficiency and acceleration, and the added strength translates to increased pilot safety.

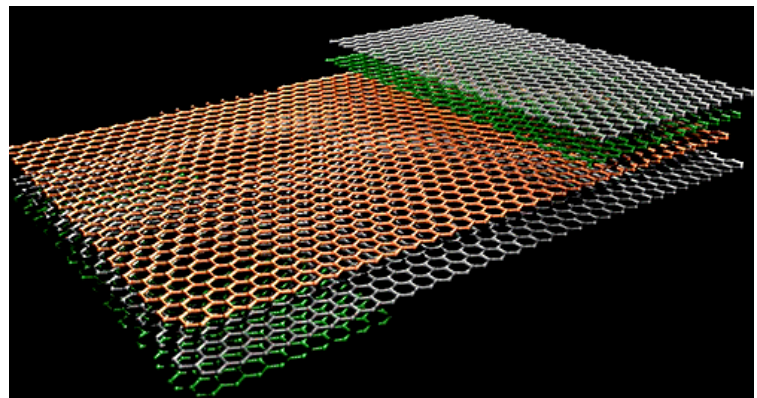
Fullerene nanotubes can also be effective semiconductors with the right arrangement of atoms. This makes nanotubes (partnered with graphene sheets) the preferred option for transistors in microprocessors and other electronics.

Graphene

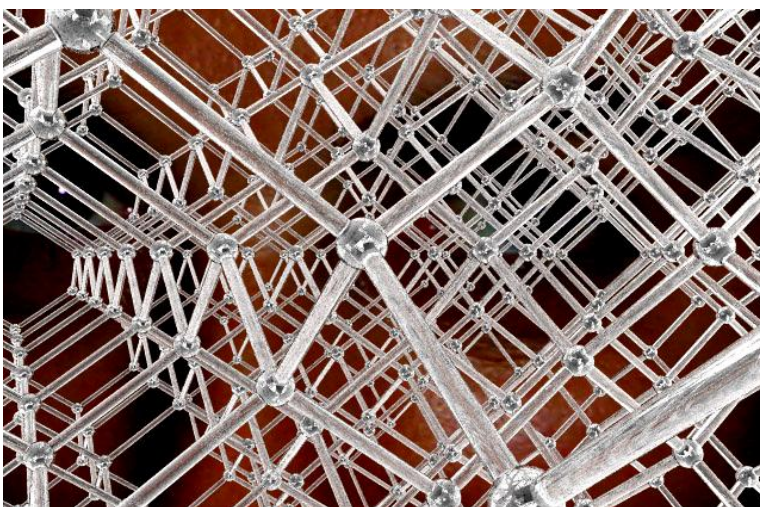


Graphene is a monolayer of hexagonally arranged carbon atoms. It can have a very wide range of electrical properties depending on how the sheets are created and arranged. Room temperature superconducting graphene can be created.

Laminates of graphene are very strong and superlative thermal conductors. They are a common constituent of laminated armour, being able to resist penetration and dissipating thermal energy efficiently and quickly to reduce the stresses caused by local overheating



Diamondoid Sheet (AKA Diamond Plate)



The ability to precisely control the manufacturing of diamond, at the molecular level, has resulted in a product improved by several orders of magnitude over the natural material. Diamond can be produced as sheets, wires, rods, slabs and in complex shapes. Its structure can be subtly manipulated to create analogous 'diamondoid' materials increasing its versatility further

Diamond is light and strong: the strength-to-weight ratio of diamond is over 50 times that of steel. By modifying its structure to make it tough and shatter proof as sheets and diamond fibres, diamond has

become the partner to fullerene nanotubes as the construction material of choice. Great strength is only one property that we prize highly: when we make computers we are more concerned by electrical properties. Here too diamond excels.

4: Nano-manufacturing

Making electronics highlights another problem (though the issues are applicable to structural fabrication as well). It's not enough to make a pure crystal, it must also have an extremely precise and complex pattern of impurities. The exact location of the dopant atoms in the semiconductor lattice controls how devices function and where signals can propagate. Local order is crucial to make each device work, but long range complex order is crucial to make the computer as a whole work. Similarly by emulating (in non-metallic materials) metal alloy structures the strength and stiffness of the structural products are greatly enhanced and can be finely tuned

Nanotechnology, by definition, lets us economically manufacture almost any specified structure that is consistent with the laws of chemistry and physics. To simplify the problem somewhat we can narrow our focus to structures that resemble diamond in a broad sense: the diamondoid structures. This class includes (among other things) diamond crystals of arbitrary shape but with stable unreactive surfaces and with impurities at precise locations in the diamond lattice. The objective is to manufacture particular diamondoid structures once the location and type of every atom has been specified by design.

Nanobots are able to manipulate individual atoms, quickly and accurately. They are capable of positioning the tool to within something like an atomic diameter - a few angstroms. Thus, positional accuracy of 1 to 2 angstroms for the positioning tool is required. When mining this accuracy is required to pick up the correct atom identified by the seeker nanobot.

The goal of molecular manufacturing to build exactly what we want at low cost is now routine. Many if not most of the things that we want to build are complex (for example a molecular AI computer). Having precise programmed positional control at such a small scale lets us make a truly broad range of macroscopic molecular structures. This level of positional control requires **very** small mechanical robotic manipulators. If we are to make anything of any significant size with this approach, we need vast quantities of these manipulators. The ability of nanobot assemblers to manufacture other general purpose fabricators lets us build large numbers of such devices at low cost. This general approach has let us develop a low cost general purpose molecular manufacturing technology.

How does it work in practice? **Convergent Assembly** is the preferred solution (for details see the section below on station building).

Artificial Intelligence (AI)

The high expectations for AI research in the late 20th Century and early 21st Century were never fulfilled. Only one AI system has developed an intellectual capacity greater than that possessed by a goldfish. That one system is **WIKI** - which became self aware in 2394, though, WIKI is an *idiot savant*. It is conscious of its own existence but has very little if any 'social' awareness. However progress increased rapidly once researchers stopped concentrating on trying to make 'artificial humans' with the phenomenally broad adaptability that humans have. AI has developed into something far more useful than mere synthetic people. We now have AI systems that are excellent at monitoring and controlling very complex systems, measuring, evaluating and balancing a multitude of parameters at phenomenal speeds to maintain stability and very precisely defined, specific outcomes - your sub-light and jump engines for example.

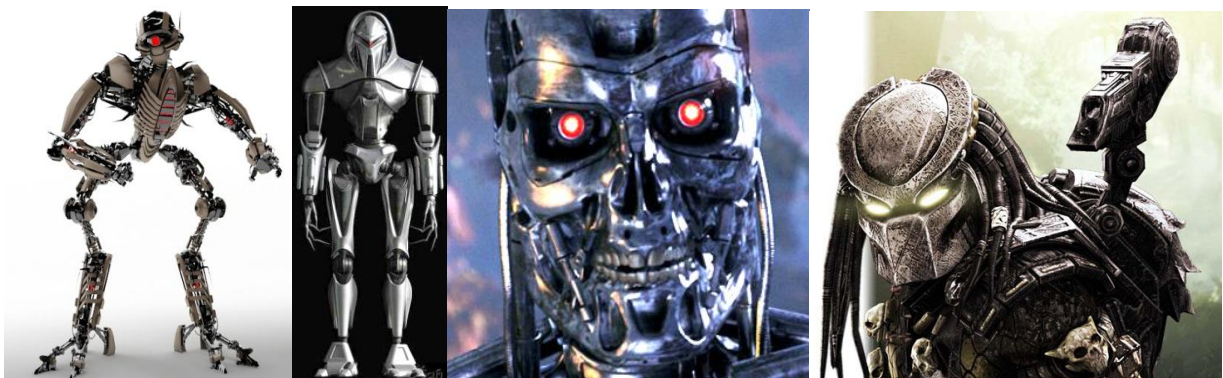
Attempts at giving AI systems mobility so as to increase their versatility were also singularly unsuccessful.

The first attempts were very utilitarian, with little thought of making the AI androids humanoid;



Though practical for environments where humans couldn't easily work, the hoped for versatility was missing because the mobile units were not acceptable for populated areas.

The second generation attempted to make the android chassis more human-like, though practicality was still a high priority.



Trial introduction of these models actually lead to mass public hysteria and violent civil protests to have the models withdrawn, despite retrofitting more friendly and less threatening smiling 'faces' . . .



A short lived third generation didn't get beyond the focus group stage



There was one final attempt, codenamed Project Nolyc, to create a universally acceptable humanoid chassis for AI units. It required more than a decade of work using vat grown skin and muscle. There were difficult intermediate stages when trying to stabilise the vat grown flesh over the titanium endoskeletons that lead to outcomes that never saw the light of day . . . except in a pizza fuelled nightmare



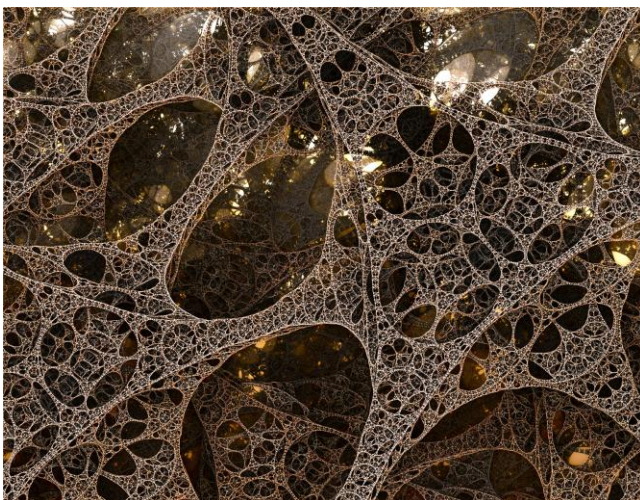
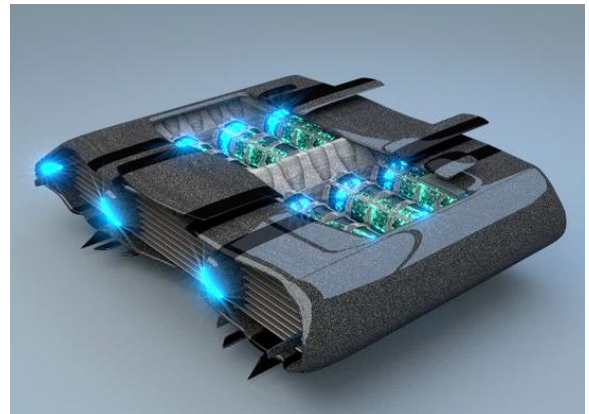


Finally two chassis were released - Model Numbers 6 and 8 - codenamed '*Cap-Six*' and '*Boomer*'. It is probably a comment on the nerdiness of the development team members that only they were surprised when research polls clearly showed that only around 50% of the human population approved of the new designs! In fact the disapproving 50% lobbied governing bodies to outlaw them.

Pre-orders from mercenary pilots was extremely buoyant, but under public pressure the models were withdrawn and all work on AI transport chassis ceased.

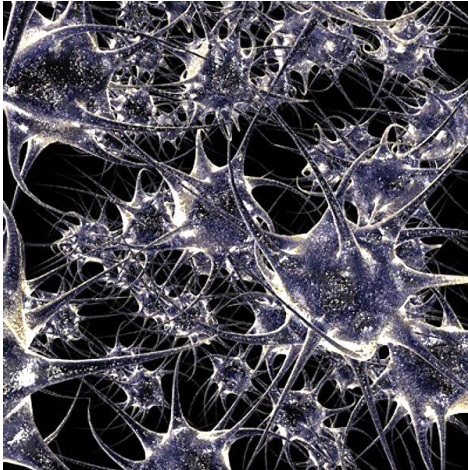
Rumours circulate about the fate of the pre-production chassis of these two models but despite much investigation concrete facts are unavailable.

All AI units are now permanently physically fitted into the systems they control. The main processing core is encapsulated in a chip and typically looks like this. They are embedded into sophisticated electronic interfaces to allow them to monitor and control the systems they are responsible for running. They also have a communications interface to receive instructions and output information and data.



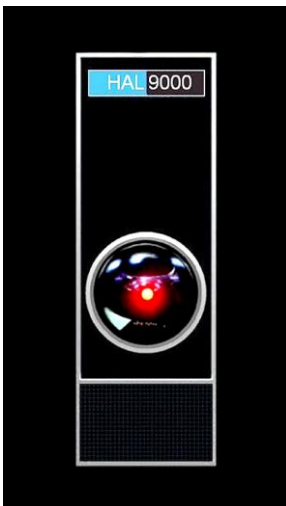
The main processing core is in the form of a neural network of billions or trillions of synthetic neurons which have multiple interconnections mimicking the structure of the human brain, and this construction design gives AI's their ability to learn and evolve though only to the degree limited by their size.

magnification x100 000



This electronic microphotograph shows a tiny part of the network illustrating the multiple connections between the nodes.

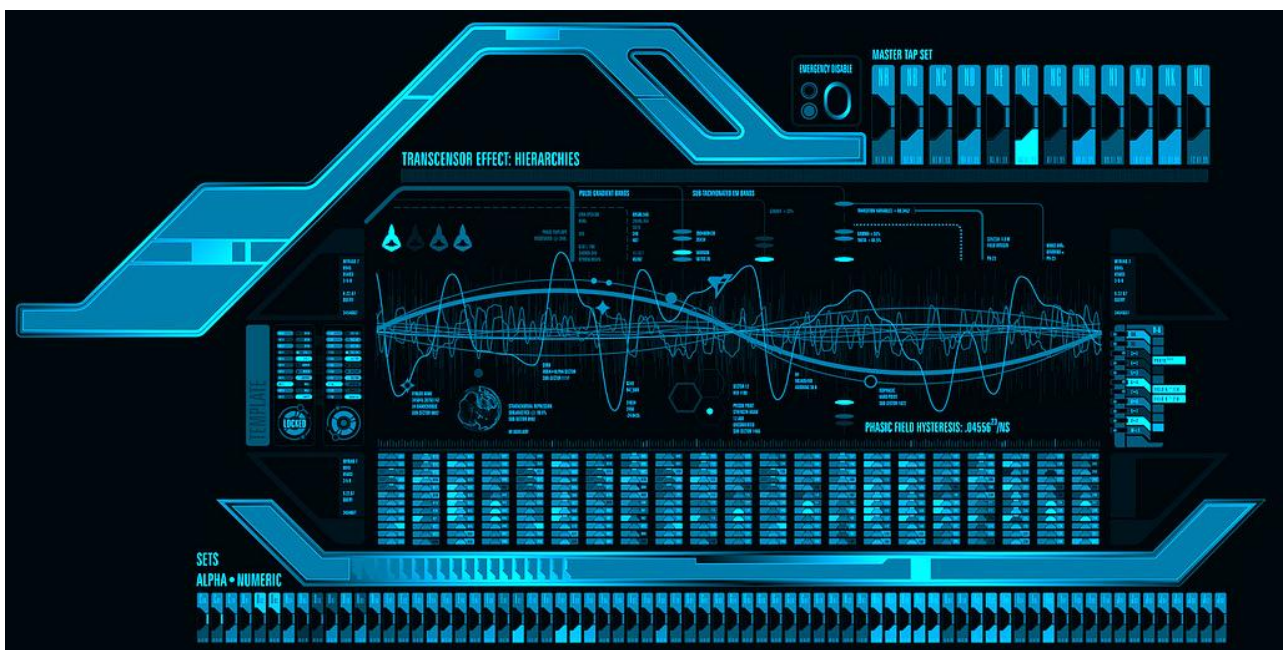
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AI Interfaces have evolved substantially. The earliest were verbal, using 'mechanical' devices only when data needed to be input. Typical of this type is one of the very earliest.

The HAL 9000 AI malfunctioned resulting in the death of two astronauts. The fate of the third crewmember had never been determined. Part of the problem was that the verbal nature of the interface prevented direct access to AI subsystems which would have allowed the astronauts to regain control. Issues had also arisen when the AI needed to show data to the team - their attention needed to be focussed in several areas leading to inefficiency in situational processing and decision making

This led to the development of a holographic virtual screen with easily transformable readouts and 'touch' controllable virtual buttons:



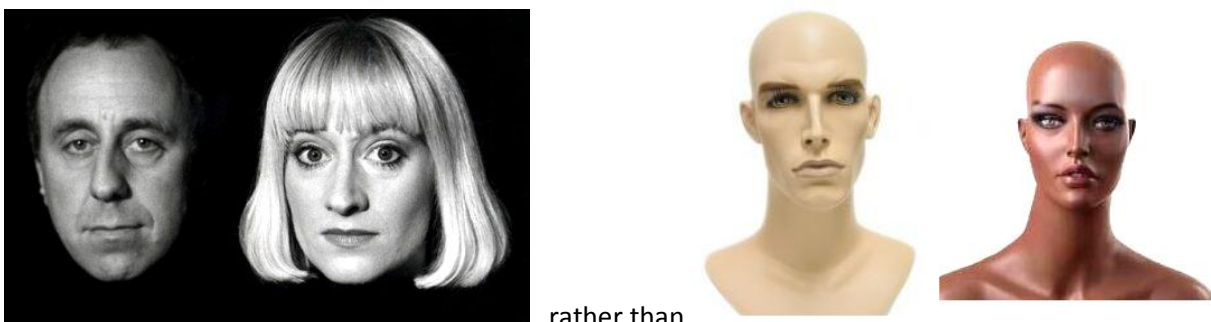


In more complex situations it became apparent that operators valued and hence were more efficient when the two systems were combined, especially so when some semblance of interacting with a 'person' was included. early holographic faces were simple, even crude but enhanced effectiveness markedly

The 'human' part of the interface became more and more realistic as tests showed improved performance and holographic projection technology developed steadily



- the optimum proved to be realistic figures of 'average' attractiveness - more perfect faces lead to a feeling of inferiority amongst human users!

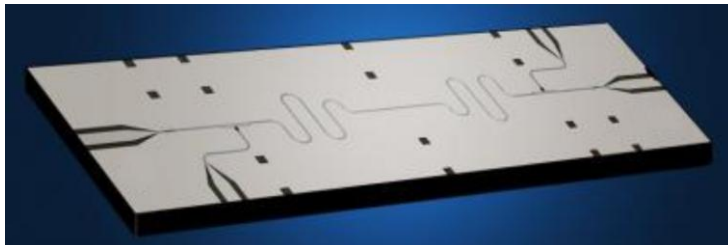
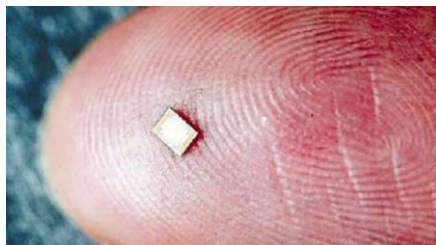


rather than

Development continued and today it is common for more advanced AI cores, for example those controlling major facilities or large ships, to project a holographic image when interacting with humans. This holographic interface is traditionally called **Holly** (for obvious reasons) and again by tradition there is a specific male and a female version - the AI chooses which of the two gender images is appropriate to use according to the function of the system it controls.

Advanced Neural Network Artificial *intelligence* - ANNA - An AI System for Mercenaries

Complex AI is very expensive. However a system has been developed that is affordable by the more experienced and affluent mercenary. To reduce costs and data processing overheads the system doesn't have a visual interface. ANNA modules are not easy to obtain. (The Hints&Tips Guide provides some information for tracking one down.)



The main processor is small and embedded into an interface module incorporating a backup power supply, making the unit self contained in the event of a ship-wide power failure. The installation of the connection interface into your ship is straightforward and only takes a few hours.

ANNA's operation is based on a voice recognition and response (VRAR) module with an ability to learn idiosyncratic speech patterns. The ANNA AI has capabilities ranging from managing routine ship operations such as navigation, docking and cargo management to assisting the pilot with such tasks target acquisition, threat identification and pre-programmed combat manoeuvres, increasing ship/pilot effectiveness and survivability during combat operations.

ANNA is thus able to translate commands given in a variety of sentence forms . For example the phrasings like . . .

Anna execute jump to next waypoint
Anna execute jump to next nav point
Anna execute jump to rendezvous point
Anna execute jump to rendezvous coordinates
Anna engage the FTL
Anna engage the jump drive
Anna fire up the FTL
Anna execute jump to next nav coordinates
Anna jump to next waypoint.
Anna jump to next nav point
Anna jump to next rendezvous point
Anna jump to next rendezvous coordinates

. . . will all result in ANNA checking the programmed jump coordinates and then priming and activating the jump drive to move to the next navigational waypoint in the sequence. ANNA then responds verbally at the completion of the task.

Part 2: The Technology

Section 1 - Travel

Drive Technology including Worm Holes

Sub-lightspeed drives

Background: 20th Century Physics & Engineering

Processed fuel is converted into plasma which is accelerated and ejected at near light speed from the main engine exhausts or from the manoeuvring thrusters.

It is generally thought that Engine classes (C1 - C10), have around the same initial acceleration capability but different plasma ejection velocities. As a result all civilian ships accelerate at nearly the same rate up to around 2000m/s but have different maximum velocities based on the ejection speed of the plasma. For a more detailed description and explanation of this see the section below 'Just how fast can I go?'

Military ships have modifications from reverse engineered Vonari technology and have drives with more efficiency plasma accelerators to increase the max velocity of the plasma and therefore accelerate faster and have higher top speeds to equivalent civilian frames.

Comparative data - based on a C1 civilian drive with maximum velocity = 1

C1 breaks CMD into particles of mass 10 and accelerates them to a velocity $V=1$; hence max velocity = 1
C10 breaks CMD into particles of mass 1 and accelerates them to a velocity $V=10$; hence max velocity = 10

This is because more work is necessary to break down the particles, convert them to plasma and accelerate them to a higher speed

Acceleration (related to plasma mass x plasma velocity) is nearly constant because : $10 \times 1 = 1 \times 10$

Following Newton's law of equal and opposite action and reaction, the top speed of a ship obviously depends on its mass - the more mass the lower the top speed. Pilots trade off more armour, weapons and equipment slots in return for increased mass and hence a slower ship with poorer agility. See Appendix for Frame Specifications (Alliance, Federation and Military)

The use of an 'afterburner' or 'military burner' supercharges the drive unit and allows the acceleration and the maximum speeds to be exceeded but at a vastly increased cost in the rate of fuel use. In combat this is an acceptable trade off. An optional retro-fitted booster to the basic afterburner system is available. Afterburners allow ships to exceed this maximum and to accelerate more rapidly. However all ships in Evochron are designed to have a maximum speed of about 7800 - 7900.

A major step forward came when military research released build details of the 'IDS multiplier' which increases plasma acceleration efficiency without a meltdown of the injectors. This was achieved by streamlining energy input rate and providing more efficient cooling along with the development heat resistant metallo-ceramic alloys. This results in an increase in plasma velocity by a factor of between 2x and 5x

thus C1 with IDS multiplier @ x4 breaks CMD into particles of mass 10 and velocity $V=4$; hence max velocity = 4

The afterburner drive (also sometimes referred to as the afterburner overdrive) uses energy from the ship's main power system for additional thrust. It is an optional add-on to the afterburner (aka military burn) system fitted as standard to all ship frames.

It can improve afterburner performance about 35-70%, depending on frame and engine configuration, but can only operate for short bursts due to the dependency on the ship's energy reserves. This is another piece of equipment that competes for main energy system output.

The standard factory fitted afterburner has a powerful pump and cooling system so it can burn fuel at an accelerated rate whilst preventing damage to the plasma creation chambers and plasma acceleration module. The retrofit afterburner drive booster increases the energy to the plasma creation and acceleration system but quite quickly overloads the cooling system - hence it is meant for very short duration emergency situations.



Experimental designs to boost the cooling system lead to such rapid energy depletion that the research was abandoned.

Just how fast can I go? - Experiments in Engine Performance

Background: 20th Century Physics & Engineering

Part I - What is my top speed?

As a scientist I was intrigued with an assumption by an experienced pilot that if you set your ship into Inertial Flight Mode and use your afterburner you will accelerate to 9999 or until you run out of fuel. It got me thinking. I was fairly sure from experience that the rate of acceleration decreased as speed increased. I had assumed therefore that there would be a maximum speed that a ship could achieve and that it would not necessarily be the 9999 limit on a ships velocity indicator. Obviously you might run out of fuel before you hit top speed.

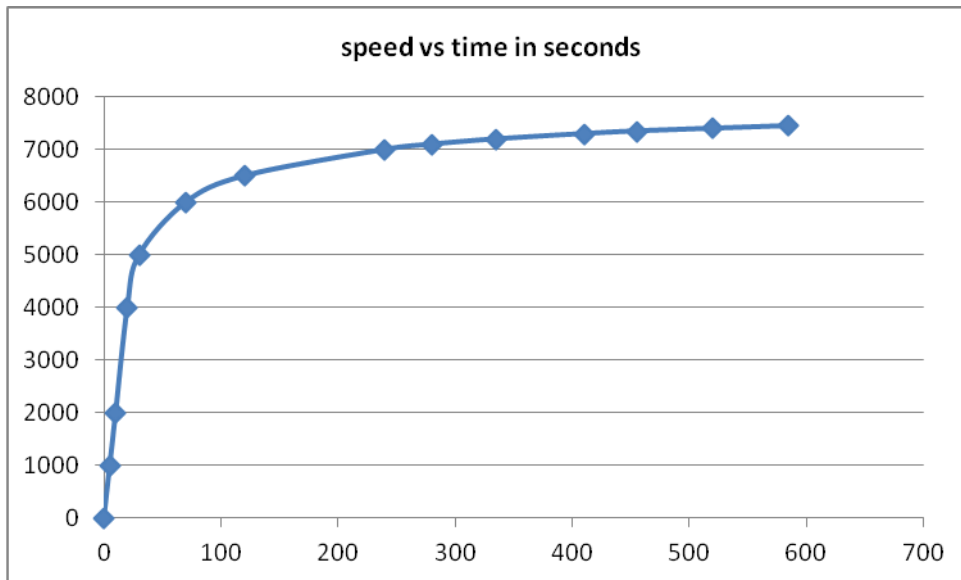
I decided to find out what was happening.

To find out what the top speed of available ships is, I chose measure the performance of several different classes of civilian and military ship, choosing a top and bottom class frame from each;

- A fully stripped out Talon with a 2800 capacity fuel tank
- A lightly equipped Ferret with its maximum 400 capacity fuel tank
- A Leviathan with a 2000 capacity fuel tank
- A Chimera with a 2000 capacity fuel tank

I'll give detailed data for the Leviathan - the other three ships behaved in basically the same way.

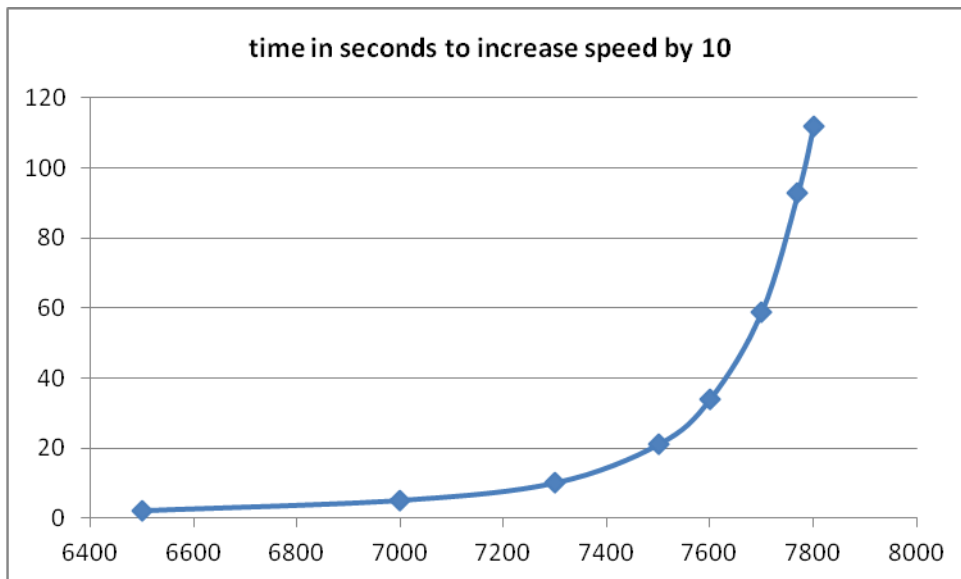
The Graph 1 shows how speed increases with burn time. The steepness of the curve is a measure of the rate of acceleration - the steeper the curve the faster you are acceleration. From a standing start, using afterburner in Inertial Flight Mode, the initial acceleration up to 5000 is very good, but acceleration starts to fall off very quickly after that; the conclusion is that there is little point trying to accelerate beyond 5000 using the afterburner. The change in speed is not straight line - it is a curve that gets flatter and flatter - a power law. It also gets close and closer to a final value - the maximum speed you can go. A graph that levels off slowly, approaching a final value is known as an asymptotic graph!



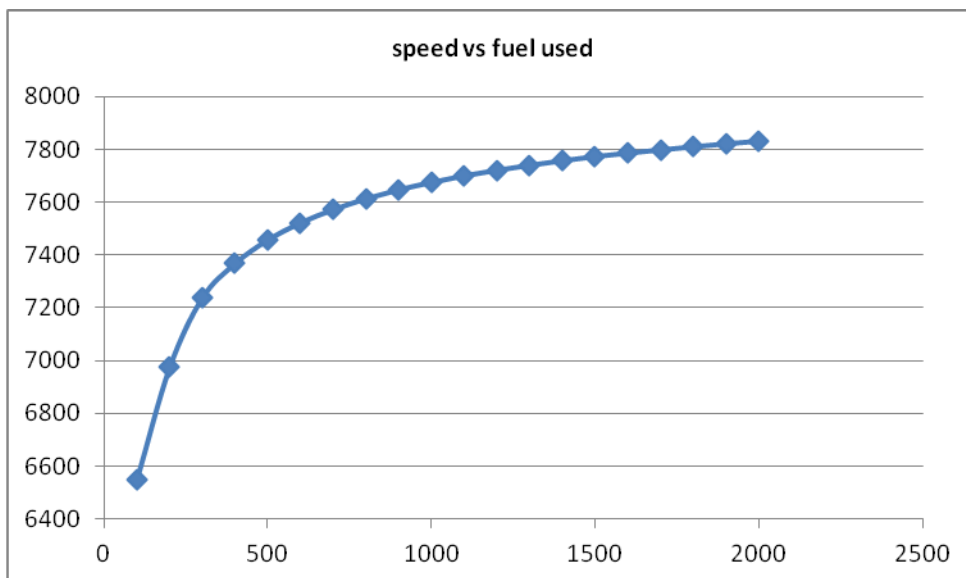
Although the fuel ran out before the top speed was reached I used the trend in change of acceleration to calculate (extrapolate) that the maximum speed achievable would be just under 7900.

All four ships have a maximum attainable speed of between 7800 and 7900

The second graph shows the time it takes to increase your speed by 10 at different starting speeds. It shows that the time taken increases at an increasing rate; This is another way of showing that the changes are not straight line but are a power law. For example it takes 19 seconds to go from 7500 to 7510, but 91 seconds to go from 7800 to 7810 and a whopping 165 seconds to go from 7875 to 7885. Since fuel is burned at a constant rate this also means that every increase of 10 in speed takes ever more fuel as you go faster.



The third graph shows how speed is related to the amount of fuel used.



To accelerate from standing start to 6000 takes 50 units of fuel - equivalent to an average of speed increase of 120 per unit of fuel.

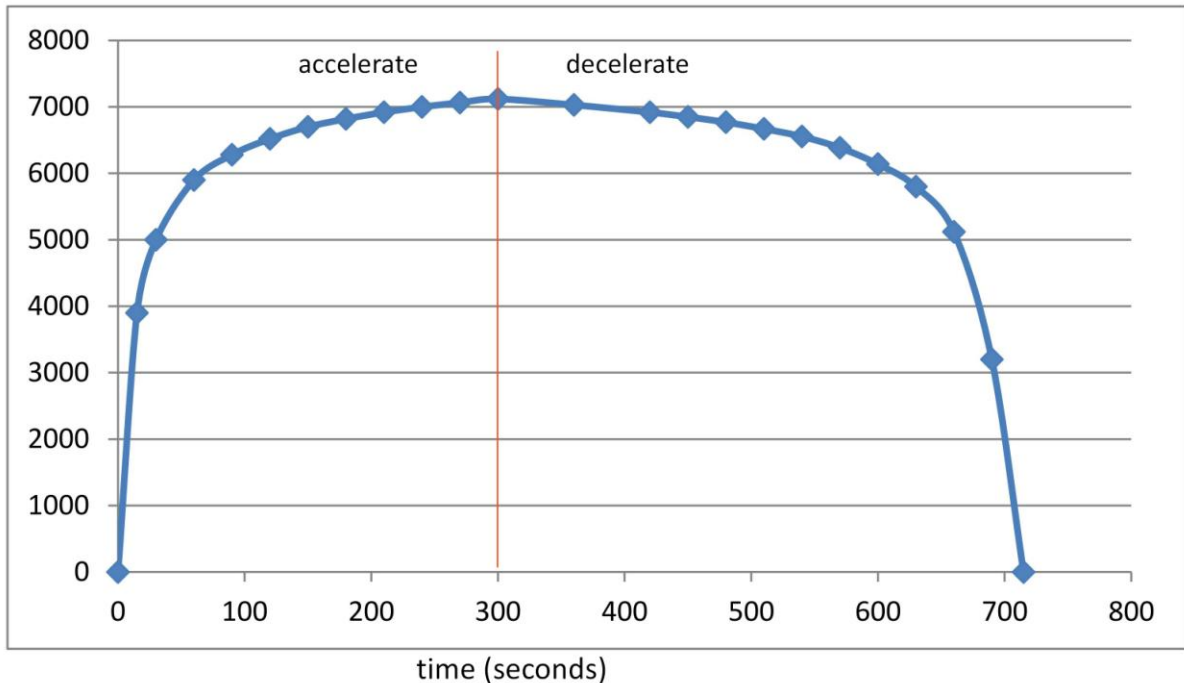
50 units of fuel will also accelerate you from

- 6000 to 6700 (an average speed increase of 16 per unit of fuel)
- 6700 to 6940 (an average speed increase of 5 per unit of fuel)
- 7312 to 7377 (an average speed increase of 1 per unit of fuel)

The trend continues until we can see that 100 units of fuel will accelerate you from 7874 to 7882 - equivalent to an 12.5 units of fuel for an increase in speed of 1! Even with unlimited fuel this trend shows that ships have an absolute maximum speed

What happens when I slow down?

Deceleration also uses sub-light engines. Graph 4 show a full acceleration / deceleration cycle in a Chimera:



It took 300 seconds to accelerate to 7120 and 415 seconds to slow down again since the reverse afterburner wasn't used in the slowing phase. The curves are symmetrical - the faster you are travelling the slower velocity changes occur under a constant thrust.

To slow down quickly and hence conserve fuel, just do a jump! (Thanks to **TJJ** for this one). If you are short of fuel this could be into a station if you can see it on the NavMap or know the coordinates or it could be just to a point nearby.

Bingo fuel is equal to **(class of Fulcrum Drive +10)** - the extra 10 units of fuel allows for slowing down after the jump plus a bit to manoeuvre into the station you build or deploy!!

The Explanation (or Why are we limited to less than 8000mps using sub-light engines?)

One would expect that under a constant force (the engine burn) in a friction free environment acceleration would remain constant and hence velocity would continue to increase until fuel ran out. However, there is friction in space - even interstellar space contains hydrogen and helium atoms, plus odd bits of material spat out in supernovae. Certainly not enough to slow your acceleration above a velocity of 5000 or so, though

There are a number of factors that lead to engineered limits of acceleration and maximum velocities. Firstly is the fragility of the human frame!

Ignoring Relativity and assuming we maintain the rapid initial acceleration (30 seconds to reach 5000m/s) then to reach SoL (300 000 000m/s) would take 10 million seconds = 117 days (continuous afterburner). The acceleration works out at around 170 m/s^2 - so we are actually accelerating at 17g.

At this time the performance of *inertial damping technology* (see below) is relatively poor and pilots are subjected to a much reduced but still high acceleration of 4 - 5g. Hence the need for acceleration suits. Obviously there is a limit to how long a pilot, even encased in an acceleration suit can withstand this punishment and so there is little point in developing propulsion systems that allow significantly greater accelerations to reach even higher top speeds. The result of the last improvement in Inertial Damping technology was the release and retrofitting of the IDS multiplier system. Future improvements might see further increases in acceleration and top speed, but it will be dependent on a parallel increase in energy generation and storage technology.

Secondly is the effect of the 'muck' in space. Your ship is protected by the shield system which acts as a matter deflector (as well as protecting you from particle and laser weapons!) There is spacial distortion caused by the graviton particles in the shield matrix field. There is a limited amount of energy available to the ship and as it travels faster the shields have a greater amount of dust, molecules and ionised particles to deflect and hence have to use a higher proportion of the energy. The relativistic effect of the shield matrix on the matter it has to deflect is large; the mass increase of the particles at the point they interact with the shield hence leads to an exponentially increasing energy requirement.

Finally, there are limits imposed by the engines use of a plasma ejection system. If travel is required above 6000 mps the ships' designers decided that jump engines would be the preferred method of moving from place to place. As a consequence they calibrated the ships central control AI to shunt energy to the shields at cost to the engines to ensure the safety of the ship. The ship's acceleration is controlled by the momentum of the ejected plasma and basically there isn't enough energy (nor ability of the plasma focussing system) to handle higher plasma through put or increased ejection speed - hence the speed limit is reached asymptotically (ie the speed approaches the maximum speed at a slower and slower rate)

Obviously a more streamlined shape is more efficient (but more expensive to make and maintain) - hence military ships (based on darts!) can accelerate faster than civilian ships - this is coupled with the higher specification plasma production and ejection systems in military ships, also giving them a higher maximum speed than the equivalent civilian frames. However, military designers like civilian designers still realise that combat pilots using normal engines would and should work within a limit of 5000 - 6000mps. They are expected to use the Fulcrum Jump Drive to micro-jump into and out of the fur-ball. Hence the military designers have limited the top speed of military ships via the energy distribution control AI core, just as the civilian designers did, leaving more energy available for other ship systems

Part II - effect of engine class on ship performance

I was also intrigued by the commonly held view that 'It is common knowledge that the class of an engine has little effect on a ship's acceleration, only its top speed. Afterburners increase both acceleration and top speed - hence their usefulness in combat. Military engines have a higher acceleration than civilian engines as well as higher top speeds for the equivalent class of frames'

In my initial experiments I found that all civilian ships have the same acceleration regardless of engine class; two errors were found in this study: (my thanks to *splatives* for pointing this out!)

1: the timing precision (to nearest second) is not sensitive enough to 'see' the differences in acceleration over such short time - civilian frames take around 3-4 seconds to achieve 1000m/s and 6-7 seconds to reach 2000m/s

2: the assumption was (wrongly) made that because frames have the same initial acceleration (due to lack of timing precision) that it was not worth looking at accelerations to higher speeds, especially since most high acceleration situations are in combat and speeds are generally below 2500m/s

I repeated the experiments but with an increased timing precision of measuring to the nearest 0.05s. It is impractical to measure to greater precision with the equipment commonly available!

The results are interesting!

I used a Starmaster (with C1 - C3 - C7 - C10 engines) and a Talon (with C1 - C3 - C7 engines). The Talon hasn't got enough build points to carry a class 10 engine!

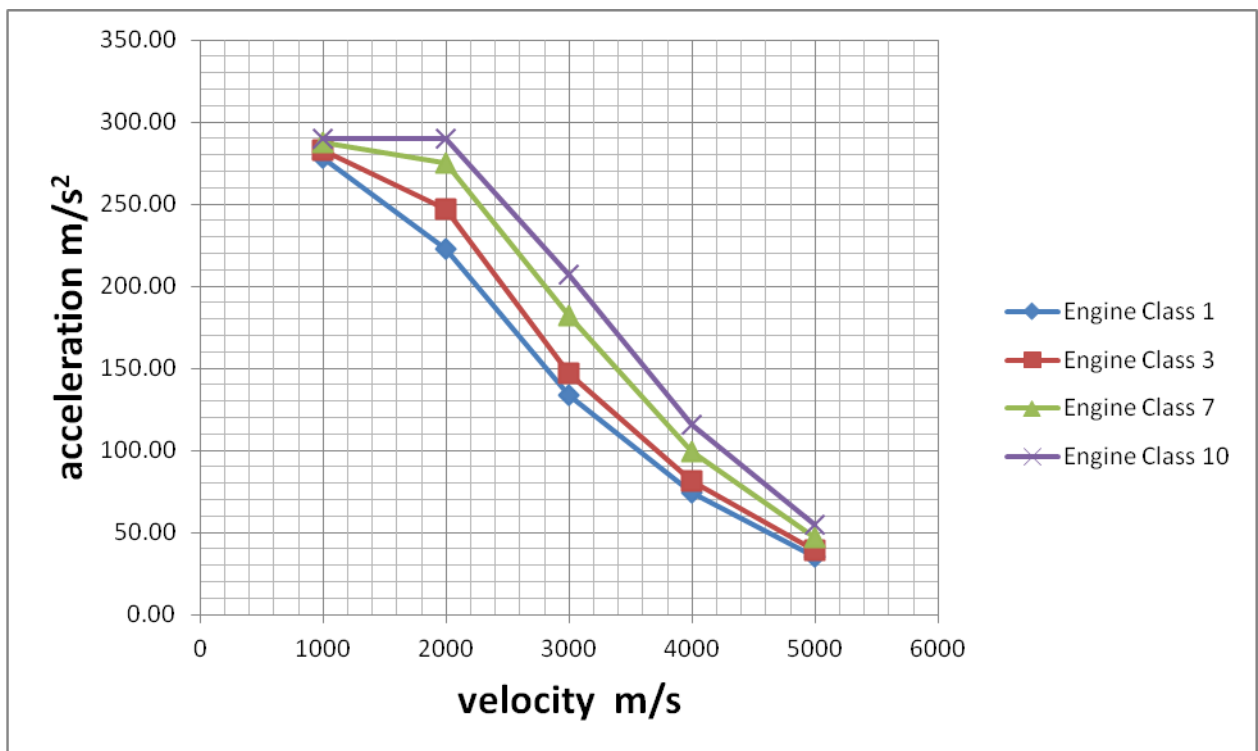
The ships were accelerated from a standing start to 5000m/s using afterburners. The time interval for each 1000m/s of acceleration was measured four or five times and the data averaged. The raw data is available to anyone who would like to play with it - please send me a U2U

The analysis was carried out in a spreadsheet

First series of experiments - how does engine class affect acceleration?

Starmaster

The first graph requires a little explaining: It shows the accelerations rates for each subsequent 1000m/s speed increase. So the first point in each graph is the acceleration for 0-1000m/s, the second point is for acceleration from 1000m/s to 2000m/s



This shows that accelerations for from a standing start to 1000m/s is very similar; The time taken drops steadily from 3.6 seconds (C1) to 3.54 seconds (C10). This equates to accelerations of 280m/s and 290 m/s respectively. This equates to less than half a percent increase in acceleration per engine class increase.

The difference becomes more noticeable between 1000m/s and 2000m/s. The acceleration between 1000 and 2000 m/s decreases as the engine class decreases.

The following table shows the accelerations for 0 - 2000m/s for each engine class

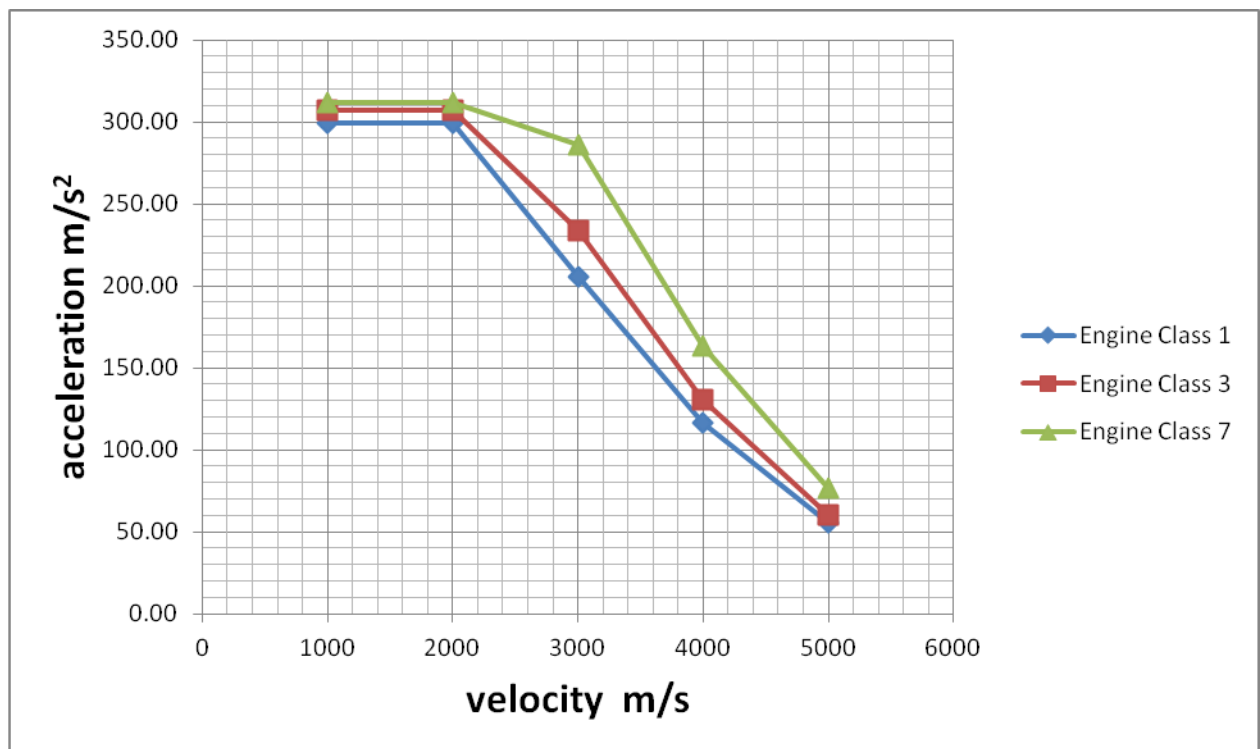
	<i>0-2K acceleration</i>	<i>Acceleration relative to engine class 1</i>	<i>% increase in acceleration compared to engine class 1</i>
EC1	245.60	1.00	0
EC3	262.93	1.07	7.1
EC7	280.50	1.14	14.2
EC10	300.90	1.23	22.5

0-2000 m/s was chosen because there is little difference in acceleration within this range - above 2000 m/s the acceleration slows noticeably. It is also the velocity range in which most combat occurs.

This data shows that engine class does start to have an effect. taking a Class 1 engine as the baseline, each better class of engine (C1, C2, C3 etc) will increase your acceleration by about 2% over the first 2000 m/s

The first graph clearly shows the decrease in acceleration as speed increases; Accelerating from 4000 m/s to 5000 m/s is at about 50 m/s² compared to around 280 m/s² for the first 1000 m/s increase

A similar result was obtained for the **Talon** frame :



Second Series of experiments: How does engine class affect performance of different frames?

This series of experiments examined how a particular class of engine affects the acceleration of different ships. The Starmaster and Talon were chosen to represent the extremes in civilian frame classes.

Starmaster				Talon			
	0-2K accel	relative	%	0-2K accel	relative	%	
E1	245.60	1.00	0	299.40	1.00	0	
E3	262.93	1.07	7.1	305.81	1.02	2.1	
E7	280.5	1.14	14.2	311.77	1.05	4.1	
E10	300.9	1.23	22.5				

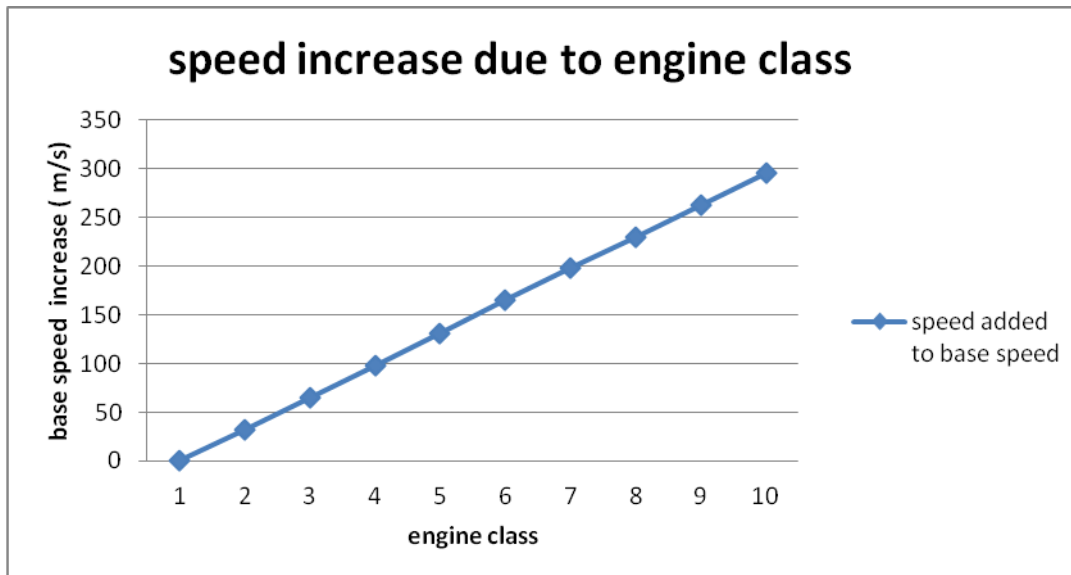
It can be clearly seen that using the same class of engine on two different frames does have an effect on performance. The C1 engine accelerates a Starmaster from 0-2000m/s at 247m/s² and a Talon at 300m/s².

The smaller and lighter Talon is accelerated 22% faster, which is to be expected.

Conclusion - which engine should I buy?

The results of these experiments strongly suggest that the 'cost' (credits and assembly points) of a higher engine class are not worth it if you are **only wanting better acceleration**. Probably an afterburner booster or a military frame will be a better bet, but . . .

Engine class has a big impact on final top speeds and this effect is magnified using the IDS multiplier. This graph shows how much faster each engine class will make you ship travel **without** using the IDS multiplier:



Couple this increase with the IDS Multiplier and you can create a ship with a high top speed without using the (fuel thirsty) afterburner. The maximum top speed in reality is around 3000.

So after you have chosen your frame, choose the engine that will add enough to your frames base speed so that when you multiply this by five you get a ship that is fast enough for you!!

This table shows the speeds added to your frame's base speed for each engine class at each IDS multiplier factor

	speed added to base speed				
	x1	x2	x3	x4	x5
E1	0	0	0	0	0
E2	32.5	65	97.5	130	162.5
E3	65.5	131	196.5	262	327.5
E4	98.5	197	295.5	394	492.5
E5	131.5	263	394.5	526	657.5
E6	164.5	329	493.5	658	822.5
E7	197.5	395	592.5	790	987.5
E8	229.5	459	688.5	918	1147.5
E9	262.5	525	787.5	1050	1312.5
E10	295.5	591	886.5	1182	1477.5

This shows that a C10 engine can add nearly 1500 to your frames base speed when you use the IDS multiplier at x5!

So - choose an engine that gives you the top speeds you want, not for acceleration!

What accelerations are we subject to?

All ships are equipped as standard with Inertial Dampers. The data shows why!

When you accelerate from a standing start to 2000 m/s you should be subject to an acceleration of around 280 m/s^2 . $1g = 10 \text{ m/s}^2$. This means that in afterburner acceleration from a standing start you should be subject to an acceleration of 28g! Even accelerating from 4000 to 5000m/s subjects us to 5g

Trained and selected pilots can withstand 5g for a short period, though they can't do much under that strain and certainly not handle a ship in a combat situation. Survival is threatened above about 10g

So, how do we survive (and manage to fly our ships)? - Inertial Damping Technology!

Another cheer for the geeky scientists of Evochron!

How does Inertial Damping Technology work?

Background: [Quantum Theory](#) of Gravity merged with [Relativistic Gravity](#)

Without some form of 'inertial compensation' ships would either have to accelerate much more slowly, or kill their occupants with excessive g-forces. Research into inertial negation to counter the effects of sudden velocity changes that would impart structural stresses on capital ships when suddenly accelerating to or decelerating with sub-light and jump drives lead to the development of the *Structural Integrity Field* (SIF) generators that are also installed in large stations. These fields do **not** cancel inertia - they just strengthen structures to withstand the stresses. Both theoretically and practically it proves impossible to create an inertial negation device that can protect the crew from being splattered against the closest fore-facing bulkhead if the ship accelerates too quickly!

Inertia is a result of Newton's First Law of Motion that states that

"if an object experiences no net force, then its velocity (speed and direction of movement) is constant: the object is either at rest (if its velocity is zero), or it moves in a straight line with constant speed (if its velocity is non zero)"

Inertia is a result of the object's mass resisting changes to its direction and/or speed of travel (ie its velocity) and hence the only way to reduce inertia (tendency to continue moving as it is) would be to reduce its mass - the theoretical and practical impossibility mentioned above.

Researchers moved to a different areas of research. Einstein showed that acceleration is indistinguishable from gravity - if you are in an enclosed lift (elevator) and it starts to go up, you cannot tell whether it is the elevator moving up or gravity that has increased (measuring equipment can't tell either!). Similarly if the elevator starts to move downwards it feels as if gravity has got less. If the elevator is in free fall you will become 'weightless' - gravity has been 'counteracted' by an acceleration. In all these situations your mass has not changed at all. Researchers worked to apply the reverse, and counteract an acceleration (and hence the effect of inertia) with gravity!

Researchers, engineers and technicians adapted the graviton particle generators used in capital ships and stations, making them adjustable in strength and direction. Such devices do not negate or alter inertia – they cancel its effect by creating a gravitational field opposing the acceleration of the vessel. Similar graviton particle generators as are found in tractor beam and shield matrix systems. This technology proved to be quite effective, especially when linked to the ships flight control AI systems.

In addition to the devices which generate gravity perpendicular to the decks of the ship, there must then be devices which generate them parallel to the decks. This would be the ships 'inertial dampening field generator,' as it would damp out, or minimize, the effects of inertia on the crew. Whenever the ship accelerates in one direction, this system produces a corresponding gravity field in the opposite direction, and everyone on board feels fine. The operation of this would be tied to the engines, and only when extreme accelerations were demanded would slight inefficiencies cause the crew to feel some effect.

The first versions were quite bulky and energy intensive. Refinements reduced size and power consumption and increased response speeds and reliability - a failure or slow reaction would lead to the crew being reduced to wet red (or green or blue) splats on the bulkheads! Comprehensive inertial dampening technology is routinely built into capital ships.

The generators need to evaluate the acceleration in three dimensions and create a counter field in three dimensions. In mercenary ships, because of size constraints, the generators look like this;



The four antennae at the top are angled so that between them they can generate a graviton field on any required direction. Within each angled generator module is complex set of graviton particle 360 degree emitters:

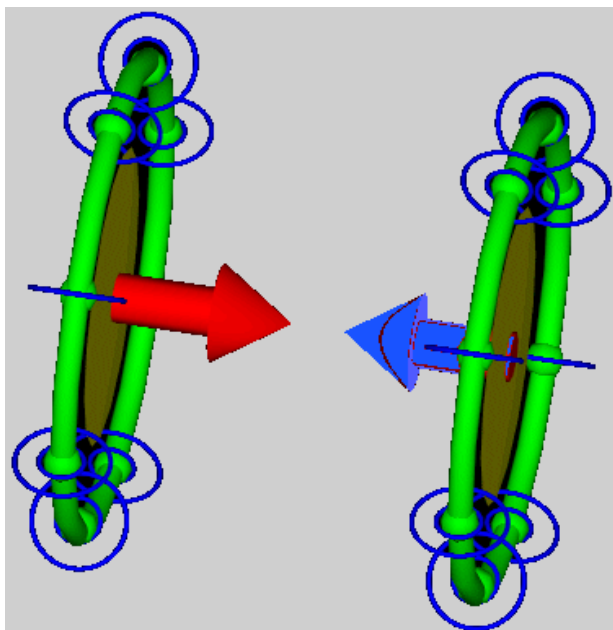


The individual emitter unit are hexadirectional and can rotate around their long axis

. . . four emitters are packed into a rotatable carousel. The graviton inertial compensator can direct 96 fields (4x4x6) in an appropriate combination of directions and field strengths to compensate for accelerations in any combination for perpendicular or lateral vectors.



However it is still proving difficult to minimise size and energy use to an extent that allows **effective** systems to fit into smaller ships, typical of those used by mercenaries and especially when carrying crew in different positions in the ship. The operative word is 'effective'. ID technology fitted to mercenary ships is only partially effective as we mentioned above - this is the trade off between energy use and size against rapidity of response and strength of the artificial gravity field. Hence the need for anti-gee combat suits and combat harnesses and seats. G-forces are reduced to a tolerable level (at least for short periods of time)



The system must be able to rapidly map (in 3D) the inertial force field generated by acceleration in any and all three axes that will lead to major shear forces experienced by the pilot and then calculate the counter graviton field needed to counteract these inertial forces and then generate and direct the graviton particle streams required to generate the compensating gravity field to prevent the crew being overwhelmed - and all within microseconds.

Despite improvements in miniaturisation and efficiency of the graviton field generation and directional control AI systems, cannon fire and missile impacts swamp the technology's ability to compensate. The result is the severe shaking experienced when a ship is hit by cannon fire during combat.

Research in IDT is ongoing - the last improvement allowed the retro-fitting of the IDS multiplier technology to all mercenary craft; although the multiplier doesn't improve acceleration, IDT does allow pilots to accelerate harder for the longer time periods required to achieve the higher top speeds.

Why can't we reach the Speed of Light?

Background: [Relativity Theory](#)

According to Einstein mass increases with velocity, but the effect of your speed only really starts to have an impact at around $\frac{1}{3}$ of the SoL. The acceleration rate achieved in a typical ship would require a long time to reach even a small fraction of the speed of light and hence a lot of fuel.

Quick calculations using the relativistic mass - speed equation from General Relativity show the exponential relationship between speed and the resultant relativistic mass. Starting with the ship's mass = 1.0, then as speed approaches the SoL, the ship's mass increases like this:

Fraction of SoL	Relative mass of ship
0.10	1.05
0.50	1.15
0.67	1.35
0.80	1.8
0.90	2.5
0.99	5.5
0.995	12.5
0.999	25
0.9999	75
0.99999	390
0.999999	575
0.9999999	1 750
0.99999999	3 900
0.999999999	12 250
0.9999999999	387 500

The ship has more than doubled in mass by 90% SoL, increased to 25x its mass by 99.9% SoL. The numbers from there show how quickly the increase in mass increases. Increased mass needs increased force to accelerate it (force=mass x acceleration and hence acceleration = force / mass) and when the SoL is reached the ship's mass becomes infinite requiring an infinitely large force to speed it up further - hence in normal space SoL is the speed limit.

Relativity shows that as speed increases the passage of time inside the ship as measured from the outside world slows; for the pilot of the ship time appears to be passing as normal. So even if you could get across the galaxy in a reasonable time (as opposed a third of a century) by getting close to the speed of light, for the external (to your ship) world hundreds or thousands of years would have passed. FtL travel is effectively a one way trip into the distant future for the crew of the ship.

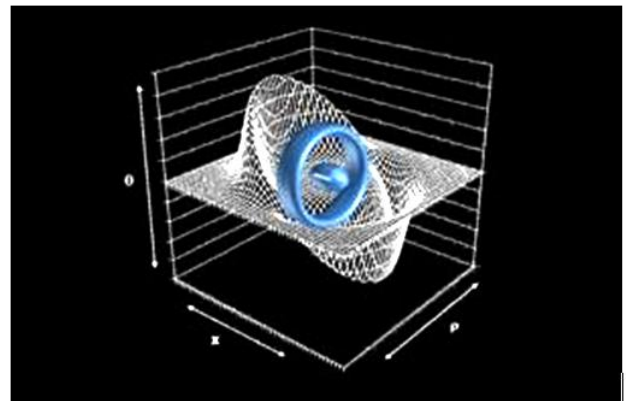
For more explanation look up 'the twin paradox' on **WIKI** or **GOOGLE**.

Studies in the late 20th Century showed that the fuel requirement for a plasma engine using water as the reaction mass would require a small moon sized water asteroid (from the oort belt) to provide enough fuel to get to 0.2 SoL, given the ship itself would need to be big to carry the crew requirements for a very long journey. For example the journey from Earth to the nearest star system at 0.2 SoL would take 20 years. The historical Voyager probes launched by NASA in the 1980's headed out of the Solar System at 1800 km/s taking more than 20 years to reach the edge of the Sol system. They are travelling towards the nearest star system to Sol and are expected to reach it in around another 39 700 years.

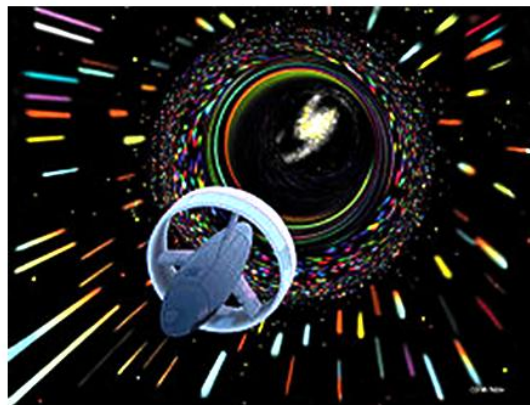
All of which shows why the Fulcrum Drive had to be invented (in 2178) before humanity could reach the stars.

With the common availability of jump drives and jump gates the only reason to try for SoL travel is to send probes into very deep space but in reality automated probes deploying refuelling stations would be quicker, cheaper and far more efficient!

Wormhole travel was a staple trope of 'science fiction' in the mid to late 20th century, more so as the boundary equations for wormhole creation were re-examined. NASA (USA - Earth - Sol) scientists discovered that it 'might be possible' to open one. This really translated as 'wasn't impossible'!



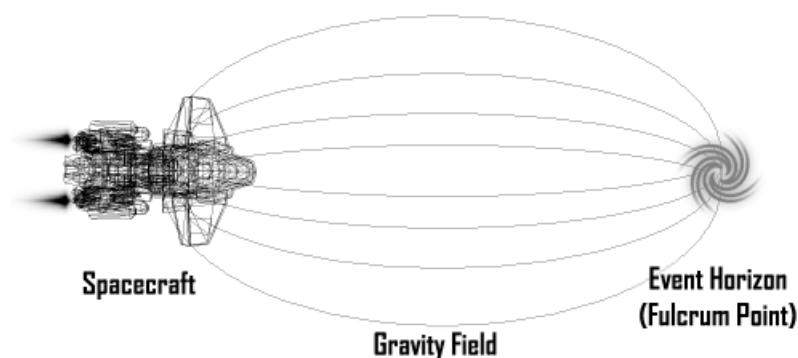
They published various papers but the technological difficulties left it as an 'interesting idea' for the next 150 years. They did however propose an experimental design (right) on which the first successful Fulcrum Drive test probe (below) was based!



Fulcrum Jump Drive

Background : Relativity

The term 'Fulcrum' in physics refers to a pivot point of a lever. This central location of contact accurately reflects the principle behind the jump drive technology found in our ships.



A Fulcrum Jump Drive operates by creating a pivot point in space between two locations. One of the locations is the ship's current position while the other is a destination the pilot selects and enters into the navigation computer to tell the jump drive where to go. When activated, the jump drive concentrates a massive amount of energy to form an

artificial event horizon (fulcrum point) in front of the ship. As power to the event horizon increases, the gravity it generates also increases and forces the ship to be drawn closer to the fulcrum point. The gravity field is extremely precise, focused directly back toward the ship it is attracting.

The jump drive maintains the event horizon at a set distance ahead of the ship, so as the ship continues to move forward at an increasing velocity, the fulcrum point also moves at the same increasing rate, staying ahead of the ship at a consistent distance.

Eventually, the increasing force of the event horizon and its gravity brings the ship to an extremely high velocity, fast enough for the ship to safely pass through the fulcrum point. When the ship reaches the event horizon at the required speed, it triggers the folding of space between the two points, the ship passes through the event horizon and arrives at the destination location. Because Fulcrum Point folds space between two points, the ship does not have to be facing the destination before activating the drive. For the same reason the direction that the ship will be travelling after the jump is the same as before the jump. The scope of the event is so precise and narrow, that only the ship itself is able to pass through. However, even to create an event horizon this small requires an extremely high amount of energy. Ships are generally left drained of their power reserves and the release of energy creates a bright flash of light visible to any nearby viewers.

Effectively the jump drive creates and temporarily stabilises a small wormhole and accelerates the ship so that it can safely pass through without the damage which normally occurs when near a WH event horizon.

Fuel is used at the rate of 1 unit per sector of jump, plus extra fuel (around 1.5 units) to decelerate the ship regardless of jump distance - a 2400 volume fuel tank can traverse about 2000 sectors with a fuel reserve of 100 units using a Mantis Drive. However, if you fly inertial the extra fuel *isn't* used. But when you get to your destination, the Autopilot will shuttle back and forth until you run out of fuel and are doomed unless you are there to switch it off - is it worth the risk?

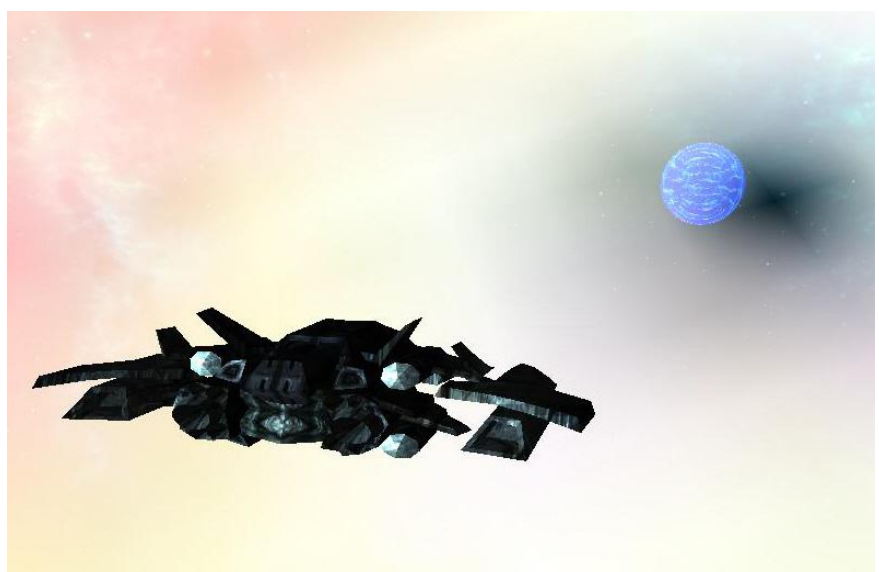
The higher the class of jump drive the more sectors can be traversed per jump. Since the deceleration fuel use is constant, higher class drives are also more efficient. For a class 1 drive the 'extra' fuel is 60% of the total 'jump' fuel used whilst for a class 10 (Mantis) drive the 'extra' fuel is only 13% of the total.

System to system jumping (Black Holes, Wormholes & Gates)

Background : [Relativity](#)

This depends on wormholes. The basic theory is the same as the small event horizons generated by the Fulcrum jump drive, but utilises 'permanent' WHs. All appear as blue spheres with a rippled fluid surface. There are three types:

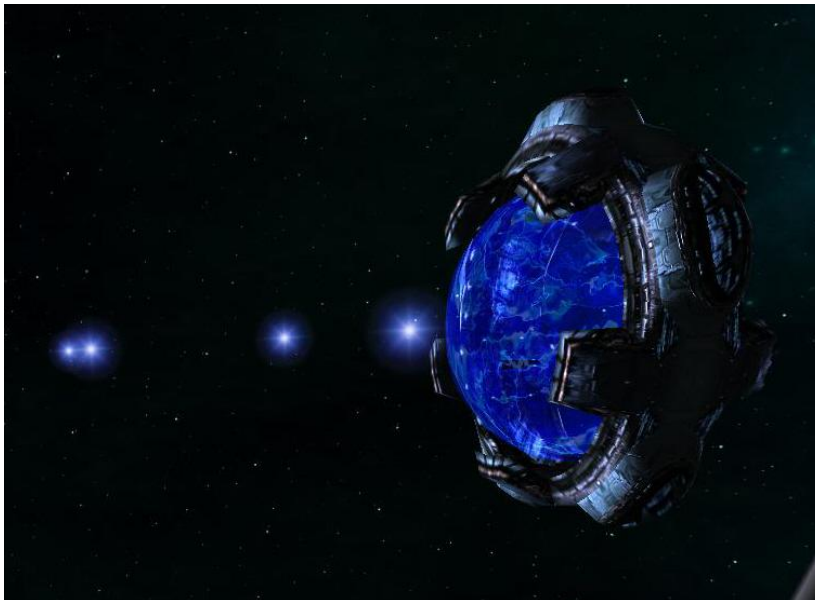
Type I worm holes are found at the centres of some BH's. Not all BH's have the conditions needed to create and stabilise a WH. Be warned! - conditions inside a BH make it a major challenge to survive long enough to jump into the WH event horizon. Exiting through a WH is the only way to leave a BH.



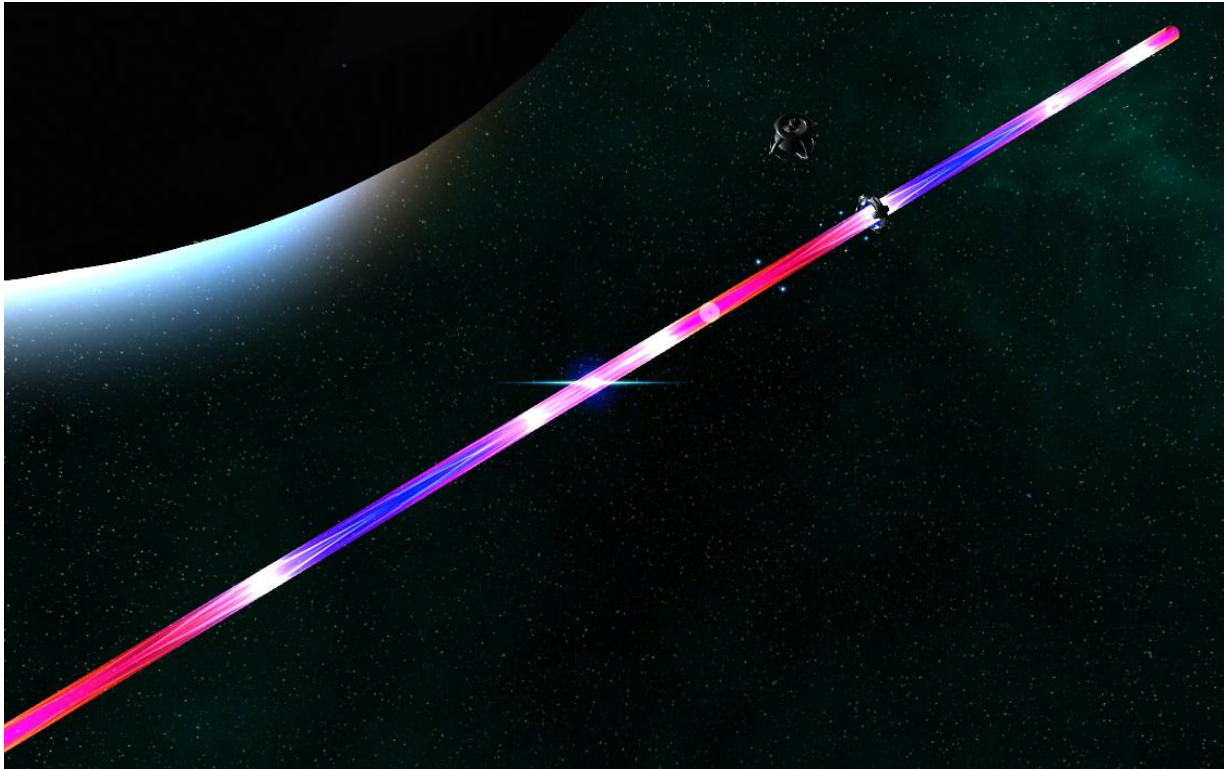


Type II worm holes were formed inside BH's and were stable enough to survive the eventual evaporation of the BH by its emission of Hawking radiation (see earlier). The negative mass/energy 'exotic material' created in the intense BH gravity field interacting with CDM became incorporated into the WH 'mouth' and stopped it from collapsing after the BH has evaporated away.

Type I & II wormholes can be considered to be 'wild' (as in wild animal).



Type III worm holes - the Jump Gate is one of mankind's most important inventions. The gate mechanism first produces a microscopic WH event horizon in the centre of the ring. 'Exotic (negative mass/energy) matter' is created in the gate surround, mimicking what happens in a BH, and is injected into the event horizon causing the WH mouth to increase in size - it also stops the created WH from collapsing. The balance is very sensitive and so the WH is only stable as long as the gate generators and the AI control systems are operating.



The WH mouth is extended into a visible tube for a brief period as the ship enters it and the ship can be seen starting it's jump - a truly beautiful and awesome sight!

Speeds of the four technologies compared to the speed of Light

Background: [Relativity](#)

1: Jump Drive Performance

Source Marvin:

The averaging for the Jump Drive tests was done using an Avenger with 2400 units of fuel. For the lower class drives, I set an easterly course and let the drive run for two hours on autopilot. For the class 5, I ran the test until the fuel got down to about 80 units (which was almost two hours).

JUMP DRIVE PERFORMANCE DATA

Jump Drive	Sectors per Minute	Fuel per Minute	Fuel per Sector
C2	7.964197	7.997451	1.004175
C3	11.875259	11.916839	1.003501
C4	16.019498	16.135822	1.007261
C5	19.639794	19.768439	1.006550
Mantis	38.990761	39.143333	1.003913

Figures are based on a ship traveling in Inertial mode with energy settings of -5S/5W.

For the Mantis drive, the test ran for almost an hour before I ran low on fuel. The inertial and energy settings were as described at the bottom of the chart. Each test was ended (the stopwatch halted) at the point where autopilot was disengaged and energy built back up to 100%. Remaining fuel was noted after the ship came to a full stop.

Method of calculation:

Avenger Basic Settings:

- Inertial - Engaged
- Energy - Set to -5S / 5W

Mantis Jump Drive:

- From: -968, 0, -2403 to -578, 0, -2403 = 390 sectors in 10 min = 39 sectors per minute

Class 5 Fulcrum Jump Drive:

- From -2274, 0, -3700 to -2074, 0, -3700 = 200 sectors in 10 min = 20 sectors per minute

To calculate ETE (estimated time en route):

1. Measure or calculate X-Z component ($c1 = \text{SQR}(x^2 + z^2)$).
2. Measure or calculate combined component ($c2 = \text{SQR}(y^2 + c1^2)$).
3. Divide combined component by sectors per minute for corresponding class engine.

2: Speeds of the four technologies

Calculating a speed for each technology is difficult - it depends on a number of factors. For example a gate jump takes the same time regardless of distance, and therefore will be 'faster' over longer distances - the RiftSpace and Andromeda results below show this. The following speeds are calculated for typical journeys for each of the methods of travel

method of travel		x light speed
sub-light drive	@ velocity = 1000 - 5000 short range movement within a sector	0.000 003 - 0.000 02
jump drive technology	2000 jumps using a Mantis Drive	0.05
	One sector jump	0.07
gate technology	typical jump between systems	130
wormhole jump	e.g. to Rift Space - 10 secs transit time	410
blackhole jump	e.g. to Andromeda - 2 x 10 secs transit time including jump into BH	730

SoL = 300 000 kilometres / second

The reason a one sector jump is (perhaps surprisingly) 'faster' than a 2000 sector journey is the effect of the recharge time between jumps on the multiple jump journey.

The BH jump to Andromeda is faster than the WH jump to RiftSpace simply because the distance is much greater

So in very broad terms, rounding the speeds (in terms of the speed of light) we get

sub-light drive	jump drive	gates jump	BH/WH jump
0.000 01	0.1	100	500

This means that jump drives are 10 000x faster than sub-light engines ; gates are 1 000x faster than the jump drives and BH/WH jumps over long distances are 5x faster than gates.

If jump drives appear to be slow, it's because the SoL is so fast. A jump drive moves you at between 15 000 and 21 000 kilometres per second!

A realistic working speed achieved by a mix of jumps and gates can be found by flying across Evochron between Emerald and Onyx. The journey used a Mantis (10 sector jump drive) and the location of the gates was known. The average time taken is 130 seconds and the distance (taking into account the diagonal trajectory of the journey) is 6888 sectors. The speed achieved 18 times SoL. The ship took 2 minutes 10 seconds; a pulse of light would have taken 39 minutes to make the same journey! So would radio waves - think about a conversation with a 39 minutes delay between speaking and the other person hearing you! (see FtL Communication below)

Section 2: Weapons Systems

Background: Pre-21th Century physics & engineering + [Relativity](#) + [Quantum Theory](#)

Weapon Lab - design your own customised weapons

For more than a century there has been a virtual armament fabrication and supply monopoly with one major manufacturer in the Alliance and one in the Federation. Although they each supply specialised weapons to their respective Navies they agreed many years ago to produce and sell a standard set of cannon and missiles to the mercenary market. This led to a significant reduction in R&D costs and manufacturing costs and, like the 'GorfBurger'™ empire, allows mercenaries to buy a uniform product across the whole of Evochron!

The Navy has the opportunity to specify cannon and missile parameters and characteristics to allow them to produce load-outs for specific combat environments. For many years mercenaries have been clamouring for the opportunity to buy customised weapons as well.

Ever ready to take up an economic opportunity, *Sapphire Industries* recently negotiated a licensing deal with the 'Big Two' manufacturers to fit a limited version of their weapons design and fabrication system to every trade station in Evochron. The result is the 'Weapon Lab'!

Enter any trade station and you are now presented with a new option along with the shipyard - the WL. The Weapon Lab lets you design and build custom weapons from raw materials for a small fee. The weapons you design will require a certain number of units of different materials to construct and you must have those materials in your ship's cargo bay or in the local station's hangar before you start. If you don't have the required materials, you will need to either buy them or mine them. The Weapon Lab will also let you save your designs as templates, so you can later retrieve exact specifications to rebuild weapons you've designed and saved earlier.

You can design and build three different types of weapons: particle cannon, beam cannon, and missiles. Each type is divided into separate classes.

Particle cannon have Plasma Particle, Metal Projectile, Rail, and Fusion classes to choose from.

Beam cannon have Refractor, Metal-Vapour, Coil, Neodymium, and Fusion lasers to choose from.

Missiles are divided into Impact, Reactive, Fragmentation, Shaped Charge, and Compound Core classes.

Each class has unique default attributes that may have advantages and/or disadvantages compared to other classes. For example, a Fusion cannon may provide a much higher default yield than a Plasma cannon, but at a significantly slower firing rate. The Weapon Lab menu offers slider bars in the upper part of the console display that let you adjust different parameters of a weapon's design. With cannons for example, you can adjust settings to trade off yield for a faster firing rate and vice versa. For missiles, you can exchange speed or agility and range for a more powerful detonation. If you build a design and decide you want to try something else, you can sell the weapon at most locations to recover some of the cost. Custom weapons generally don't carry a high value and are not a recommended item for trading, but they can provide an important functional benefit for your ship in combat. There are entrepreneurs who will build a custom weapon to your specification - for a premium. This is convenient if you have a military frame (with its limited cargo space).

Each type of weapons has different input parameters that can be fine-tuned. Each class of weapon within the types has the same input parameters. Each type of weapon has output parameters that control the performance of the weapon being designed. The table below summarises this.

	<i>Input Parameters</i>	<i>Output Parameters</i>
<i>Type: Particle Cannon</i>		
<i>classes:</i> <ul style="list-style-type: none"> • plasma • metal projectile • rail cannon • fusion 	<ul style="list-style-type: none"> • emitter output • actuator speed • capacitor reserve • heatsinks 	<ul style="list-style-type: none"> • yield • heat • energy • range • rate of fire
<i>Type: Beam (Laser) Cannon</i>		
<i>classes:</i> <ul style="list-style-type: none"> • refractor • metal vapour • coil • neodymium • fusion 	<ul style="list-style-type: none"> • emitter output • capacitor reserve • heatsinks 	<ul style="list-style-type: none"> • yield • heat • energy
<i>Type: Missiles</i>		
<i>classes:</i> <ul style="list-style-type: none"> • impact • reactive • fragmentation • shaped charge • compound core 	<ul style="list-style-type: none"> • detonator capacity • thruster power • guidance system • casing armour 	<ul style="list-style-type: none"> • yield • agility/speed • range • CM resistance

The following sections begin by describing the standard weapons in each class that have been available for many years and then follows with details relevant to the additions available via the Weapon Lab. This in turn is followed by information on how to use the Weapon Lab.

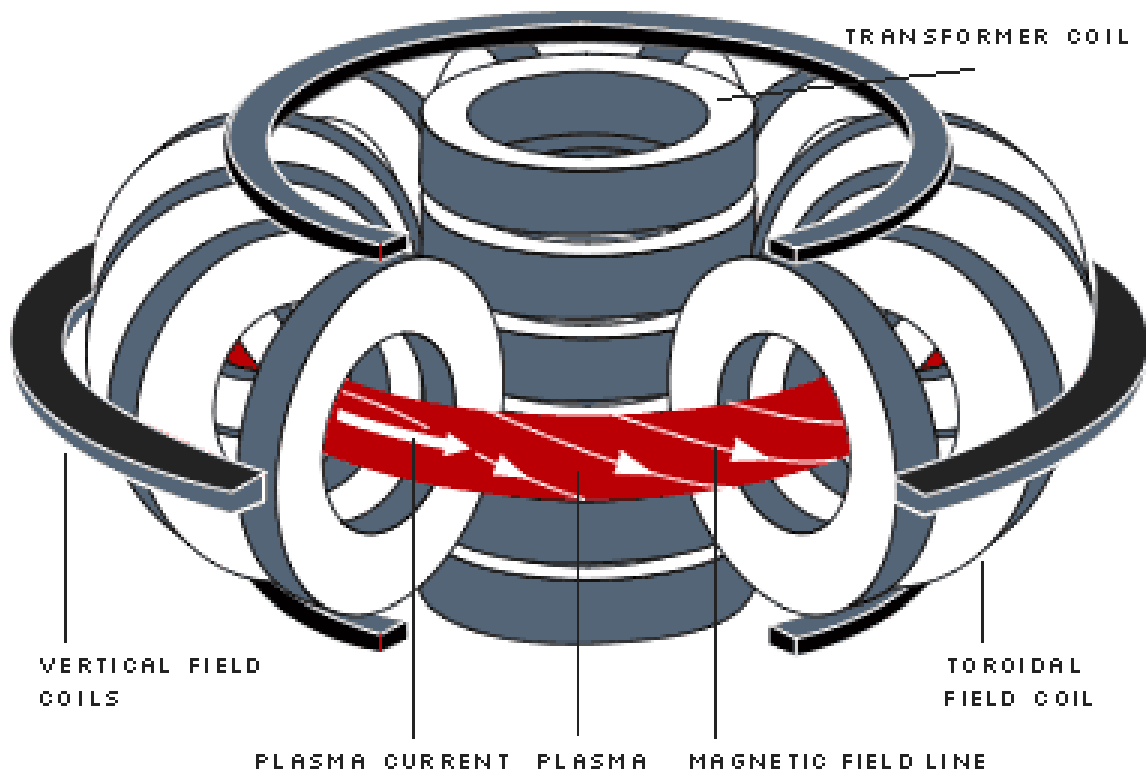
Particle Cannon Classes

Plasma Particle Cannon

Plasma particle cannon have been available as the standard cannon for many years.

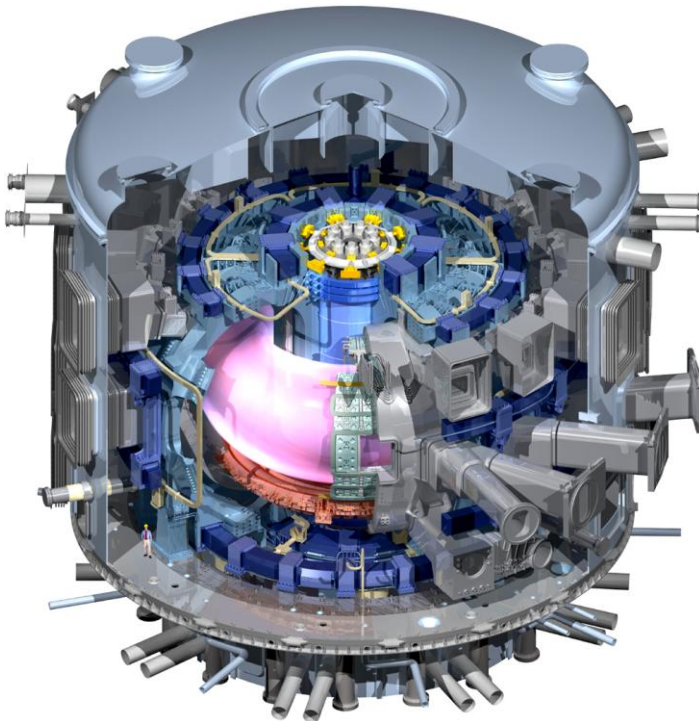


CDM is 'harvested' and then converted into normal atomic matter. Packets of matter are heated to 6000 K in a plasma chamber converting them into plasma. The plasma is stored within an electromagnetic containment ring (red in the simplified diagram below) within the chamber until required by the cannon.



This section of the plasma generator acts as plasma storage until the plasma is required by the various ship systems that require it - for the cannon it acts as the cannon's 'magazine'. As a result of its versatility, the plasma generation and storage unit is a complex piece of equipment (see image below).

To summarise: the plasma is created continuously and is stored within the containment ring, ready for use, and the ring acts as a self refilling storage unit! When the cannon is activated, the firing sequence is cyclic and therefore creates plasma packets which are emitted by the cannon. This cyclic nature of the cannon's operation serves two purposes;



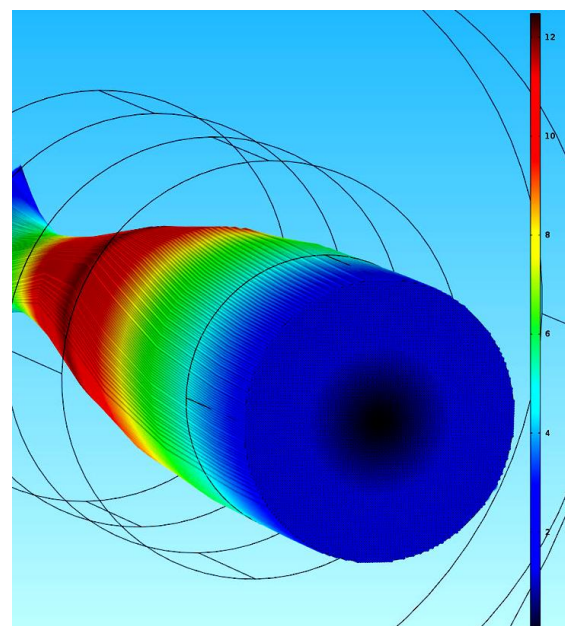
- Firstly the time delay between a packet being 'fired' and the next packet of plasma being delivered to the electromagnetic lens / acceleration system allows the cooling system in the barrel of the cannon to work with an reasonable degree of efficiency - without the cooling cycle, the cannon would overheat (and hence shutdown) much sooner.
- Secondly, if the plasma was emitted as a continuous beam, the electrostatic acceleration phase and the electromagnetic focussing lens would be significantly less efficient resulting in the plasma beam dispersing more rapidly and hence significantly reducing the cannons' range.

The first step in the firing cycle is the extraction of a measured amount of plasma from the containment ring and its transfer to the acceleration tube in the barrel section of the cannon. The second step involves shaping the packet in focussing 'electromagnetic lenses'.

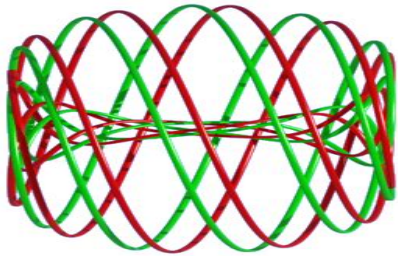
Finally the packet is subject to electrostatic acceleration to a very high speed; the plasma is confined within an magnetic field during the acceleration phase both to protect the barrel and to increase the cannon's range.

The lens focuses the relatively diffuse plasma packet by concurrent lateral compression (into a narrow cylinder) and longitudinal compression to shorten the cylinders to create a high density cylindrical plasma packet. The packets are called **plasmoids**. The name *plasmoid* was coined in the 20th Century by Winston H. Bostick (1916-1991) to mean a 'plasma-magnetic entity'.

A plasmoid has an internal pressure stemming from both the gas pressure of the plasma and the magnetic pressure of the field. To maintain an approximately static plasmoid radius, this pressure must be balanced an external confining pressure. In the acceleration section barrel this is produced by a magnetic field. When the packet leaves the barrel it enters the field-free vacuum and will then expand and dissipate limiting the cannon's effective range.



To maximise the stability of the plasmoid packets, this focusing technology creates a weaponised plasma form, where the plasma packets are polarized to 'spin' along a firing axis.



Since a plasmoid is a coherent structure of plasma an induced magnetic field is created within the packet due to its spin. This diagram shows a simulation of the induced field. The plasmoid is travelling left to right and rotates around its flight path.

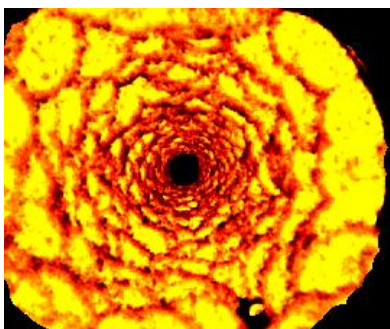


The plasma is therefore emitted not as an amorphous blob, but in the form of a short tube - an elongated torus.

The creation of the 'spin field' stabilises the plasmoid to some degree increasing the effective range before electrostatic repulsion between the plasma particles and the gas pressure dissipates the plasmoid packet.

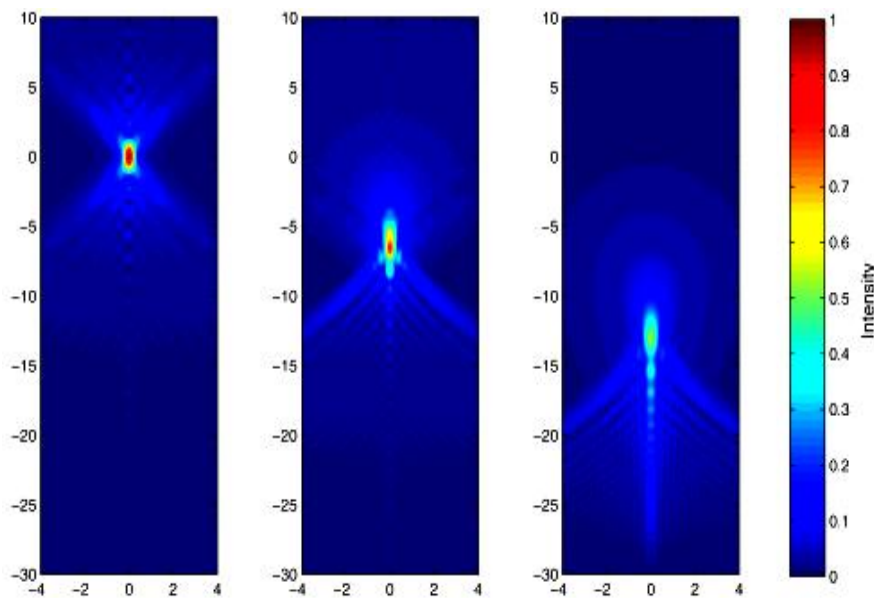


However the packet does dissipate quite quickly reducing the effective range of plasma cannon to below 800 metres



This rare image of an approaching plasma packet was taken with a hardened ultra high speed camera. Milliseconds later the camera was turned into a high temperature nano-sized particulate cloud!!

After the plasma packet leaves the cannon barrel it begins to dissipate



This sequence of diagrams and the one below show the dissipation of a plasma packet due to the mutual repulsion of the charged particles: The plasma packet is moving from top to bottom

The spin induced field prevents the packet from dissipating laterally (from the sides) but the packet lengthens and the plasma intensity decreases - the red/yellow high intensity plasma (0.6 - 0.9) - spreads out and reduces to an intensity of around 0.4 after around 66% of its range

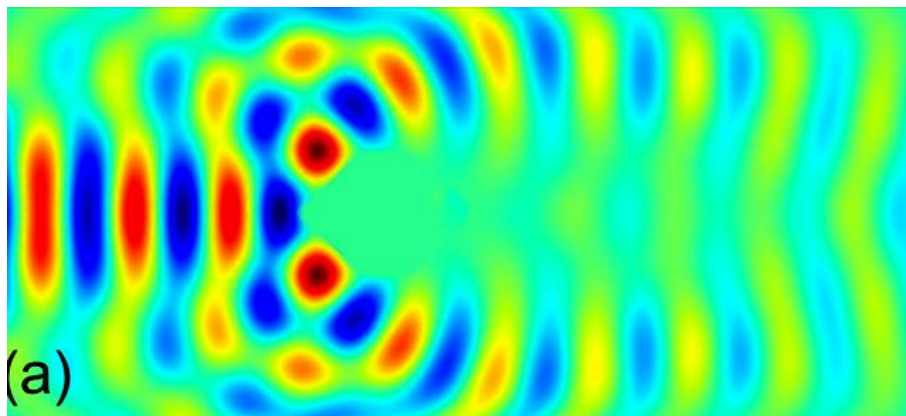


diagram (a) shows the plasma packet dissipating rapidly withing the acceleration tube in the absence of the em lens's focussing;

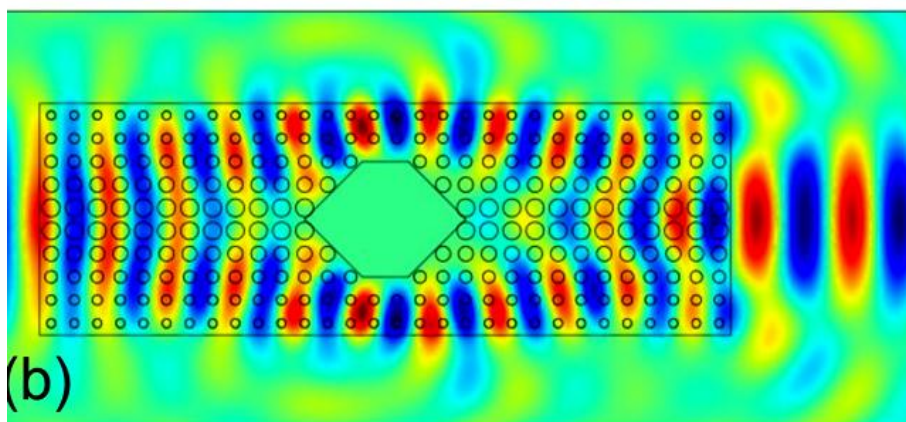
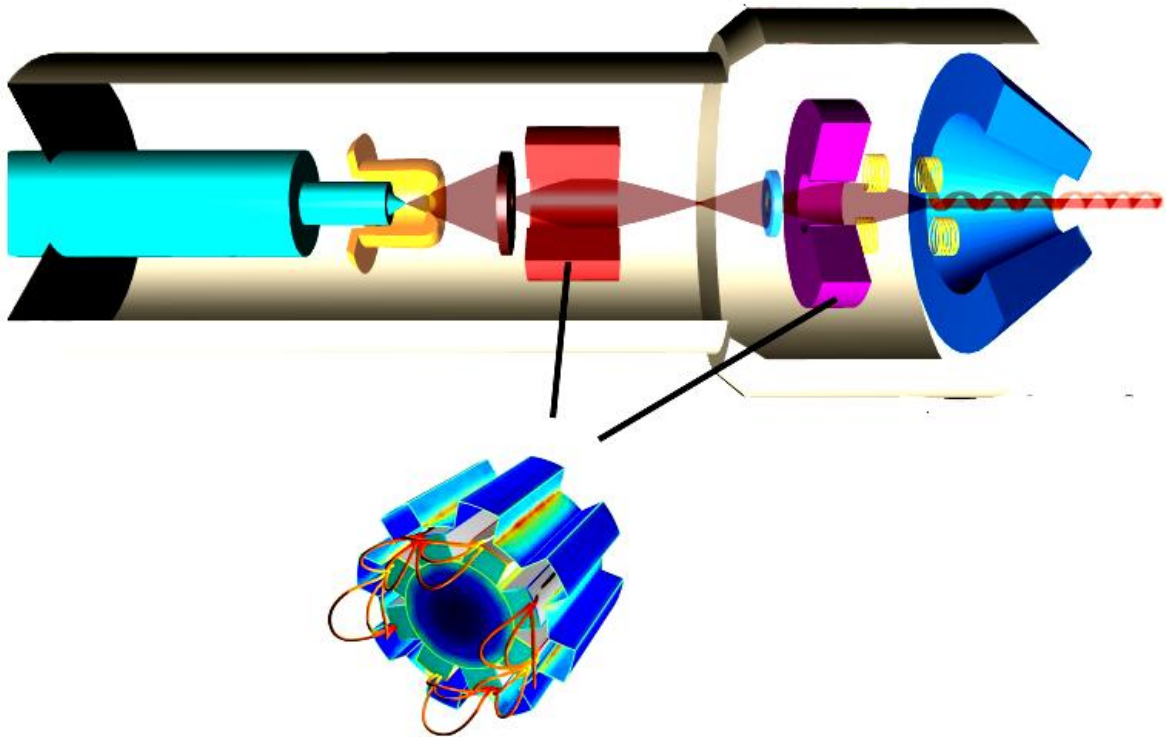


diagram (b) shows the collimating effect of the em lens concentrating the plasma packet;

The electromagnetic lens is inevitably a complex piece of equipment:



The damage is caused by the combination of very high energy (temperature), momentum (mass x velocity) and kinetic energy (mass x velocity²) of the plasma packets.

The standard C1 - C10 particle cannon available at trade stations produce plasma 'packets' with different energies; the lower class weapons with low yields use energy at a lower rate and hence have a faster recycle rate. Shields are damaged by the disruptive effect of the high energy charged plasma particles disrupting space-time when they intersect the shield field matrix, draining energy from the shield. Shields are taken down by draining energy faster than a target ship's energy generators can recharge the shield capacitors. However, Laser cannon are more efficient at reducing shields and use energy at a lower rate. Seasoned combat pilots recommend using laser cannon to take down shields and then particle cannon to hit the hull armour.

The hull is damaged by the extremely high temperature of the plasma packets. The hull is ablated - the solid melted and then vaporised! Military research into ablative armour (which acts in the same way as the ceramic tiles on some of the older planetary shuttles) were unsuccessful on the whole because the extreme energy levels of the plasma 'ate through' the hull material at a fast enough rate to destroy it. Attempts to conduct the heat away failed for similar reasons - the plasma delivers energy faster than it can be dealt with. However both developments do allow the hull armour to survive a little longer. See below for a more detailed description of types of armour available.

Summary: Plasma consists of high energy charged particles and so plasma packets tend to fly apart due to the mutual repulsion of the particles. The electromagnetic lens systems focus them as effectively as possible, but cannon ranges are limited to a max of around 700 metres. (Beam weapons can have a much higher range, but for practical combat reasons they are linked to the cannon so that the pilot can use the two in tandem). A beam cannon at long range is both hard to control against a small fast moving target and also doesn't inflict damage quickly enough to disable a ship or destroy it without particle beams being used as well.

Cannon with specific effects have been developed by tweaking the plasma mix and mass of the plasma packets. The Weapon Lab offers an even greater choice of particle cannon classes including several that emit solid uncharged metal slugs at very high speeds. These are discussed in the Weapon Lab section below.

The **Eclipse** and the **Banshee** trade space in the ultra high temperature plasma packet chain for an interleaved chain of denser packets with increased mass. CDM is converted in the form of very small particles. These are partially ionised, accelerated to the same speed as the plasma packets and are slotted into the stream of plasma packets. The ship is hit by one type after the other. The outcome is that the kinetic energy 'slaps' the ship around, though it is not as effective at damaging the hull, the plasma packets deplete the shields and do hull damage. Once the shields are down and the hull breached both plasma and solids wreak havoc inside the ship. The major benefit of kinetic weapon is the extreme disorientation of the hostile pilot.

The **SunRail** and the **Trebuchet** were an experiment that, whilst not being a failure, weren't as effective as theoretical calculations had suggested. They are not a popular choice. Tight plasma packets are not maximally efficient in depleting shield energy, but are very effective at causing hull damage when the shields are breached. With these two cannon, the plasma mix is spread out more and so more of its energy is utilised in the disruption of the shield field matrix, resulting in a faster shield depletion and hence a bigger drain on the ships energy generators and store. The **Trebuchet** sacrifices some shield damage capacity so that when a shield segment fails (either intermittently or totally) it can still cause some hull and energy subsystem damage.

It was a great idea in theory but most pilots found their own combinations of beam/particle weapons to be more effective for their combat style. Some argue however that as part of an attack group against capital ships they can take the shielding down significantly quicker - the jury is still out!

A simple view of which cannon are most effective would be to multiply the firing rate per minute by the yield (damage done) per hit. This gives the maximum damage inflicted per minute. In theory the higher the better. However higher class cannon have a lower rate of fire and deplete ship's energy reserves more quickly. They cannot be fired in long bursts without depleting the energy store, requiring a pilot to be without cannon in the combat zone until the store recharges. Another factor to consider is the cannon's range - a longer range allows you to inflict damage before you opponent can hit you. Either keeping in the 'sweet zone' - just out of their range but within yours - or getting hits in first and causing their ship to 'rattle and roll', putting off their aim are both effective combat tactics.

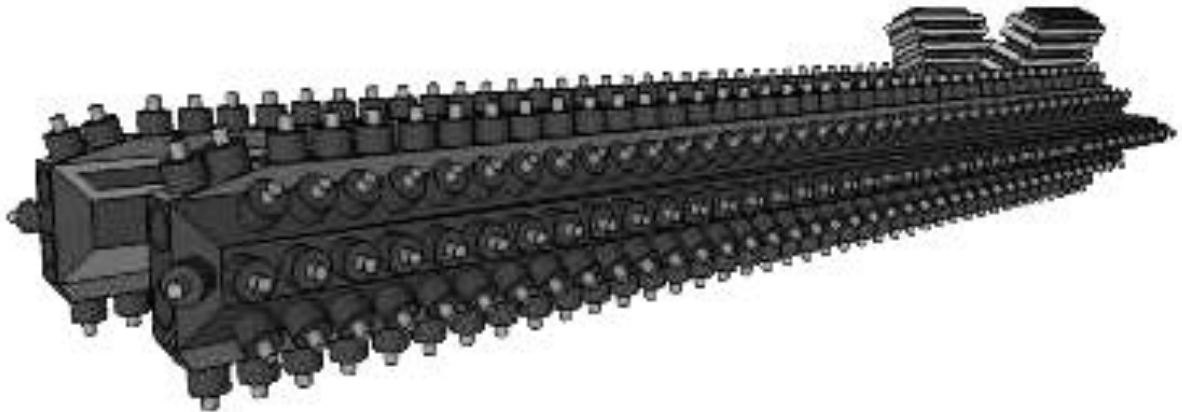
Secondly, this simple analysis assumes that every shot hits. In a combat encounter, using MTDS it is rare that all shots hits. Mercenaries experiment until they find a combination of yield and fire rate that suits their combat style.

Fusion particle cannon

One of the newest developments in the weapon systems is the Fusion Pulse Cannon, a weapon outcome of the last advancements in the gravitic enhancement of the fusion process. These represent an improvement of the standard plasma cannon, allows the plasma to reach critical fusion temperatures before impact, causing more damage. The build up of the energy of the plasma bolt is obtained inside the barrel of the weapon by careful matching of the Gravitic fusion reactor and the plasma pulse accelerator linked as a 'dense plasma focus system'.

A **dense plasma focus (DPF)** is a system that produces, by an electromagnetic field, acceleration and compression, a short-lived plasma packet that is so hot and dense that it can cause nuclear fusion and emit X-rays. The electromagnetic compression of the plasma is called a 'squeeze'. The concept was developed in the mid 20th century by J.W. Mather and also independently by N.V. Filippov. At that time the fusion could only be induced into microscopically small packets of plasma and remained an interesting theoretical idea for the next four centuries!!

The plasma focussing device is similar to but stronger than that of the *plasma particle cannon*. The DPF ejects plasma in the form of a plasmoid, without 'squeezing' it but because of the more extreme conditions inside requires a more complex generating and acceleration electromagnetic field system. The following diagram shows the complex arrangement of multiple field coils around the 'barrel'.

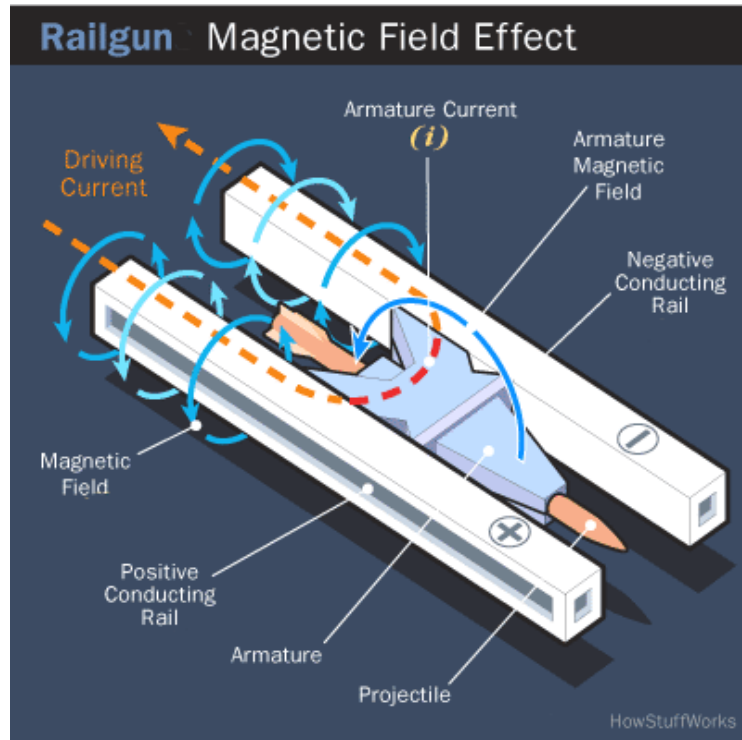


The barrel and the rest of the systems are wrapped in a case to create an easy install package. The grey plate just in front of the plasma chamber is part of the cooling system.

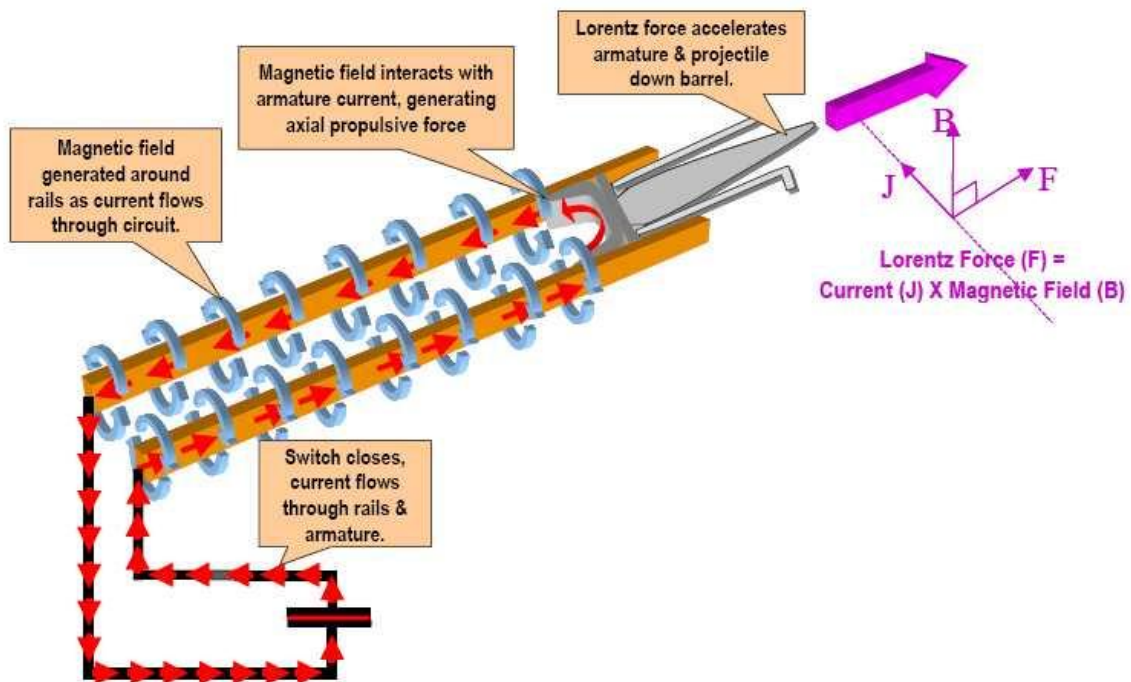


Railguns

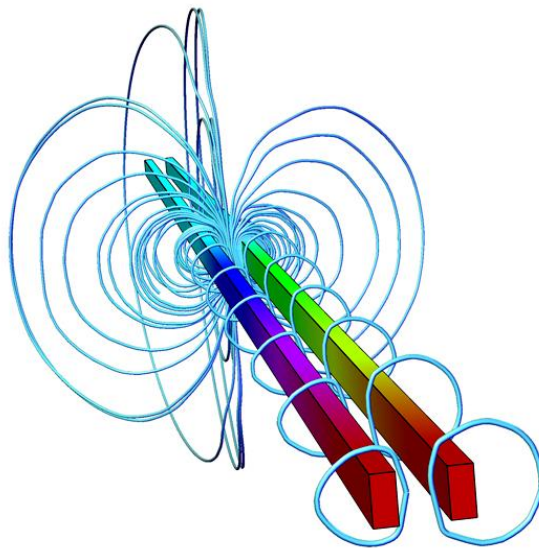
Railguns (aka 'slug throwers') are potent weapons, a masterpiece of the Earth Alliance technology. Conceptually simple, it is just a linear electric motor that accelerates a conductive projectile, though it requires very good material technology to reach the extreme velocities needed to become a really operative and effective weapon.



Schematically the system is quite simple



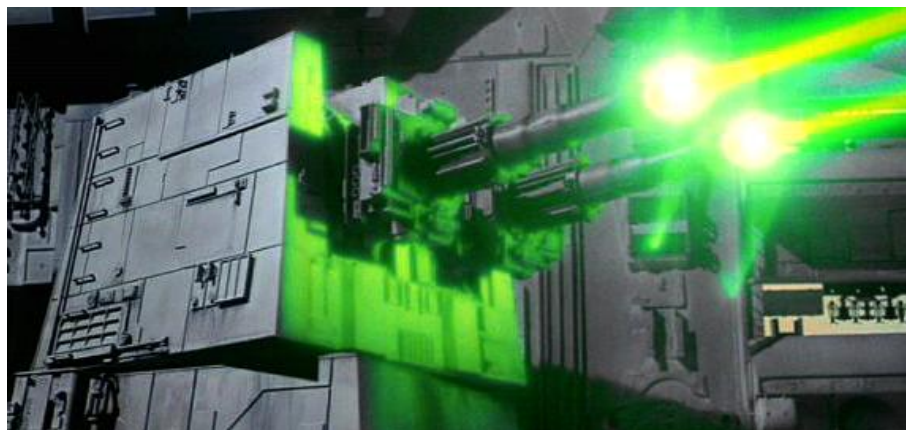
The magnetic field is complex in shape, though not difficult to generate:



The rounds fired are solid, dense metallic projectiles made of an iridium/cobalt based alloy, extremely dense (about 20 g/cm^3 , about 2.5 times the density of steel) and relatively narrow. At the impact because of the extremely high speeds generated by the superconducting magnetic field cores, the kinetic energy of the slug is so high and so concentrated on a small area, that this inner core initially depletes the shield energy rapidly and once the shield matrix is near collapse is virtually unstoppable and can locally breach the shield.

Since their introduction railguns have been popular with crews because of their robust construction, impressive damage infliction and affordability. When first introduced, railguns had a low rate of fire weapons (5 rounds/minute), using heavy aluminium projectiles. The projectiles were (0.5 metres in diameter x 5 metres long and weighing about 4.6 tonnes each) and the rail guns and magazines took up the bulk of the central part of specialised capital ships! The whole ship had to be aimed at the target - there was very little lateral movement of the guns available (less than 5 degrees in any direction!)

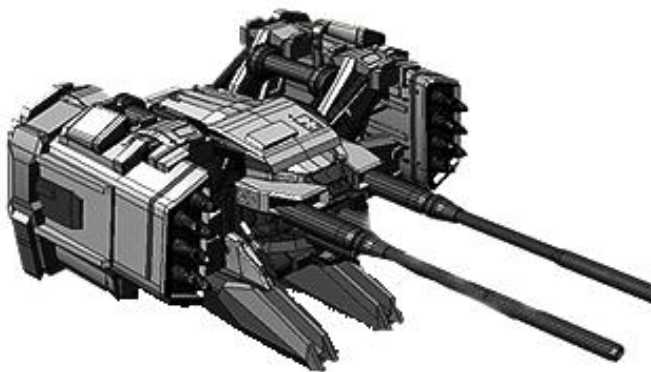
These bulky and slow first generation weapons were partially replaced in Navy capital ships by pulse cannon; Theoretical calculations showed a major increase in damage capability without requiring an ammunition supply; however early pulse weapons had a lower piercing power.



A big advantage of pulse cannon though was the ability to build them into turret batteries. The first Vonari -Human War was an hard teacher, but in those desperate days, the Navy 'Rail Frigates' were among the few warships able to inflict heavy damage to the Vonari units, in the occasions when they were able to survive the firsts seconds of the battle and open fire against the enemy.

In recent times, dating from the immediate aftermath of the war through to the developments of the mid 2250's, a new generation of much smaller railguns has begun the renaissance of this weapon system for mercenary ships! Mercenary ships are small and hence don't have the enormous (fusion) energy capacity of capital ships: the main differences are in scaling down the size (and hence energy requirements) of both the projectiles and the guns, the large aluminium slug has been replaced with a small but very dense metal projectile, accelerated in a ionized helium 'bubble' wrapped around the projectile itself that eliminates any friction between barrel/rails and projectile; the rate of fire of the latest products, thanks to a new revolver feeding system and to the 'frictionless' projectile, is very high. The piercing power of the small 50 mm penetrator munitions used is great enough to pierce all the known armour once the shields have failed, even the ones belonging to the Vonari.

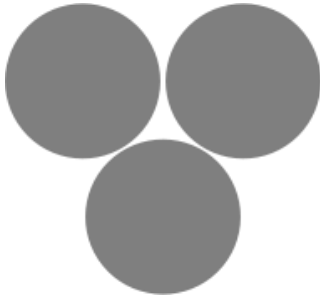
On capital ships these weapons are built into multiple cannon turrets and the rate of fire allows a devastating saturation suppression fire for local area control.



Many mercenaries would love to be able to fit such a set up on their craft.

Metal Projectile Cannon

Whereas railguns are effectively an electric machine gun, Metal Projectile Cannon are based on the same dense tungsten rod explosive kinetic energy impact technology that is used in Impact Missile warheads. The smaller cannon munition size contains fewer and smaller tungsten rods. The smaller volume of detonating explosive is balanced against the smaller rod size allowing a similar hypersonic speed (25 000 m/s) to cause damage by the transfer of kinetic energy. The explosive charge is contact fused and accelerates the rods upon impact with the shield or hull armour. For fuller technical details see 'Impact Missiles' in the section below.



There are three 500g rods in each round, each rod with a maximum kinetic energy of around 160 GJ at the point of impact. Whilst the relatively small size reduces the kinetic energy delivered per round compared to the equivalent missile the rapid rate of continuous fire from a cannon adequately compensates but the damage is initially limited to the shield's energy reserves. There is a greater kinetic affect, disorientating the hostile pilot because of the continuous bombardment. These cannon are less energy hungry and might be more suited to smaller less well equipped ships

Railguns and Metal Projectile cannon rounds cannot be seen in flight. A special light emitting round is included in the ammunition feed. These are called tracers!

'Trajectory Identification Technology' (AKA tracer)

In both military and non-military organizations, it has been common practice in tactical combat to employ materials capable of providing a visible trace of a projectile's trajectory after firing, so assuring that the projectile has been delivered to its desired target site and its flight path traced from cannon to target.

Historically a tracer projectile is constructed with a hollow base filled with a pyrotechnic flare material. The pyrotechnic material used in tracer rounds is designed to emit intense light or heat without exploding. Tracer round composition varied, but an often-used mixture combines strontium compounds to colour it along with a metal such as magnesium to 'burn'. Early tracer technology was modified for use in space combat by adding peroxide or perchlorate formulations which are oxygen rich and allow the tracer to burn in a vacuum. Chemicals are added to colour the flame - strontium compounds produce red light, barium compounds produce green. These tracer rounds tend to be quite bulky and heavy because of the chemical payload they require. Railguns rounds are too fast for this technology to work.

Glow Ammo is a recent innovation, developed by Andy Hollerman, Ph.D. to replace tracer rounds based on burning chemicals.

Glow Ammo provides a non-incendiary, tracer effect especially visible from the pilots's perspective and less so the target's.



The glow can be seen from a wide angle to the rear and sides of the tracer round's trajectory.

He says the idea came from watching triboluminescence, which is a non-incendiary method of producing light produced by breaking or rubbing crystals together

The Cannon Relay System doubles the energy capacity of the primary weapon system and adds two additional gun barrels to an installed particle cannon.



It works by storing extra power in a network of capacitors, supplying sufficient energy for two firing cycles of the primary weapons thus doubling the rate of fire. The capacitor efficiency is greatly increased using nanotechnology to increase the surface area of the capacitance charge storage plates.

The Cannon Heatsink helps keep primary particle cannon cooler during their firing cycles, allowing them to fire at significantly faster rates. Overheating of either beam or particle cannon can cause severe damage the system components, so weapons systems automatically shuts down before the damage occurs

In plasma based particle weapons overheating distorts the plasma acceleration chambers and electromagnetic focussing 'lenses'. In beam weapons overheating distorts alignment of the lasing mirror chambers, preventing the energy cascade required for producing the coherent emr 'beam'.

Cooling via a cannon heatsink is obviously beneficial to a pilot's combat life expectancy! The plasma is fired in packets to allow a firing - cooling cycle to optimise the cooling efficiency of the heatsink.



Beam Cannon Technology

All beam weapons use the transformation of matter to energy as described in Einstein's equation. The energy is released as electromagnetic radiation. A small proportion is within the visible range of the spectrum so that pilots can 'see' the beam - somewhat like tracer rounds of a few centuries ago.

The difference between the classes (C1 - C5) is in the intensity and the wavelength of the emr emitted. C1 emit in the infra red (heat) through visible and into ultra violet regions (causes sunburn!!). The energy of emr is related to the wavelength which gets shorter at higher energies. The beam classes go up through X-rays, gamma rays and cosmic rays in order of increasing energy content.

The main damage is done to the shields. Experienced combat pilots recommend using beam cannon to take down a ship's shields, since beam weapons use energy at a lower rate than particle cannon. The emr disrupts the shield field matrix, which requires more energy to reform it. The 'damage' eventually drains the ships shield generation capacity. Whilst beam weapons can do some hull damage a combat pilot requires particle weapons to create sufficient damage quickly enough to destroy the hostile.

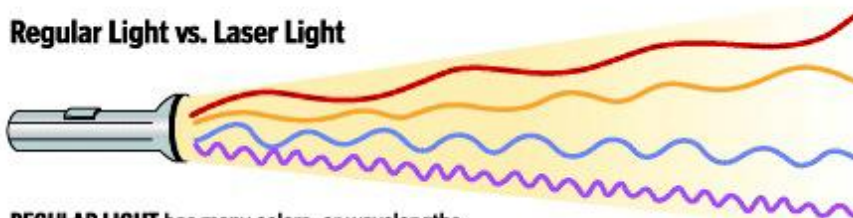
Laser Physics

These **directed-energy weapons (DEW)** project energy in an aimed direction without the means of a projectile. All five are based on laser technology, producing a coherent beam of high energy photons.

Lasers are more than just powerful flashlights. The difference between ordinary light and laser light is like the difference between ripples in your bathtub and huge waves on the sea. You've probably noticed that if you move your hands back and forth in the bathtub you can make quite strong waves. If you keep moving your hands in step with the waves you make, the waves get bigger and bigger. Imagine doing this a few million times in the open ocean. Before long, you'd have mountainous waves towering over your head!

A laser does something similar with light. It starts off with weak light and keeps adding more and more energy so the light waves become ever more concentrated. The 'white' light produced by an ordinary flashlight contains many different light rays of different wavelengths that are out of step with one another ('incoherent'). But in a laser, all the light rays have the same wavelength and they are coherent (absolutely in step). This is what makes laser light such a powerful concentration of energy.

Regular Light vs. Laser Light



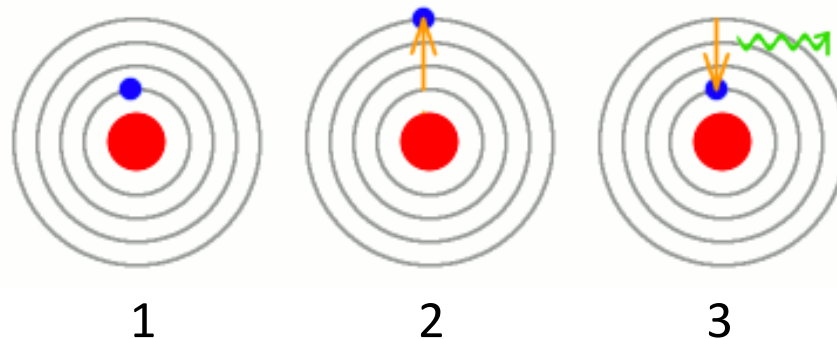
REGULAR LIGHT has many colors, or wavelengths, mixed together, creating white light. The light waves spread out as they travel.



LASER LIGHT is of the same wavelength, with all of the waves in phase, or in step, with one another. A laser is always a single color because the waves are the same length. Because the waves are parallel, a laser light stays in a tight beam for long distances.

Laser is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.

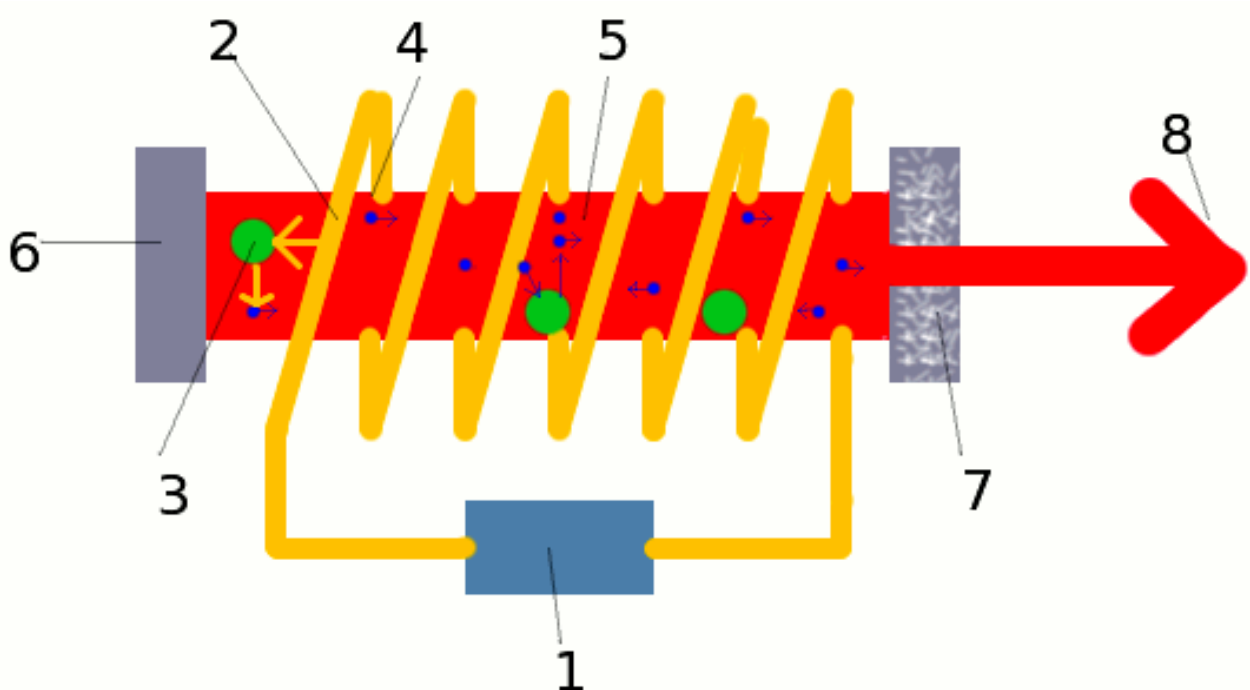
Lasers are possible because of the way light interacts with electrons. Atoms make light in a three-step process:



1. They start off in their stable 'ground state' with electrons (blue) in their normal places.
2. When they absorb energy, one or more electrons are kicked out farther from the nucleus into higher energy levels (grey circles). We say the atom is now 'excited.'
3. However, an excited atom is unstable and quickly tries to get back to its stable, ground state. So it gives off the excess energy it originally gained as a photon of energy: a packet of light.

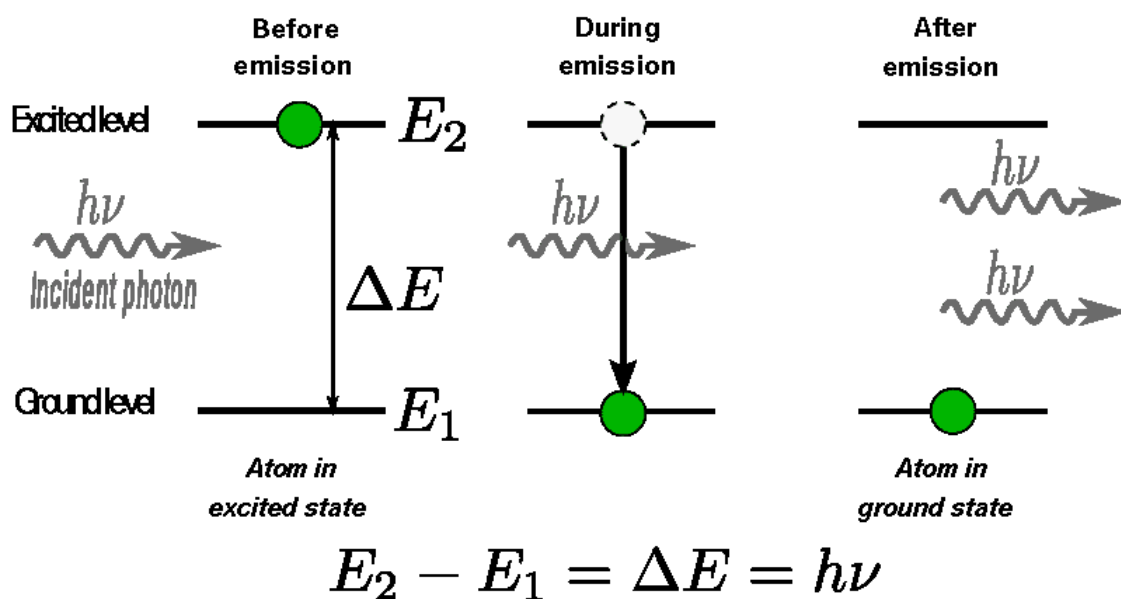
A laser is effectively a machine that makes billions of atoms pump out trillions of photons (light particles) all at once so they line up to form a really concentrated light beam.

A ruby laser is one of the first to be built. It contains a long crystal made of synthetic ruby (shown here as a red bar) with a high intensity flash tube (yellow zig-zag lines - [2]) wrapped around it to provide a flash of white light that triggers the laser action. The flash tube looks a bit like a fluorescent strip light, only it's coiled around the ruby crystal and it flashes every so often like a camera's flash gun.



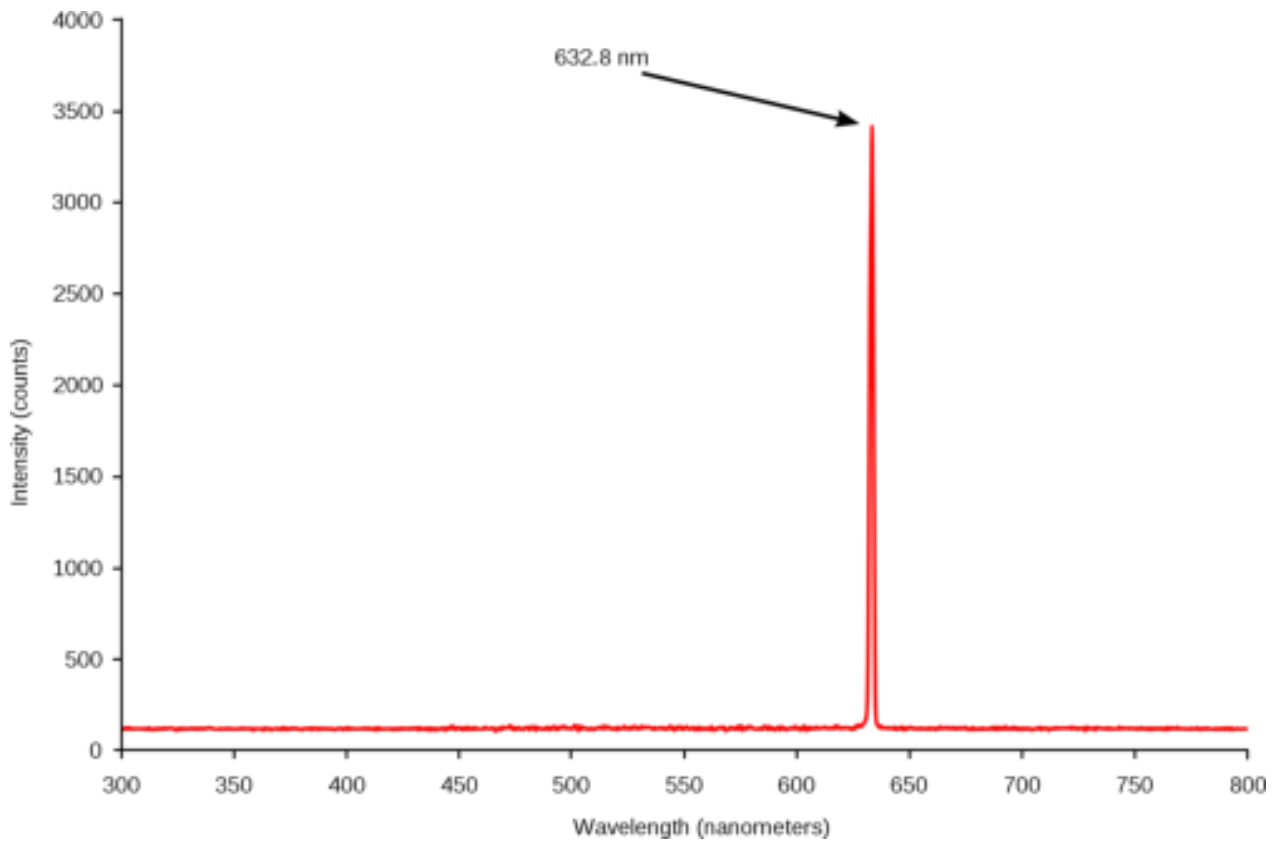
How do the flash tube and the crystal make laser light?

1. A high-voltage electric supply makes the tube flash on and off.
2. Every time the tube flashes, it 'pumps' energy into the ruby crystal. The flashes it makes inject energy into the crystal in the form of photons.
3. Atoms in the ruby crystal (large green blobs) soak up this energy in a process called absorption. When an atom absorbs a photon of energy, one of its electrons jumps from a low energy level to a higher one. This puts the atom into an excited state, but makes it unstable. Because the excited atom is unstable, the electron can stay in the higher energy level only for a few milliseconds. It falls back to its original level, giving off the energy it absorbed as a new photon of light radiation (small blue blob). This process is called spontaneous emission.
4. The photons that atoms give off zoom up and down inside the ruby crystal, traveling at the speed of light.
5. Every so often, one of these photons hits an already excited atom. When this happens, the excited atom gives off two photons of light instead of one. This is called stimulated emission. Now one photon of light has produced two, so the light has been amplified (increased in strength). In other words, 'light amplification' (an increase in the amount of light) has been caused by 'stimulated emission of radiation' (hence the name 'laser', because that's exactly how a laser works!)
6. A mirror at one end of the laser tube keeps the photons bouncing back and forth inside the crystal.
7. A partial mirror at the other end of the tube bounces some photons back into the crystal but lets some escape.
8. The escaping photons form a very concentrated beam of powerful laser light.



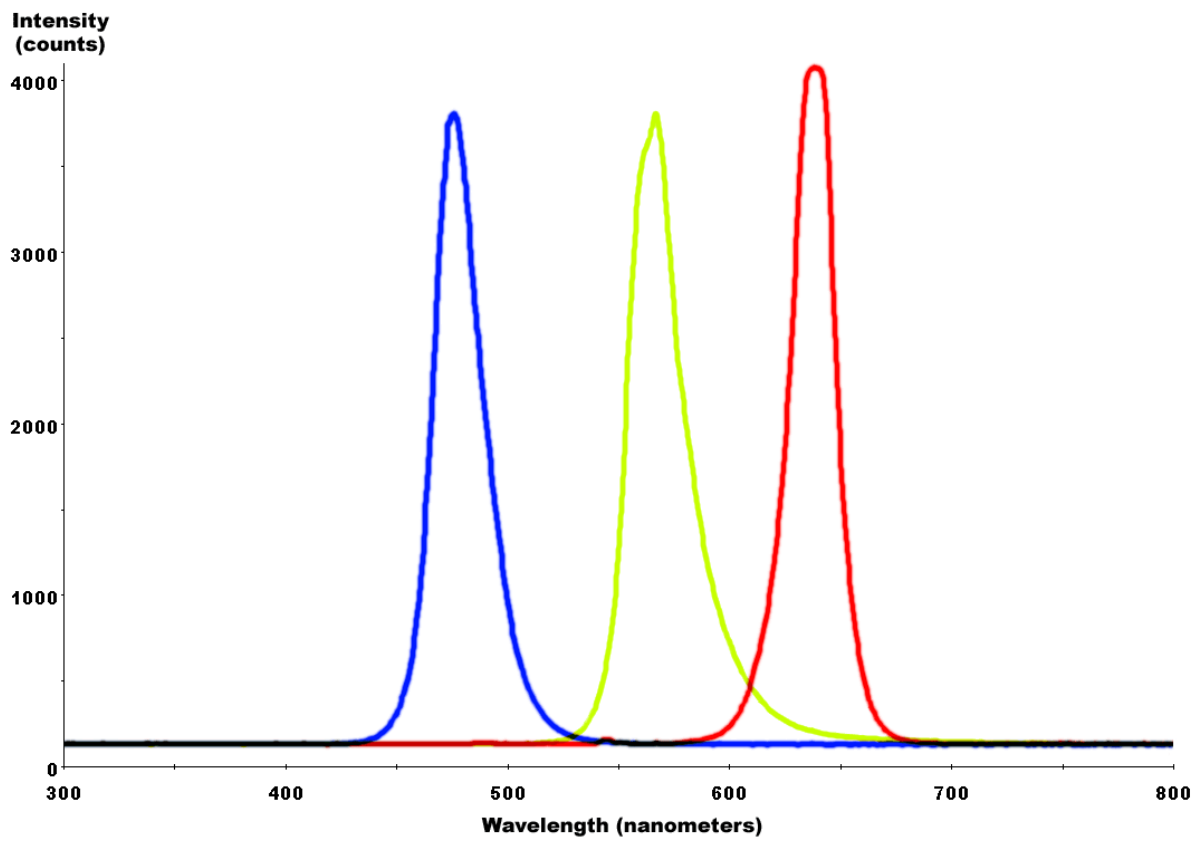
The diagram of the spectrum of this laser illustrates its very high spectral purity (limited by the measuring apparatus). The .002 nm bandwidth of the lasing medium is well over 10,000 times narrower than the spectral width of a light-emitting diode (spectrum shown below the laser spectrum.)

The bandwidth of a single longitudinal laser mode is much narrower still!



Above: spectrum of a laser;

Below - spectrum of a white light LED



The material in the laser that contains the atoms that will become excited is called the gain medium. This is excited by an external source of energy into an excited state. Different types of laser (and hence different types of beam cannon) use different methods to excite the atoms. The different technologies therefore produce beams with different energies.

The gain medium of a laser is normally a material of controlled purity, size, concentration, and shape, which amplifies the beam by the process of stimulated emission described above. This material can be of any state of matter: gas, liquid, solid, or plasma. The gain medium absorbs energy, which raises some electrons into higher energy ('excited') quantum states. The Weapon Lab design screen allows you to alter some of these parameters that determine the beams characteristics.

Laser Summary (for nerds)

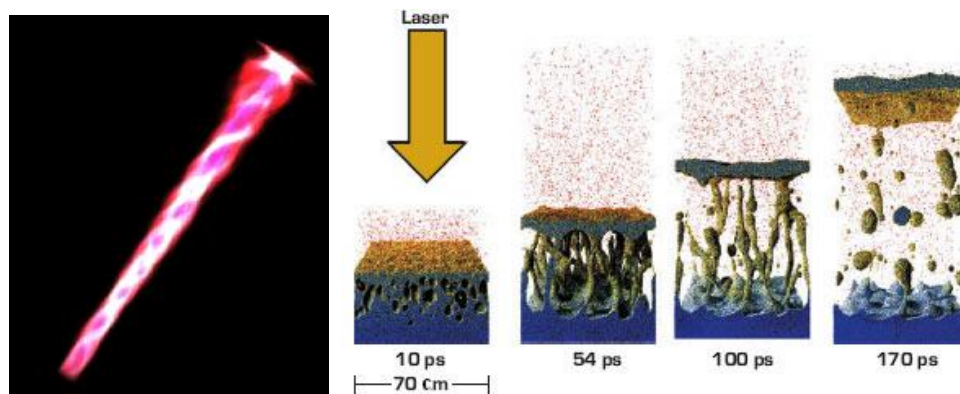
To summarise the important part as far as pilots are concerned - the beam - the light generated by stimulated emission is very similar to the input energy in terms of wavelength, phase, and polarization. This gives laser light its characteristic coherence, and allows it to maintain the uniform polarization and monochromaticity established by the optical cavity design. This is a fundamental property of laser 'light' - all the photons have the same wavelength and all the waves are in step with each other. Just as two water waves produce a higher water wave when they cross each other the photons energy 'stacks up' creating a very energetic beam of light energy.

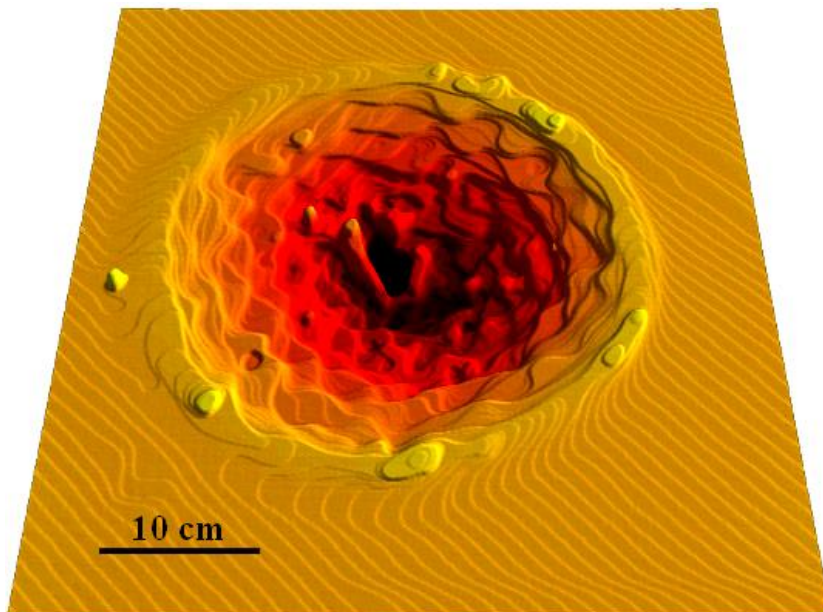
Beam Weapon Characteristics.

Beam weapons run in pulsed as opposed to continuous wave mode

To be effective as a weapon requires the production of pulses having as large an energy as possible. Since the pulse energy is equal to the average available power divided by the repetition rate, this goal can sometimes be satisfied by lowering the rate of pulses so that more energy can be built up in between pulses.

In laser induced ablation a small volume of material can be evaporated if it is heated in a very short time, whereas supplying the energy gradually would allow for the heat to be absorbed into the bulk of the piece, never attaining a sufficiently high temperature at a particular point. Hence beam cannon produce pulsed high energy photon packets. The energy of the photons is enhanced by 'mode locking', enhancing ablation. Again, because of the extremely short pulse duration, such a laser will produce pulses which achieve an extremely high peak power. The following pictures show a single photon packet (pulse) and an ultra rapid sequence of a hit by a photon packet onto armour to demonstrate laser ablation.





This image shows the impact crater in composite armour from a single photon packet from a Class three beam weapon

Beam Weapon Types

Background: 20th Century Technology & Engineering

There are many different ways of energising a laser creating a range of cannon types that produce beams carrying different amounts of energy - Class one cannon are the least energetic - Class 5 the most. The difference between the various models of beam cannon comes down to where in the electromagnetic spectrum their photons are (radio photons are the least energetic, gamma photons the most energetic)

Class 1: Refractory Beam Cannon are based on **Photonic Crystal laser technology**. The term refractory arose because the original materials used had very high temperature strength due to their nanocrystalline structure. Even though the high temperature characteristics were not related to their lasing ability the name stuck! They are based on nanostructures that provide the mode confinement and structure required for the energy feedback to take place They are easy to build and maintain (and hence cheap), are mechanically robust and have an acceptable energy performance

Class 2: Metal Vapour Beam Cannon are based on **Gas laser technology** - the example used to explain basic laser technology above. Lasers using pure metal vapour produced from an elemental copper source are difficult to construct because of the extremely high temperature, about 1500 °C, necessary to create such vapour, severely limiting the materials for the vapour containment vessel and mirrors. Copper halides, specifically copper chloride, copper bromide and copper iodide, have been substituted since they form vapours at much lower temperatures, in the range 300-600 °C, but operation at such temperatures remains difficult. Copper compound vapours also increase the complexity of the pump signal applied to the device. Typically, two energizing pulses in quick succession are required, the first to dissociate vapour molecules, and the second to cause the dissociated ions to lase. R&D into the effect of mixtures of metals proved to be more successful. The metal vapour used in your cannon is actually a gaseous alloy of strontium and copper.

Class 3: Coil Beam Cannon have enhanced power output based on **Excimer Lasers technology**.

Excimer lasers are a special sort of gas laser. Gas lasers are also known as **coil lasers** because of the use of a coiled 'bottle' to concentrate the maximum lasing material in the smallest space. Excimer lasers are powered by an electric discharge in which the lasing medium is an excimer, or more precisely an exciplex. These are molecules which can only exist with one atom in an excited state. Once the molecule transfers its excitation energy to a photon, therefore, its atoms are no longer bound to each other and the molecule disintegrates. This drastically reduces the population of the lower energy state thus greatly facilitating a population inversion. Excimers currently used are all generated by the QVee extraction of materials from CDM. Excimer lasers typically operate at ultraviolet wavelengths.

Class 4: Neodymium Beam Cannon are based on **solid state laser** technology. **Solid state lasers** use a crystalline or 'glass' rod which is 'doped' with ions that provide the required energy states. For example, the first working laser ever created was a ruby laser, made from synthetic ruby rods doped with corundum. The population inversion is actually maintained in the 'dopant', such as neodymium. These materials are pumped optically using a shorter wavelength than the lasing wavelength, often from a flashtube or from another laser. The Megajoule level of output is achieved by a neodymium laser that requires a three stage boosting from IR to UV and then up to X-ray.

Class 5: Fusion Beam Cannon use positronium annihilation to drive a very powerful gamma ray laser. The positronium is extracted from CDM by a QVee unit within the cannon.

Class ??: Chemical Laser Beam Cannon are powered by a chemical reaction permitting a large amount of energy to be released quickly. In the laboratory they outclass all other types of laser. Scaling up is not straightforward and creating the robustness required of a combat weapon would present many challenges. However, such very high power lasers are especially of interest to the military, and it is rumoured that continuous wave chemical lasers at very high power levels (TJ), fed by streams of gasses, have been developed.

The requirement for carrying large amounts of chemical reactants and the equipment requirements for the extremely high energies involved make these impractical for mercenary ships even if the military would admit to developing the technology. Some Naval SpecOps Battlecruisers and Destroyers as well as important ground bases are said to be equipped with chemical laser cannon.



We have been lucky to obtain sufficient details based around several (unconfirmed) reports of sighting across Evochron, to create an artist's impression of an CL equipped Spec Ops Infiltration Destroyer

These ships are rumoured to be the only capital ships fitted with effective stealth technology developed, as with much advanced technology, from Vonari designs.

We must emphasise that such reports are presently unconfirmed

Missiles:

Background: Engineering

Until the introduction of the Weapon Lab, mercenaries were constrained to choose from a standard set of missiles. These are equipped with basic propulsion units and 'chase' electronics to lock onto target heat signature giving the missiles a FaF capability (Fire and Forget). Various amounts of 'explosives' cause the damage. Missiles are equipped with close proximity fuses so that a direct hit is not needed.

When you buy a standard missile its electronic IFF (Identify Friend Foe) subsystem is programmed with your ship's identity beacon code. The missile will not lock onto you if it loses its primary target. However, it is unable to identify any other ship in the vicinity as non-hostile and so may lock onto 'friendlies' if its primary target is lost or destroyed. The eight-pack Excalibur has something of a reputation for biting the goodies as well as the baddies! Research into auto identification of 'friendlies' has proved unsuccessful - systems that could identify 'friendlies' were too easily spoofed by hostiles broadcasting 'friendly' codes.

Specialised 'off-the-shelf' Missiles

There are several specialist missiles available that are fitted with detectors that target appropriate ship subsystems

Leech: the explosive payload is replaced with an EM pulse generator which scrambles the electronics of the ship including the AI system control module. This system could in theory be used as the CM facility fitted as standard to ship frames. However the individual pulse generators are too bulky and too costly for the rate at which they would be deployed in a typical combat situation. There is also risk taking out the electronic systems of friendly ships in the vicinity (including the ship that fired them!) The pulse is triggered by a proximity sensor.

Cyclone: is a readily available Impact Warhead Missile. Other Impact missiles can be customised in the Weapon Lab

Lynx & Rage: sophisticated electronic detectors and a modified version of the em pulse generator are fine-tuned to the engine and weapons sub-system control electronics. Being a narrow bandwidth pulse it is stronger and hence able to do more damage than the broader spectrum Leech - the specifically targeted systems therefore remain off line for a longer period.

The Fulcrum Torpedo (FT) utilises an antimatter/matter warhead with containment field! After a preset travel time the antimatter containment field is collapsed and the ensuing matter/antimatter annihilation creates a super heated high energy burst. Few things can withstand a FT explosion.



Fractions of a gram of antimatter are all that is required (see energy calculations above) Antimatter can only be held in a shaped magnetic containment 'bottle'. The strength of the required magnetic field (in such a small volume) requires superconducting magnets and a very complex AI controlled shaping system. There have to be several backup safety mechanisms incorporated so that the missile can withstand the stresses of normal handling, loading and firing. If the bottle fails, even for a microsecond, the warhead explodes.

Because of the complexity of holding antimatter in a matter based missile the construction is significantly more complex than 'normal' missiles and hence it is significantly more expensive than any other missile (with the exception of the Regenerative Excalibur Missile System - though the Excal gives you unlimited missiles for free after the initial purchase).

There were some experiments with low temperature superconductor materials that are significantly less expensive than the ambient temperature materials being used. The cooling system utilised the low temperature of surrounding space to keep the containment field generator at 120 degrees below zero via a heat radiating 'fin' on the ships outer hull. This was designed to be a passive system utilising the temperature differential between the near zero of space and the 'hot' containment generator inside the ship. Initial tests were promising but in real life tests several problems arose;

The fin had to be made much larger and an active heat pumping system used since heat loss was less efficient inside the shield matrix, and if the fin was outside the matrix it was too easily damaged.

A secondary cooling system had to be fitted for situations where the ship was in a 'hot' environment, for example near a star or jumping through a WH (gates, fulcrum drive or 'wild').

This need for dual cooling required a dedicated AI temperature control sub-system since the FT mechanism is obviously 'fail to lethal'. Attempts to create a 'fail to safe' containment bottle ejection systems became so complex that they were expensive and too bulky to be fitted into a standard frame. Passive cooling was abandoned and high temperature materials retained.

Excalibur Pack: How the Excalibur self-regeneration missile packs work is top secret. A few pilots have tried to 'reverse engineer' the sealed fabrication units (the grey ribbed box in the diagram below) but a series of spectacular accidents and pilots who simply 'dropped off the radar' has taught a strong lesson.

To maximise the effectiveness of a multiple missile launch system, the missiles have to be launched in a very short time. Launching all eight missiles at once or in bursts of four increased the complexity, size, mass and cost of the missile modules beyond the budget of the target market.



The research team developed a mechanism that was inspired by the historical **Vulcan**

AutoCannon which used rotating multiple barrels to increase rate of rate of fire. (This in turn had been based on the 18th Century Gatling machine gun!) The external part of the system is around 10 metres in length consists of a four rapidly rotating launch tubes held on a mount. Missiles are launched when their launch tube moves into the top centre ('fire') position. The first missile is launched and the launch tube mount rotates 90°. The second missile is launched as the first tube begins its reload sequence; the tube mount rotates again and the first tube completes its reload sequence and this cycle continues until all eight missiles are fired.

A launch tube has three quarter rotations during which it is reloaded with its second missile and the missile primed. A complete Excalibur Pack launch requires two complete rotations of the tubes with each tube launching two missiles. The Excalibur system launches its missiles sequentially, rather than multiple missile bursts. The launch system handles eight missiles in under two seconds. A single launch tube even with a rapid reload mechanism couldn't handle such a rate of fire.

Tentative theories (aka scuttlebutt!) have suggested that CDM harvested from the space around the ship could be the source of the matter needed to create the body of the missile and the control AI cores; a miniaturised quantum vacuum fuel generator could provide the fuel (equivalent to a miniaturised fuel processor station) and the small amount of antimatter to create the explosive warhead but this is all speculation (3 mins isn't long to recreate the reload of eight missiles!). As one pilot said in frustration when his unit malfunctioned a long way from a repair facility " . . . Vice only knows how the @#*\$ thing works!"

Military research personnel, when asked how the Excal pack works replied (with straight faces) " . . . very well indeed!"

The following section describes the missiles available for customisation in the Weapon Lab;

Basic Warhead Characteristics

The warhead is the primary element of the weapon; it accomplishes the desired end result - effective damage to the target. Target damage is directly related to three parameters:

Damage Volume: The warhead may be thought of as being enclosed by an envelope that sweeps along the trajectory of the missile. The volume enclosed by this envelope defines the limit of destructive effectiveness of the payload.

Attenuation: As shock and fragments leave the point of origin, a reduction in their destructive potential per unit area takes place. Attenuation can be likened to an expanding sphere, in which the energy available per unit area constantly decreases until it is completely harmless.

Propagation: This is the manner in which energy and material, emitted by the warhead at detonation, travel through the medium in which the blast occurs. When the propagation of a payload is uniform in all directions, it is called isotropic. If not, it is called non-isotropic. In space the medium is the armour and the hull of the hostile

Missile Warheads Classes - summary

All missiles share a set of common technologies; propulsion, CM evasion, armour shielding, FaF capability etc. They are designed to firstly swamp the targets shield system with the initial explosive energy burst and then to penetrate the hull. Since there are several types of armour in use there is a need for several types of missile warhead to tackle them. The Weapon Lab makes the following customisable missiles available

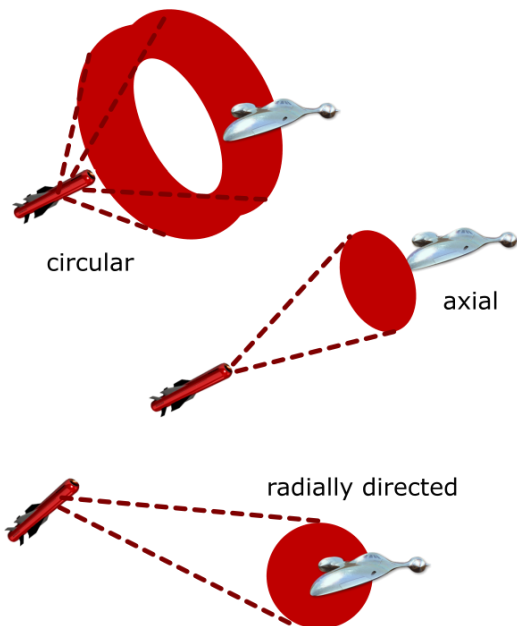
Impact Missile: uses solid tungsten rods travelling at speeds of around 8% the SoL to cause damage by the transfer of kinetic energy that is in the TeraJoule (TJ) range

advantages: because there is no explosive in the warhead after penetration damage is limited to the ship section it hits, making salvage more likely. The rods are accelerated by an explosive charge triggered on contact with the target making the (simple) detonation system harder to spoof

Compound Core Missile: use a double explosive charge - the first detonation will activate reactive armour, using up its protective capability - the second charge can then directly attack the weakened area

advantages: very effective against reactive armours used in higher class frames

Fragmentation Missile use a proximity detonation system to create a cone of high speed (high kinetic energy) fragments that enhance the hit rate of the missile (though not all fragments will hit!); AI control of the direction of explosion can target the fragment cone and create a variety of fragment patterns. Frag missiles are less effective on more modern armour



advantages: stresses large areas of the shield matrix at the same time making it more likely that a point targeted missile or cannon fire can penetrate the shield if used at the same time

Reactive Missile combine the advantages of fragmentation missiles with the ability of compound core missiles to swamp reactive armour. The first detonation triggers the reactive armour (or weakens composite armour). In the first detonation the missile employs newly developed meta-materials to enhance the effectiveness of the high speed fragments to penetrate more modern armour. The number of hits created by the large number of fragments swamps reactive armour, weakening it across large areas and hence making point hit missiles and cannon fire more likely to hit a weakened area

advantages: very effective against reactive armours used in higher class frames and quite effective against multilayer armour due to the better penetration abilities of the meta-materials

Shaped Core Missile: use a shaped explosive charge to create a molten heavy metal 'rod' that moving so extremely fast that it punches through armour

advantages: very effective against modern armours used in higher class ships and by the Vonari

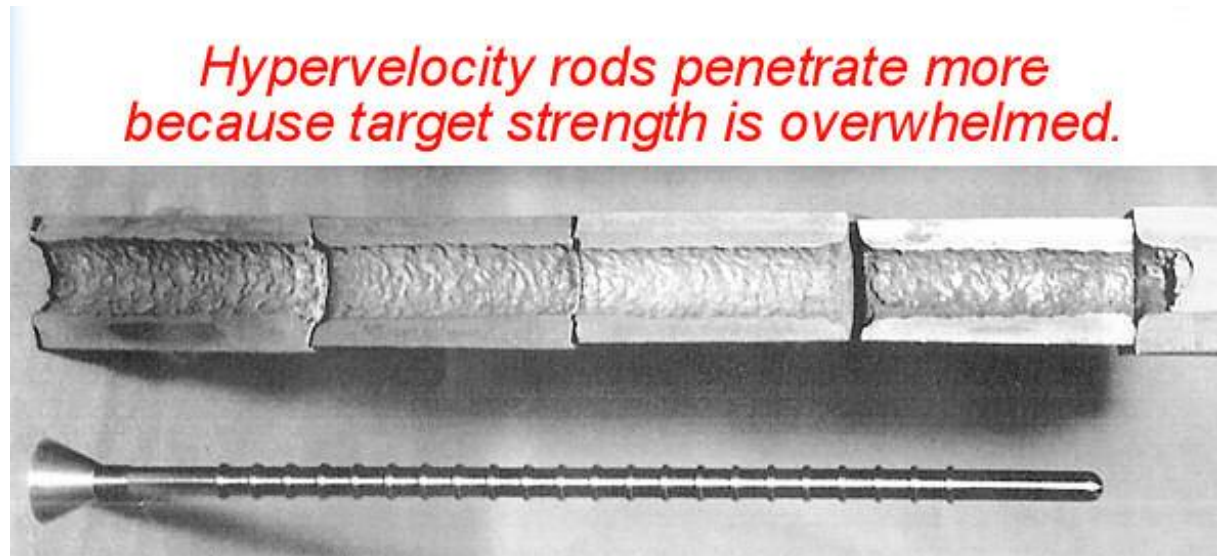
Missile Warhead Technology - details

Impact Warheads

The **Cyclone** is the readily available version available at all trade stations.

There is a double meaning to their name: firstly they use a contact fuse rather than a proximity detonator - the simplicity in this design makes it less likely that the detonation phase can be jammed. Experience shows that a hit inevitably leads to a bang! The second is that the payload is one or several solid metal rods. The role of the explosive charge is simply to accelerate the rods to very high speeds. The rods have greatly increased penetration probability than fragments, even from the meta-material reactive missile.

The concept came about as the result of a serendipitous discovery during the testing of the contact fuses of a conventional 'blast warhead' missile! For the tests the normal explosive package was replaced with a steel rod of similar mass and much to the surprise of the test crew the steel rods were able to penetrate significant thicknesses of steel plate. The kinetic energy was so high that testers were surprised to find that practice rounds (fitted with an 8-inch solid mild steel rod penetrator) were penetrating (admittedly out-dated) naval fighter hardened alloy armour.



Further tests with denser metals like tungsten in place of the steel showed that these warheads can deliver sufficient kinetic energy to penetrate significant thicknesses of roll-hardened armour (from any angle!) and reasonable thicknesses of composite armour as well as inflicting high energy depletion on a shield matrix.

The concept also has the advantage that, lacking a high explosive charge, damage inside the target is relatively localised, making it possible to salvage the damaged ship. The solid penetrators power through armour (which at the speeds and energies involved behave like viscous liquids) and may fragment inside the target into smaller particles that ignite to cause a high-temperature localised incendiary explosion.

However, in order to be effective they have to hit their target! The cylindrical shaped projectiles, however, may tend to break and/or tumble in their deployment if proximity fuses are used. The projectiles may approach the target at such a high oblique angle relative to their direction of flight (ie semi-sideways!) that they do not effectively penetrate the target.

A higher lethality kinetic energy rod warhead can be created by including a means for angling the individual projectiles when they are deployed to prevent the projectiles from tumbling and to provide a better penetration angle; by selectively directing the projectiles at the target, and also by incorporating special shaped projectiles. However, testing showed that in a small ship combat situation a contact detonation was required to ensure that sufficient penetrators hit the target and at the correct orientations - proximity detonation simply wasn't effective enough given the limited size and mass of the missiles.

The downside is the need for very high accuracy - nearby isn't good enough! Their exceptionally high accuracy is ensured by the missile's main secret, the so-called **transverse control engine**, developed by *General Thrusters Industries* on Talison, which effectively rules out misses during the final approach trajectory. The transverse control engine is still without parallel in Evochron.

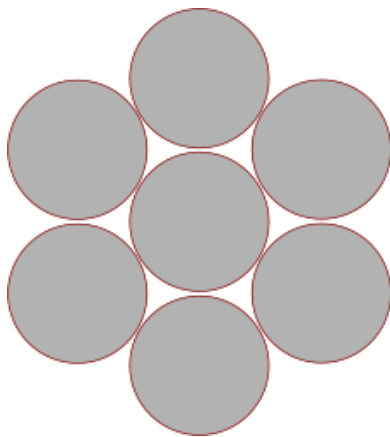
The primary components associated with a kinetic energy rod warhead is a casing, a projectile core containing several cylindrical projectiles, and an explosive charge around and behind the projectile bay with shaped explosive shields. When the explosive charge is detonated, the projectiles are deployed.

The shape of the rods has a significant impact (pardon the pun!) on performance. Much research has gone into the shape for the projectiles which are now optimised from the standpoint of strength, weight, packaging efficiency, penetrability, and lethality.



To create the necessary kinetic energies the rods are (virtually) instantly accelerated to around 25 million m/s. This is around 8% of the speed of light. At this speed a single 5kg rod has a kinetic energy of 1.5 petajoules (PJ). A typical payload core consists of a core of 7 such rods:

15625
28



This totals more than 10 PJ directly impacting the shields and/or hull in the best case scenario

The explosive yield of TNT is considered to be the standard measure of the power of an explosive. TNT releases 2.8 MJ per kilogram explosive energy. This makes each rod the equivalent of just over half a tonne of TNT and the warhead a total of 4 tonnes of TNT in ideal conditions.

Compound Core Warhead Missiles

These missiles are designed to penetrate reactive armour (see below). Typically a tandem-charge weapon is used. These warheads employ two or more stages of detonation. The first stage of the weapon triggers the reactive armour of the target, limiting the attack's effectiveness. However, after the reactive armour has protected the ship from the primary attack, it is no longer 'reactive' in that location (since reactive armour is primarily a one-time defence solution) and the location is left more vulnerable. The second detonation from the same projectile (which defines it as a tandem charge) attacks the same location as the first detonation where the reactive armour has been compromised. Since the regular armour plating is often the only defence remaining under the reactive outer covering, the tandem charge (second detonation) has an increased likelihood of penetrating the armour.

However, tandem-charges are useful only against SLERA (self-limiting explosive reactive armour) types of reactive armour, not against the NERA (non-explosive reactive armour) reactive armour types, since their inner liner is not explosive itself, thus able to withstand the small forward warhead of tandem-charge attack.

The warheads contain a shaped charge, consisting of two separate shaped charges, one in front of the other, typically with some distance between them. Usually, the front charge is somewhat smaller than the rear one, as it is intended primarily to disrupt ERA boxes or tiles. Recently, a Federation arms firm revealed a 125mm Navy flak cannon round (Hellfire) with two 'same diameter' shaped charges one behind the other, but with the back one offset so its penetration stream will not interfere with the front shaped charge's penetration stream. The reasoning behind the Hellfire having tandem same diameter warheads is not to increase penetration, but to increase the 'beyond-armour' effect increasing the damage to systems inside the hull. The Weapon Lab design software and fabricating systems have accomplished the complex engineering feat of creating two shaped charges of the same diameter stacked in one warhead allowing you to create anti-armour missiles that are significantly more effective.

Fragmentation Warhead Missiles.

When the missile carrying the warhead reaches a position close to an enemy target, a pre-scored or pre-made band of metal on the warhead is detonated and pieces of metal are accelerated to a high velocity and strike the target.

Terminal ballistics studies determined the laws and conditions governing the velocity and distribution of fragments, the sizes and shapes that result from bursting different containers, and the damage aspects of the bursting charge fragmentation.

Fragmentation warheads were originally designed for atmospheric use. Only 30% of the explosive charge's energy was converted into fragmentation energy. The rest created a shock wave in the atmosphere like a basic blast warhead. In the vacuum of space there is no atmospheric compression shockwave. Much research was required to change this to the present 96% fragment energy transfer our missiles have.

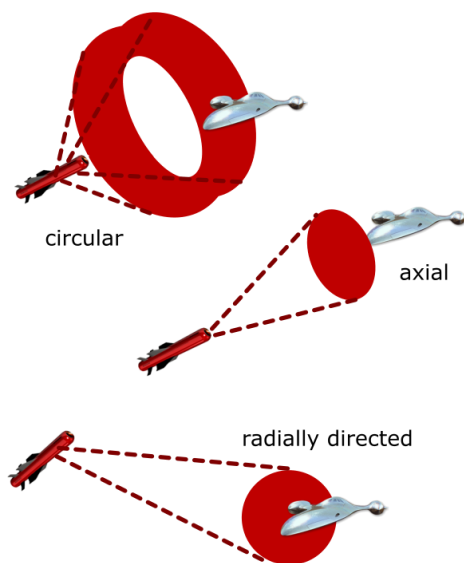
The fragments are propelled at high velocity. Whereas the effects of an idealized blast payload are attenuated by a factor roughly equal to $1/R^3$ (R is distance measured from the origin) since the blast is omnidirectional, the attenuation of idealized fragmentation effects will vary as $1/R^2$ because the blast is directional and hence relatively focussed. Herein lies the principle advantage of a fragmentation payload: it can afford a greater 'miss' distance and still remain effective because its attenuation is less.

Uncontrolled fragmentation patterns, such as those used in general-purpose bombs, occur by the natural break up of the outer casing occurring from the detonation of the surrounding explosive charge.

This event forms fragments of random size and lethality. Manipulating the fragment formation process can more predictably control fragmentation patterns and fragment uniformity. By controlling the fragment formation process, the relative size and, therefore, the optimized bulk fragment distribution pattern over an area is constrained to maximize the kill probability against an anticipated target.

Fragment trajectories follow paths determined by a simple scanner system on board the missile. The density of fragments in a given direction varies inversely as the square of the distance from the weapon. The probability of a hit on a target is proportional to the exposed projected area and inversely proportional to the square of the distance from the weapon ($1/r^2$).

Taking these two factors into account - the directional nature of the fragmentation blast and the spread, a balance can be reached; the missile must explode near enough to the target to ensure that sufficient fragments hit, but the 'shotgun' effect of the blast cone along with the directional aiming scanner system means that the missile doesn't have to be pointing at the target to score a significant hit.



This is **Selectively Aimable Warhead (SAW)**. This 'smart' warhead is designed to aim its fragment density at the target. This is accomplished by the scanner/fusing system telling the warhead where the target is located and causing it to detonate so as to maximize the energy density on the target.

Reactive Warhead Missiles

In the Federation, reactive materials (RM) are a new class of materials currently being as a means to increase the lethality of direct-hit or fragmentation warhead. Reactive materials are similar to Insensitive High Explosives (Insensitive Munitions), but are usually thermite-like. They are a pyrotechnic composition of two or more non-explosive solid materials, which stay inert and do not react with each other until subjected to a sufficiently strong mechanical, electrical or laser stimulus, after which they undergo fast burning or explosion with release of high amount of chemical energy in addition to their kinetic energy. Fragments or projectiles made of such materials have therefore greater damaging effect than inert ones, with an expected lethality increase of up to five times.

Several classes of chemical materials were investigated including intermetallic compounds, metal-polymer mixtures, metastable intermolecular composite (MIC) and matrix materials. Of these, several are employed in the WL. They are strong enough to act as structural components, sufficiently stable to survive handling and launch, to penetrate a target, and sufficiently unstable to reliably ignite on impact.

The mixtures available include finely powdered nanoparticle metalloids with one or more oxidizers and metals which can form intermetallic compounds by an exothermic reaction. The mix of 'ingredients' is pressed or sintered or bonded to a compact, high-density mass. They are optimised to achieve a suitable reaction rate and insensitivity to impact, friction, and electrostatic discharge.

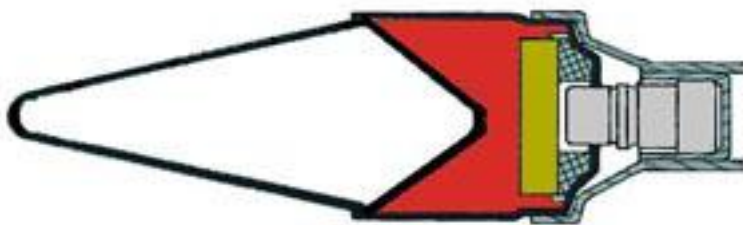
Under research are materials with high mechanical strength, high density, high energy density, and which can rapidly convert from a consolidated structural material to fine powder with large surface area, be dispersed and then ignited to produce a large energy blast that can swamp shields. These will be added to WL as soon as they are licensed.

Shaped Core Warhead Missiles

These are probably the most popular missiles in use in Evochron. Consequently we will give the most complete description and explanation.

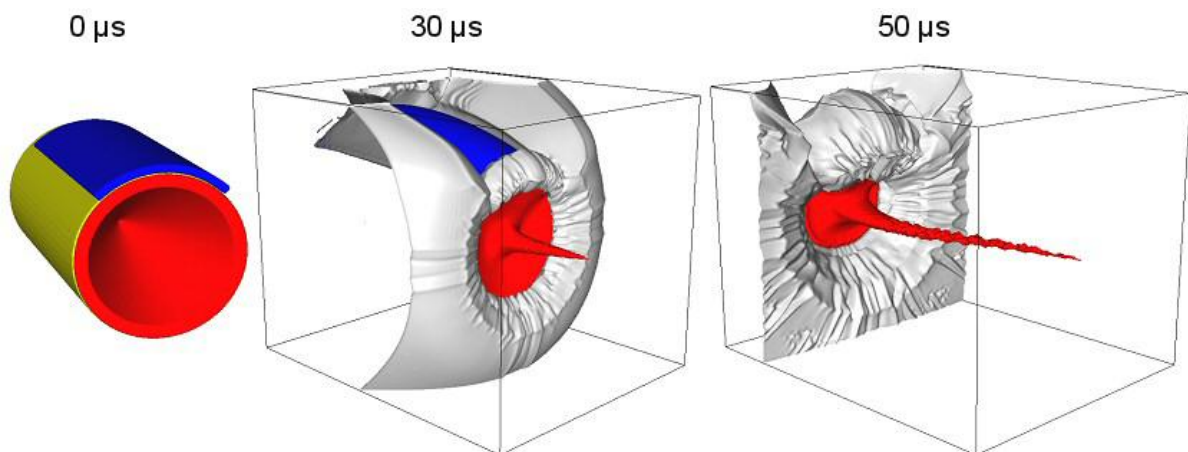
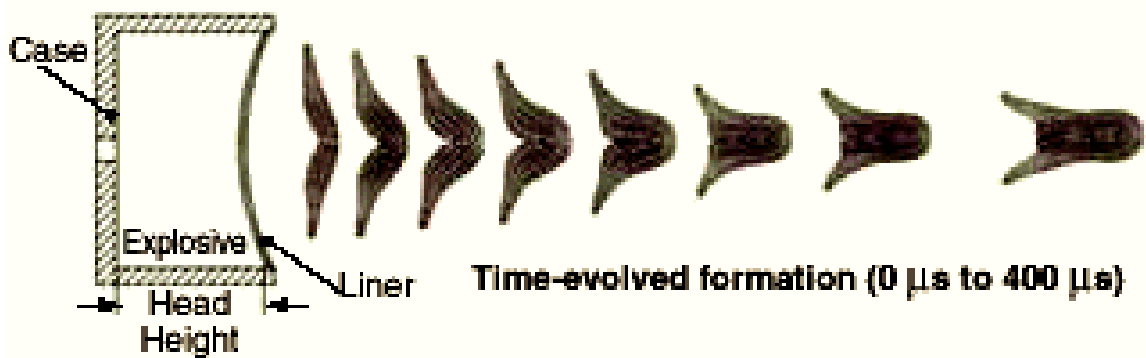
A **shaped charge (shaped core)** is an explosive charge shaped to focus the effect of the explosive's energy to penetrate armour. A typical modern lined shaped charge can penetrate armour alloy to a depth of 7 or more times the diameter of the charge (charge diameters, CD), though greater depths up to 20 CD and above have been achieved. Contrary to a widespread misconception, the shaped charge does *not* depend in any way on heating or melting for its effectiveness, that is, the jet from a shaped charge does not melt its way through armour, as its effect is purely due to its kinetic energy. This is called the 'Munroe Effect' or 'Neumann Effect' and is the focusing of blast energy caused by a hollow or void cut on a surface of explosive.

A shaped charge warhead consists basically of a hollow liner of metal material, usually copper or aluminium of conical, hemispherical, or other shape, backed on the convex side by explosive. A container, fuse, and detonating device are included.



When this warhead strikes a target, the fuse detonates the charge from the rear. Explosive energy is released directly away (ie perpendicular) from the surface of an explosive, so shaping the explosive will concentrate the explosive energy in the void.

If the hollow is properly shaped (usually conically), the enormous pressure generated by the detonation of the explosive drives the liner in the hollow cavity inward to collapse upon its central axis. The collapse of the cone results in the formation and ejection of a continuous high-velocity molten jet of liner material. The resulting collision forms and projects a high-velocity jet of metal forward along the axis. Most of the jet material originates from the innermost part of the liner, a layer of about 10% to 20% of the thickness. The rest of the liner forms a slower-moving slug of material, which, because of its appearance, is sometimes called a 'carrot'.



Because of the variation along the liner in its collapse velocity, the jet's velocity also varies along its length, decreasing from the front to back. This variation in jet velocity stretches it and eventually leads to its break-up into particles. The penetration depth of the jet depends on the length and relative density of the jet upon impact. Since the jet stretches during its flight, a better performance is obtained using a carefully calculated standoff between the charge and the target.

Velocity of the tip of the jet is on order of 7000 - 14000 m/s, while the trailing end of the jet has a velocity on the order of 1,500 m/s. This produces a velocity gradient that tends to stretch out or lengthen the jet. The jet is then followed by a slug that consists of about 80% of the liner mass. The slug has a velocity on the order of 600 m/s.

When the jet strikes hardened alloy armour plate, pressures in the range of hundreds of kilobars (atmospheric pressure on Earth = 1 bar) are produced at the point of contact. This pressure produces stresses far above the yield strength of the alloy, and the target material flows like a fluid out of the path of the jet. This phenomenon is called **hydrodynamic penetration**. The diameter of the hole and depth of penetration inflicted on the armour will depend on its density and hardness.

In general, the depth of penetration depends upon five factors:

1. Length of jet
2. Density of the target material
3. Hardness of target material
4. Density of the jet
5. Jet precision (straight vs. divergent)

The *longer the jet*, the greater the depth of penetration. Therefore, the greater the standoff distance (distance from target to base of cone) the better. This is true up to the point at which the jet particulates or breaks up (at 6 to 8 cone diameters from the cone base). Particulation is a result of the velocity gradient in the jet, which stretches it out until it breaks up. If the charge is detonated too close there is not enough time for the jet to fully develop. But the jet disintegrates and disperses after a relatively short distance, usually well under 2 meters. At such standoffs, it breaks into particles which tend to tumble and drift off the axis of penetration, so that the successive particles tend to widen rather than deepen the hole.

Jet precision refers to the straightness of the jet. If the jet is formed with some oscillation or wavy motion, then depth of penetration will be reduced. This is a function of the quality of the liner and the initial detonation location accuracy. The effectiveness of shaped charge warheads is reduced when they are caused to rotate or deflected from perpendicular in the final approach to the target.

Most of the jet travels at hypersonic speed. The tip moves at 7 to 14 km/s, the jet tail at a lower velocity (1 to 3 km/s), and the slug at a still lower velocity (less than 1 km/s). The exact velocities depend on the charge's configuration and confinement, explosive type, materials used. At typical velocities, the penetration process generates such enormous pressures that it causes the armour to flow out of its way!

The most common shape of the liner is cone geometry. Other widely used shapes include hemispheres, tulips, trumpets, ellipses, and bi-conics; the various shapes yield jets with different velocity and mass distributions. Liners have been made from many materials and tested, including various metals and glass. The deepest penetrations are achieved with a dense ductile metals; WL missiles employ tantalum because of its high density. Just about every common metallic element was tried but other high-density metals and alloys tend to have drawbacks in terms of price, radioactivity, or lack of ductility.

The maximum achievable jet velocity is roughly two and a half times the speed of sound. The speed can reach 10 km/s, peaking some 40 microseconds after detonation; the cone tip is subjected to acceleration of about 25 million g. The jet tail reaches about 2–5 km/s. The pressure between the jet tip and the target can reach one terapascal. The immense pressure makes the metal flow like a liquid, though x-ray diffraction has shown the metal stays solid!

For optimal penetration, a high explosive having a high detonation velocity and pressure has been chosen. The explosive used in high performance anti-armour warheads is HMX (octogen). It is normally compounded with a few percent of some type of plastic explosive binder, such as in the polymer-bonded explosive (PBX) LX-14, to make it less shock sensitive.

A **Waveshaper** can be incorporated in the WL. This is a disc or cylindrical block of an inert material inserted within the explosive to alter the shape of the detonation wave to increase penetration performance or to save space; a shorter charge can achieve the same performance as a longer one without a waveshaper and hence the agility or range of the missile can be tuned.

The Weapon Lab

The Evochron Military-Industrial complex has finally come to acknowledge the major role mercenaries play in both policing the established star systems and acting as a military reserve force. This should have been apparent when mercenaries flocked to serve in the Vonari wars, but Naval High Command was concerned that such an effective combat force could be a major threat to the political status quo. Military grade weapons and equipment were not made publicly available. Going one stage further, only a carefully chosen set of weapons were sold to the average mercenary. The result was that military combat ships are superior in combat.

The result was inevitable - many mercenaries joined the Naval Reserves, doing Navy missions and earning the right to fly military frames. It is rare for a mercenary today not to have dual rank - military and civilian. A positive outcome has been a growing trust and mutual respect between mercenaries and the Naval High Command.

Never reticent about finding new ways to create profit, the Military-Industrial Complex jumped at the chance to offer better spec weapons to mercenaries when the Navies relaxed their weapons prohibition. It quickly became apparent that mercenaries did not necessarily want off the peg military weapons (effectively better versions of their regular weapons) but would jump at the chance to custom design their own ideas of effective cannon and missiles. The Navy and Industry had many internal discussions over the cost-benefit of making (self-contained) weapons design and fabrication technology publically available. The industrialists finally persuaded the Navy to subsidise the development, arguing that the creation of a motivated and happy, well equipped reserve military force greatly outweighed the financial cost of making the facilities affordable for the average mercenary!

The result is the **Sapphire Industries Weapon Lab!** It is available at every trade station and city throughout the Evoverse. The costs per weapon are actually very low - the only real commitment expected from the mercenary is to provide some basic resources required for the fabrication.

There is a learning curve involved since several interdependent aspects of weapon design can be altered, each having an impact on the performance of the weapons being created. However, early tests with a selected set of pilots quickly showed that the outcomes possible were more than worth the effort!

The outcome is a happy Navy with a better equipped reserve force to meet any future Vonari threat, a happy weapons industry with a secure earnings stream and a happy group of mercenaries who can create weapons that are effective in their own idiosyncratic combat methodology! **win - win - win!!!**

Using the Weapon Lab I - Raw Materials needed

Each type and class of weapon that you want to create in the Weapon Lab requires you to provide certain raw materials. These can be in your cargo bays or stored in a hangar.

Source: SeeJay

WEAPON	ELECTRICAL	METALS	MACHINERY	FUSION
Plasma Cannon	10	13	7	1
Metal Projectile Cannon	15	16	12	2
Rail Cannon	20	19	17	3
Fusion Cannon	25	22	22	4

Refractor Beam	5	6	3	1
Metal Vapour Beam	7	8	6	2
Coil Beam	10	9	8	3
Neodymium Beam	12	11	11	4
Fusion Beam	15	12	13	6

Impact Missile	1	2	2	-
Reactive Missile	2	3	3	-
Fragmentation Missile	2	4	3	-
Shaped Core Missile	3	5	4	-
Compound Core Missile	3	6	4	-



electrical parts



machine parts



metal alloys



fusion units

Using the Weapon Lab II - Interface

When you enter the WL you are presented with a design screen beginning with the particle cannon. You can change weapon type and change class within each type - once you have reached your chosen screen you can begin to experiment with the effects of the input parameters

For *cannon*:

Emitter Output determines how much energy is imparted to each round and hence yield

Actuator Speed determines the rate that which energy is fed into the cannon and hence influences the rate of fire

Capacitor Reserve allows a greater store of immediately available energy and hence influences yield and range

Heatsinks are required to help dissipate the heat generated as the weapon is fired and hence prolong the overall firing time

You will find that each input parameter has multiple effects, trading off one improvement for another or increasing the 'costs' in terms of energy or heat production





The characteristics of the cannon you create are pretty much self evident;

Yield determines the damage inflicted per round that hits

Heat production is undesirable as it reduces the time the cannon can fire for. Once the cannon reaches a temperature where damage could occur the AI system shuts it off until it cools enough to fire again - this results in a greatly reduced rate of fire

Energy measures the rate at which your ship's weapon energy supplies are depleted

Range and **Rate of Fire** are self evident

For *missiles*:

Detonator Capacity determines the explosive yield of your missile

Thruster Power influences agility and speed

Perhaps surprisingly it is the **Guidance System** installed that influences the range

The **Casing Armour** determines the CM resistance of the missile



The characteristics of the missile you create are pretty much self evident;

Yield determines the damage inflicted by the warhead

Agility and Speed allow the missile to stay locked on to the target and to reach it quickly before the target can respond with cannon fire and CM's

Range is self evident

CM Resistance reduces the chances of the missiles being destroyed by the energy emitted by CM flares

The information offered above is summarised in the Table below

The Weapon Lab is simple to use but complex to analyse. To get you started the following table (Source DaveK) gives an overview of the effect of the various input sliders

Data to maximise parameters

Particle Cannon	Emitter Output	Actuator Speed	Capacitor Reserve	Heatsinks
Yield	max+	min+	max+	max
Energy	max	N/A	max	N/A
Range	N/A	N/A	max+	N/A
Rate	min	max+	min	max+

Beam Cannon	Emitter Output	Capacitor Reserve	Heatsinks
Yield	max	max	N/A
Energy	max	max	N/A

Missiles	Detonator Capacity	Thruster Power	Guidance System	Casing Armour
Yield	max+	min	max+	min+
Agility / Speed	min+	max+	max+	N/A
Range	N/A	N/A	max+	N/A
CM Resistance	max	min+	max	max

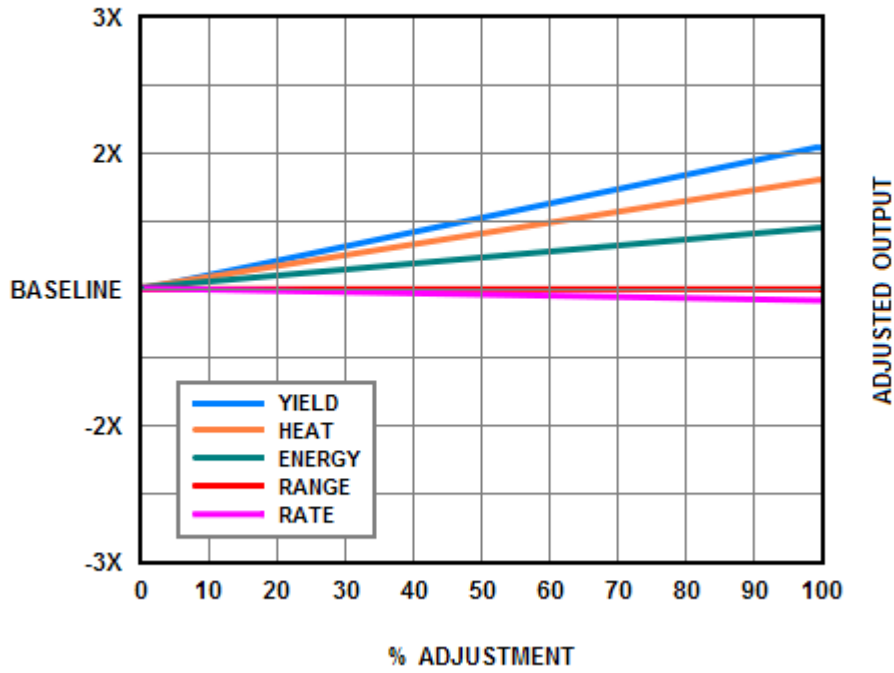
'N/A' means the parameter has no effect

'+' means the parameter has a big effect

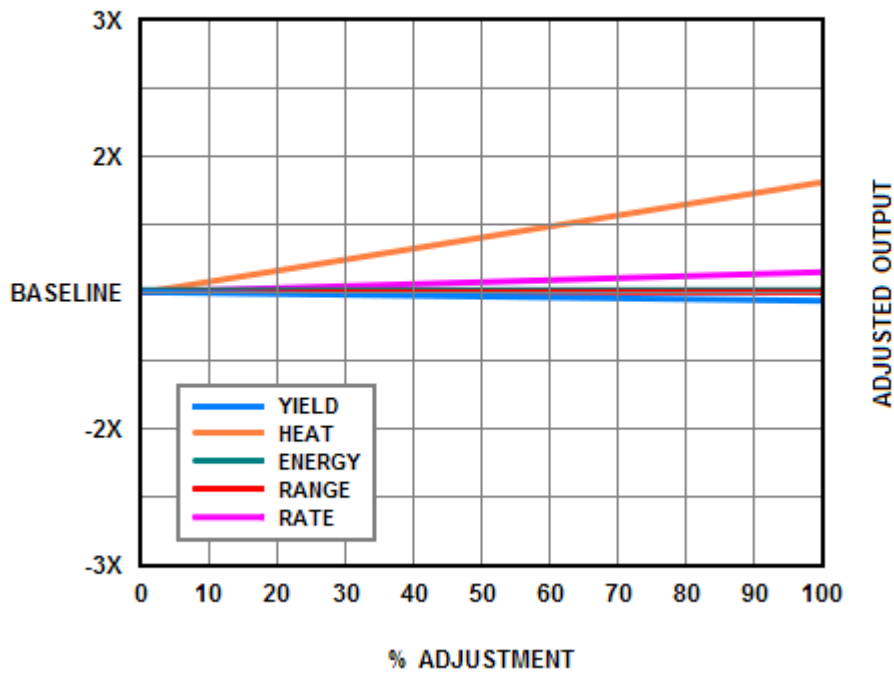
Maarschalk has created a comprehensive spreadsheet of the data for the effect of each slider on each type and class of weapon! The raw data is given in Tables below. It can be processed as you wish in a spreadsheet and it is easy to generate graphs in a variety of formats to analyse the data in ways that will help you! The following pages specify some basic data for the effect of the sliders in graphical form to show how much easier it is to understand the data.

(Graph Source: **Marvin**): The following graphs show the effect of each of the input parameters on the output characteristics of the cannon produced and demonstrate the power of graphically presenting the data.

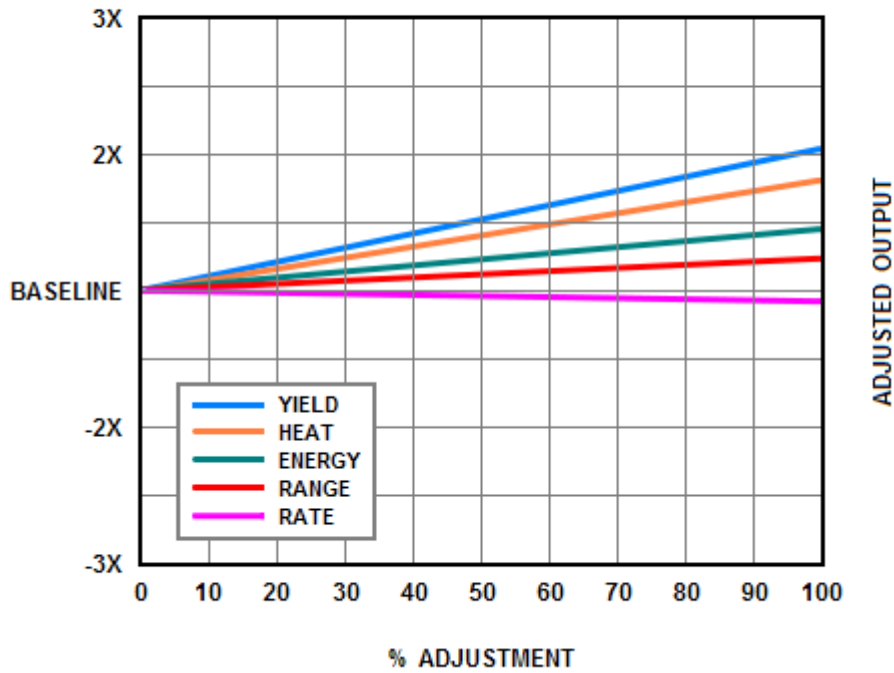
EMITTER OUTPUT



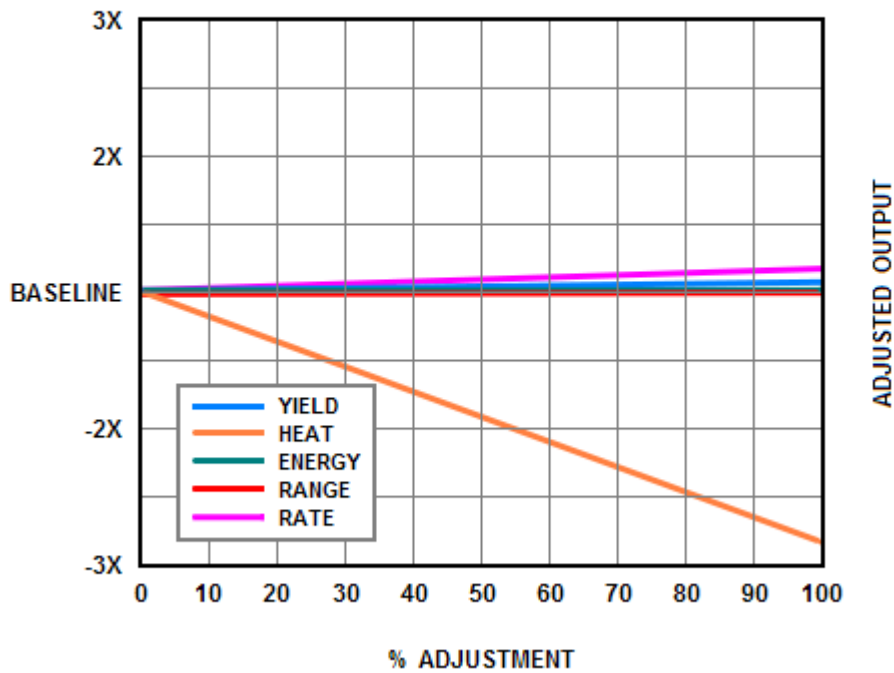
ACTUATOR SPEED



CAPACITOR RESERVE



HEATSINKS



In reality there isn't a simple recipe to produce the 'best' cannon or the 'best' missile. It will inevitably depend on your view, your combat technique and your particular missions. The only way to create your 'perfect' weapon is to experiment!

Particle Cannon Table 1: Slider settings

Plasma	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Emitter Output	100	0	100	100	100	0	100	100	0	0	100	0	0	0	100	0
Actuator Speed	100	100	0	100	100	0	0	100	100	100	0	0	0	100	0	0
Capacitor Reserve	100	100	100	0	100	100	0	0	100	0	100	0	100	0	0	0
Heat Sinks	100	100	100	100	0	100	100	0	0	100	0	100	0	0	0	0
Metal Projectile	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Emitter Output	100	0	100	100	100	0	100	100	0	0	100	0	0	0	100	0
Actuator Speed	100	100	0	100	100	0	0	100	100	100	0	0	0	100	0	0
Capacitor Reserve	100	100	100	0	100	100	0	0	100	0	100	0	100	0	0	0
Heat Sinks	100	100	100	100	0	100	100	0	0	100	0	100	0	0	0	0
Railgun	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Emitter Output	100	0	100	100	100	0	100	100	0	0	100	0	0	0	100	0
Actuator Speed	100	100	0	100	100	0	0	100	100	100	0	0	0	100	0	0
Capacitor Reserve	100	100	100	0	100	100	0	0	100	0	100	0	100	0	0	0
Heat Sinks	100	100	100	100	0	100	100	0	0	100	0	100	0	0	0	0
Fusion	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Emitter Output	100	0	100	100	100	0	100	100	0	0	100	0	0	0	100	0
Actuator Speed	100	100	0	100	100	0	0	100	100	100	0	0	0	100	0	0
Capacitor Reserve	100	100	100	0	100	100	0	0	100	0	100	0	100	0	0	0
Heat Sinks	100	100	100	100	0	100	100	0	0	100	0	100	0	0	0	0

Use the numbers **1-16** above of the Particle Cannons, to find the effect of the Slider Settings Tables, with the corresponding numbers **1-16** in the Table2 below!

Example1: **PLASMA** under **1**, all Sliders are at 100%, Now look at the right of **#1** under **PLASMA** in Table 2 and you'll see the results:
YIELD=67, HEAT =164, ENERGY =16, RANGE =760, RATE RPM =417/12

Example2: **PLASMA** under **16**, all Sliders are at 0%, Now look at the right of **#16** under **PLASMA** in Table 2 and you'll see the results:
YIELD=13, HEAT =54, ENERGY/S=11, RANGE metres =640, RATE RPM =352

Particle Cannon: Table 2 - Outputs

Plasma	Yield	Heat	Energy	Range (m)	Rate (rpm)
1	67	164	16	760	417/12
2	40	114	13	760	440/9
3	70	114	16	760	365/19
4	40	114	13	640	440/9
5	65	204	16	760	357/20
6	42	64	13	760	390/16
7	42	64	13	640	390/16
8	38	154	13	640	380/17
9	38	154	13	760	380/17
10	12	64	11	640	465/5
11	68	154	16	760	305/28
12	15	14	11	640	412/12
13	40	104	13	760	327/24
14	10	104	11	640	405/14
15	40	104	13	640	327/24
16	13	54	11	640	352/21

Metal Projectile	Yield	Heat	Energy	Range (m)	Rate (rpm)
1	72	168	17	770	407
2	45	118	14	770	432
3	75	118	17	770	355
4	45	118	14	650	432
5	70	208	17	770	347
6	47	68	14	770	380
7	47	68	14	650	380
8	43	158	14	650	370
9	43	158	14	770	370
10	17	68	11	650	457
11	73	158	17	770	295
12	20	18	11	650	402
13	45	108	14	770	320
14	15	108	11	650	395
15	45	108	14	650	320
16	18	58	11	650	342

Key
 YIELD= amount of potential damage that can be inflicted per round
 HEAT = amount of heat generated per second
 ENERGY = amount of energy used per second
 RANGE = weapons effective range in metres
 RATE = rate of fire - rounds per minute (RPM)

continued

Particle Cannon: Table 2 - Outputs continued

Railgun	Yield	Heat	Energy	Range (m)	Rate (rpm)
1	77	172	21	780	400
2	49	122	16	780	422
3	79	122	21	780	347
4	49	122	16	660	422
5	75	212	21	780	337
6	52	72	16	780	370
7	52	72	16	660	370
8	47	162	16	660	362
9	47	162	16	780	362
10	22	72	11	680	447
11	77	162	21	780	287
12	24	22	11	660	395
13	50	112	16	780	310
14	20	112	11	660	385
15	50	112	16	660	310
16	22	62	11	660	335

Fusion	Yield	Heat	Energy	Range (m)	Rate (rpm)
1	82	176	31	790	390
2	54	126	21	790	415
3	84	126	31	790	337
4	54	126	21	670	415
5	80	216	31	790	327
6	52	166	21	670	352
7	57	76	21	670	362
8	52	166	21	670	352
9	52	166	21	790	352
10	27	76	11	670	437
11	82	166	31	790	277
12	29	26	11	670	385
13	55	116	21	790	300
14	25	116	11	670	377
15	55	116	21	670	300
16	27	66	11	670	325

Key

YIELD= amount of potential damage that can be inflicted per round
 HEAT = amount of heat generated per second
 ENERGY = amount of energy used per second
 RANGE = weapons effective range in metres
 RATE = rate of fire - rounds per minute (RPM)

Beam Cannon: Table 1: Slider settings

Refractor-Laser	1	2	3	4	5	6	7	8
Emitter Output	100	0	100	0	100	0	100	0
Capacitor Reserve	100	100	0	0	100	100	0	0
Heat Sinks	100	100	100	100	0	0	0	0
Metal-Vapor Laser	1	2	3	4	5	6	7	8
Emitter Output	100	0	100	0	100	0	100	0
Capacitor Reserve	100	100	0	0	100	100	0	0
Heat Sinks	100	100	100	100	0	0	0	0
Coil-Laser	1	2	3	4	5	6	7	8
Emitter Output	100	0	100	0	100	0	100	0
Capacitor Reserve	100	100	0	0	100	100	0	0
Heat Sinks	100	100	100	100	0	0	0	0
Neodymium-Laser	1	2	3	4	5	6	7	8
Emitter Output	100	0	100	0	100	0	100	0
Capacitor Reserve	100	100	0	0	100	100	0	0
Heat Sinks	100	100	100	100	0	0	0	0
Fusion-Laser	1	2	3	4	5	6	7	8
Emitter Output	100	0	100	0	100	0	100	0
Capacitor Reserve	100	100	0	0	100	100	0	0
Heat Sinks	100	100	100	100	0	0	0	0

Use the numbers **1-8** above of the Beam Cannons, to find the effect of the Slider Settings Tables, with the corresponding numbers **1-8** in Table 2 below

Example1: **REFRACTOR-LASER** under **1**, all Sliders are at 100%, Now look at the right of **#1** under **REFRACTOR-LASER** in Table 2 and you'll see the results: **YIELD=47, HEAT =122, ENERGY =10**

Example2: **REFRACTOR-LASER** under **8**, all Sliders are at 0%, Now look at the right of **#8** under **REFRACTOR-LASER** in Table 2 and you'll see the results: **YIELD=19, HEAT =42, ENERGY =8**

Beam Cannon: Table 2 - Outputs

Beam Cannon: Table 1: Slider settings continued

Refractor-Laser	Yield	Heat	Energy
1	47	122	10
2	33	92	9
3	35	62	9
4	20	32	8
5	47	132	10
6	31	102	9
7	35	72	9
8	19	42	8

Metal-Vapour Laser	Yield	Heat	Energy
1	51	124	11
2	37	94	9
3	38	64	9
4	24	34	8
5	51	134	11
6	35	104	9
7	38	74	9
8	22	44	8

Coil-Laser	Yield	Heat	Energy
1	55	126	12
2	40	96	10
3	42	66	10
4	28	36	8
5	55	136	12
6	38	106	10
7	42	76	10
8	26	46	8

Neodymium-Laser	Yield	Heat	Energy
1	58	128	14
2	44	98	11
3	46	68	11
4	31	38	8
5	58	138	14
6	42	108	11
7	46	78	11
8	29	48	8

Fusion-Laser	Yield	Heat	Energy
1	62	130	20
2	47	100	14
3	49	70	14
4	35	40	8
5	62	140	20
6	46	110	14
7	49	80	14
8	33	50	8

Key
 YIELD= amount of potential damage that can be inflicted per second
 HEAT = amount of heat generated per second
 ENERGY = amount of energy used per second
 RANGE = linked to particle cannon
 RATE = continuous

Missiles: Table 1 - Slider Settings

Impact	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Detonator Capacity	100	0	100	100	100	0	100	100	0	0	100	0	0	0	100	0
Thruster Power	100	100	0	100	100	0	0	100	100	100	0	0	0	100	0	0
Guidance System	100	100	100	0	100	100	0	0	100	0	100	0	100	0	0	0
Casing Armour	100	100	100	100	0	100	100	0	0	100	0	100	0	0	0	0
Reactive	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Detonator Capacity	100	0	100	100	100	0	100	100	0	0	100	0	0	0	100	0
Thruster Power	100	100	0	100	100	0	0	100	100	100	0	0	0	100	0	0
Guidance System	100	100	100	0	100	100	0	0	100	0	100	0	100	0	0	0
Casing Armour	100	100	100	100	0	100	100	0	0	100	0	100	0	0	0	0
Fragmentation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Detonator Capacity	100	0	100	100	100	0	100	100	0	0	100	0	0	0	100	0
Thruster Power	100	100	0	100	100	0	0	100	100	100	0	0	0	100	0	0
Guidance System	100	100	100	0	100	100	0	0	100	0	100	0	100	0	0	0
Casing Armour	100	100	100	100	0	100	100	0	0	100	0	100	0	0	0	0
Shaped Charge	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Detonator Capacity	100	0	100	100	100	0	100	100	0	0	100	0	0	0	100	0
Thruster Power	100	100	0	100	100	0	0	100	100	100	0	0	0	100	0	0
Guidance System	100	100	100	0	100	100	0	0	100	0	100	0	100	0	0	0
Casing Armour	100	100	100	100	0	100	100	0	0	100	0	100	0	0	0	0
Compound Core	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Detonator Capacity	100	0	100	100	100	0	100	100	0	0	100	0	0	0	100	0
Thruster Power	100	100	0	100	100	0	0	100	100	100	0	0	0	100	0	0
Guidance System	100	100	100	0	100	100	0	0	100	0	100	0	100	0	0	0
Casing Armour	100	100	100	100	0	100	100	0	0	100	0	100	0	0	0	0

Use the numbers **1-16** above of the particular Missile Type, to find the effect of the Slider Settings Tables, with the corresponding numbers **1-16** in the Table 2

Missiles: Table 2 - Outputs

Impact	Yield	Agility/speed	Range (m)	CM Resistance
1	1512/37Y	85 DM/S	3400	65%
2	1347/26Y	95 Dm/s	3800	60%
3	1535/39Y	73 Dm/s	2920	80%
4	1385/29Y	73 Dm/s	2920	61%
5	1775/55Y	85 Dm/s	3400	42%
6	1370/28Y	83 Dm/s	3320	76%
7	1400/30Y	60 Dm/s	2400	77%
8	1647/46Y	73 Dm/s	2920	38%
9	1610/44Y	95 Dm/s	3800	37%
10	1227/19Y	83 Dm/s	3320	57%
11	1797/56Y	73 Dm/s	2920	57%
12	1242/20Y	70 Dm/s	2800	72%
13	1632/45Y	83 Dm/s	3320	53%
14	1482/35Y	83 Dm/s	3320	34%
15	1662/47Y	60 Dm/s	2400	54%
16	1497/36Y	70 Dm/s	2800	49%

Reactive	Yield	Agility/speed	Range (m)	CM Resistance
1	1580/42Y	83 Dm/s	3320	66%
2	1415/31Y	93 Dm/s	3720	62%
3	1595/43Y	71 Dm/s	2840	82%
4	1445/33Y	71 Dm/s	2840	63%
5	1842/59Y	83 Dm/s	3320	43%
6	1430/32Y	81 Dm/s	3240	77%
7	1467/34Y	58 Dm/s	2320	78%
8	1707/50Y	71 Dm/s	2840	40%
9	1677/48Y	93 Dm/s	3720	39%
10	1287/23Y	81 Dm/s	3240	59%
11	1857/60Y	71 Dm/s	2840	59%
12	1310/24Y	68 Dm/s	2720	74%
13	1692/49Y	81 Dm/s	3240	54%
14	1542/39Y	81 Dm/s	3240	35%
15	1730/52Y	58 Dm/s	2320	55%
16	1565/41Y	68 Dm/s	2720	51%

continued

Key

YIELD= amount of potential damage that can be inflicted

AGILITY/SPEED= Distance in Decametres per second travelled

RANGE = weapons effective range in metres

CM RESISTANCE=Percentage of resistance to Countermeasures

Example1: **IMPACT** under **1**, all Sliders are at 100%, Now look at the right of #**1** under **IMPACT** in Table2 for results:
YIELD=1512/37Y, AGILITY/SPEED=85 D/s, RANGE=3400 M, CM RESISTANCE=65%

Example2: **IMPACT** under **16**, all Sliders are at 0%, Now look at the right of #**16** under **IMPACT** in Table 2 for results:
YIELD=1497/36Y, AGILITY/SPEED=70 D/s, RANGE M=2800 m, CM RESISTANCE=49%

Missiles: Table 2 - Outputs - continued

Fragmentation	Yield	Agility/speed	Range (m)	CM Resistance
1	1640/46Y	81 Dm/s	3240	68%
2	1475/35Y	91 Dm/s	3640	64%
3	1662/47Y	69 Dm/s	2760	84%
4	1512/37Y	69 Dm/s	2760	65%
5	1902/63Y	81 Dm/s	3240	45%
6	1497/36Y	79 Dm/s	3160	79%
7	1527/38Y	56 Dm/s	2240	80%
8	1775/55Y	69 Dm/s	2760	42%
9	1737/52Y	91 Dm/s	3640	41%
10	1347/26Y	79 Dm/s	3160	60%
11	1925/65Y	69 Dm/s	2760	61%
12	1362/27Y	66 Dm/s	2640	76%
13	1760/54Y	79Dm/s	3160	56%
14	1610/44Y	79 Dm/s	3160	37%
15	1790/56Y	56 Dm/s	2240	57%
16	1625/45Y	66 Dm/s	2640	53%

Shaped Charge	Yield	Agility/speed	Range (m)	CM Resistance
1	1707/50Y	79 Dm/s	3160	70%
2	1542/39Y	89 Dm/s	3560	65%
3	1722/51Y	67 Dm/s	2680	85%
4	1572/41Y	67 Dm/s	2680	66%
5	1970/68Y	79 Dm/s	3160	47%
6	1557/40Y	77 Dm/s	3080	81%
7	1595/43Y	54 Dm/s	2160	82%
8	1835/59Y	67 Dm/s	2680	43%
9	1805/57Y	89 Dm/s	3560	42%
10	1407/30Y	77 Dm/s	3080	62%
11	1985/69Y	67 Dm/s	2680	62%
12	1430/32Y	64 Dm/s	2560	77%
13	1820/58Y	77 Dm/s	3080	58%
14	1670/48Y	77 Dm/s	3080	39%
15	1857/60Y	54 Dm/s	2160	59%
16	1692/49Y	64 Dm/s	2560	54%

continued

Key
 YIELD= amount of potential damage that can be inflicted
 AGILITY/SPEED= Distance in Decametres per second travelled
 RANGE = weapons effective range in metres
 CM RESISTANCE=Percentage of resistance to Countermeasures

Missiles: Table 2 - Outputs - continued

Compound Core	Yield	Agility/speed	Range (m)	CM Resistance
1	1767/54Y	77 Dm/s	3080	71%
2	1602/43Y	87 Dm/s	3480	67%
3	1790/56Y	65 Dm/s	2600	87%
4	1640/46Y	65 Dm/s	2600	68%
5	2030/72Y	77 Dm/s	3080	48%
6	1625/45Y	75 Dm/s	3000	83%
7	1655/47Y	52 Dm/s	2080	83%
8	1902/63Y	65 Dm/s	2600	45%
9	1865/61Y	87 Dm/s	3480	44%
10	1475/35Y	75 Dm/s	3000	64%
11	2052/73Y	65 Dm/s	2600	64%
12	1490/36Y	62 Dm/s	2480	79%
13	1887/62Y	75 Dm/s	3000	60%
14	1773/52Y	75 Dm/s	3000	41%
15	1917/64Y	52 Dm/s	2080	60%
16	1752/53Y	62 Dm/s	2480	56%

<p>Key</p> <p>YIELD= amount of potential damage that can be inflicted</p> <p>AGILITY/SPEED= Distance in Decametres per second travelled</p> <p>RANGE = weapons effective range in metres</p> <p>CM RESISTANCE=Percentage of resistance to Countermeasures</p>
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Other Weapons Technology

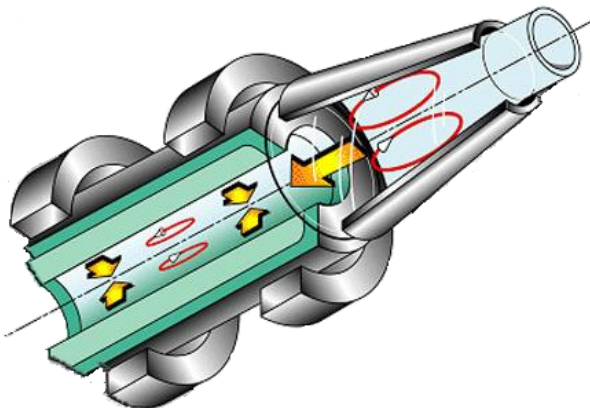
Background: [nanotechnology](#) + Engineering

Latest Breaking Developments!!

1: Navy spokesmen are denying reports that a member of the crew of a Colonial Pilot Naval Reserve vessel has developed a radical new modification to railgun technology. However, the authors of this guide have seen specs and reports of the performance of such a modified railgun. In the following reports the name of the developer and other personnel have been redacted. **The Technical Report reads . . .**

"Shields operate by creating a layer, or layers, of *phase shifting polarised* energetic distortion containing a high concentration of graviton particles around the object to be protected."

Xxxx's rail gun modification opens a hole in the shield matrix just large enough to allow the slug to pass through. The 'hole punch' is attached to the front end of the railgun barrel (think silencer on a pistol) and projects the cylindrical distortion field beam. It is basically a miniaturized solid state phase polarization analyzer and projector.



It analyses and matches the hostile's shield phase cycling pattern and then, as the slug passes through the barrel it projects a narrow beam of

phase shifted field distortion along the trajectory of but ahead of the slug. The field distortion is 180 degrees out of phase with the shield. The destructive interference of the out of phase fields collapses the shield matrix field and disperses the graviton particles.

The result is an instantaneous albeit momentary 'hole' in the shield that the slug can pass through.

There is two drawbacks however. First the range is significantly reduced because of the limit of the field matrix phase analyser. Second, because of the time taken to analyse the phase cycle of the shield, project the beam and collapse the field, the power output to the magnetic coils is reduced so they are unable to accelerate the slug as much as a standard issue railgun. The result is that the slugs hit with less kinetic energy, typically requiring two hits to completely penetrate a standard reinforced hull, but sufficient to severely damage it in the first hit.

This top secret development is obviously *very* expensive and with its limited range , it is a sniper's weapon; more - 'one shot one kill' - than the hail storm of a typical Point Defence multi-turret, rapid fire system and hence is more likely to be used in SecOps missions.

End of report

An observers report of a test firing reads . . .

Xxxxx requested the technician to turn on the shielding in the test chamber. The technician did so and the shield array in the test chamber surrounded a small square of armour plating.

Xxxxx adjusted the weapon's targeting computer. At this point the railgun became active, swivelling on its mounts as it calibrated and locked onto the armour plate.

"Start recording," Xxxxx ordered and the technician started an ultra-highspeed multi-spectral video recording camera

"X-1 Cannon test fire in 3...2...1...Fire!"

A whining sound, increasing in volume and rising in pitch could be hear as energy built up along the magnetic accelerator arrays. There was a bright flash that travelled at very high speed down the length of the cannon's barrel. An imperceptible amount of time later the chunk of armour was flung across the test chamber.

After powering down the cannon and deactivating the shield array, the technician entered the test chamber and retrieved the shard of armour. There was no obvious hole but what was once a perfect square was now dented to the point that it looked more like a cup.

The technician reported that the railgun slug had not penetrated the plate and asked if the test should be recorded as a 'fail'

Xxxxx did not concur. "That armour is designed to withstand repeated strikes from a gun like this. The point if this test is that the shield should have stopped it cold - it didn't"

Technician: "I didn't see a shield flash, the slug didn't touch it at all did it?"

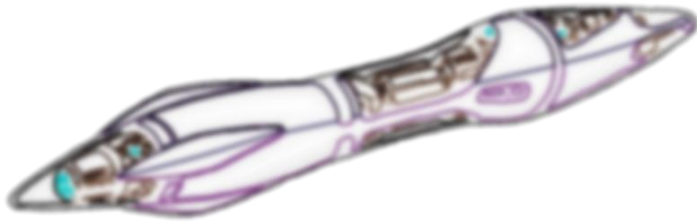
The video was replayed on the large monitor in the control room. The playback was at slowed speed from the time immediately before the railgun slug impacted the shield.

A hole opened in the shield the exact size of the slug and the slug passed through.

End of Report

If the range of the weapon can be increased, the Navy will possess an awesome capital ship cannon capable of taking down any vessel in a very short time period. It would turn the balance of the Human - Vonari conflict.

2: A much more worrying development is an alleged missile developed by a unspecified organisation, reportedly of less than legal status. Authorities across Evochron deny any knowledge of the development, claiming that it is unfounded rumour mongering. The intensity of the denial strikes us as suspicious!



However, despite the denials there are reports from several of the less populated systems of well armoured, shielded ships equipped top spec shields and weapons disappearing without warning. Leaked reports the authors have seen illustrate a (blurred) image of part of the design specification.

The report accompanying the illustration suggest that this new missile system employs the negative energy locked up in a strange material in a wormhole's 'mouth' for its destructive power. The missile locks onto its target and is fired. It detects when it is within damage range of the target and instead of simply detonating, it uses similar wormhole generation technology as the Fulcrum jump drive employs to create a micro wormhole between itself and a point closely adjacent to the target ship.

Whereas the Fulcrum Jump Drive very precisely controls the motion of a ship as it is attracted towards the wormhole mouth, controlling the rate of acceleration and hence preventing it from being damaged before it has attained a great enough velocity to enter the wormhole safely, the missile system doesn't!

The result is that there is an awesomely rapid acceleration of the target ship towards the wormhole mouth, which virtually overwhelms both the Inertial Damping System and the Structural Integrity Field Generators of the ship. The outcome is catastrophic damage to the ship's hull and innards. The completion of the missiles 'detonation' sequence comes when the ship has just entered the wormhole mouth. At this point the frame is outside normal space-time but not yet inside the relatively stable wormhole tunnel. The ship would be jumped to the other end of the wormhole if the wormhole tunnel integrity was maintained. However, the missile generator collapses the wormhole resulting in a significant portion of the ships mass being converted into pure energy; this reduces the already damaged frame to a dense but rapidly expanding plasma cloud.

The collapse of the wormhole results in a feedback energy pulse that destroys the generator - the missile is obviously destroyed in the resulting 'explosion'.

If they can ever overcome the reported feedback issue this weapon could effectively make a capital ship invulnerable by installing the generator technology into cannon turrets. The raw energy release of this technology is capable of taking down ships of a far greater size, mass, armour and shield strength than any other missile of a similar size and range.

Gun Turret employs another pilot who transfers from his ship (which remains parked in space) creating a gun turret station on your ship and from there operates a twin barrelled gimballed particle cannon of that was fitted to his/her/its ship.



If the ship is destroyed the turret gunner station is automatically ejected and transfers back to his own ship. As a result of this if the turreted ship moves out of the sector the auto eject system is activated and the turret gunner leaves



The turret operator controls offer a limited HUD and data readout. The teaming up of a defensive gunner who can watch your back and increase your attack fire power has proved to be a popular and powerful addition to ships in combat. It also provides a good learning environment for new pilots to get practical combat experience with experienced pilots.

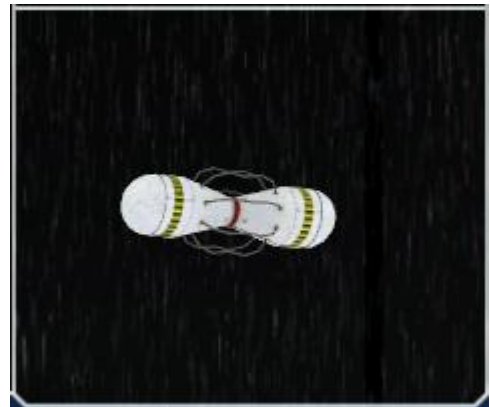
The Proximity Mine is a relatively low yield FT system minus the drive unit.



It is detonated by emr signal from your ship which shuts down the magnetic containment field (bottle) and allows matter and antimatter to mix

The Station Detonator mechanism is top secret and the technology is highly protected (see Excalibur Missile Pack above).

It targets the fabric of a constructed station as well as disrupting the structural integrity field. Rather than using explosive technology, the SD folds the fabric of space-time within the station, disrupting the structural integrity field, disassembling the matter and shifting it into the space through which a WH would normally thread. The result is that the station disappears (though there is some residual energy production visible as a flame ball).



Station Detonators were originally created to prevent station overcrowding - allowing legal authorities to clear redundant stations quickly and cleanly. Unsurprisingly a black market developed as mercenary clans fought for possession of systems. Bowing to the inevitable, local authorities started to sell SD's on the open market, officially to be able to control their sale but also, as many suspect, because it is so profitable!



Ships in the vicinity are not damaged, though it is advisable to have a fully charged shield active if you remain in the vicinity!

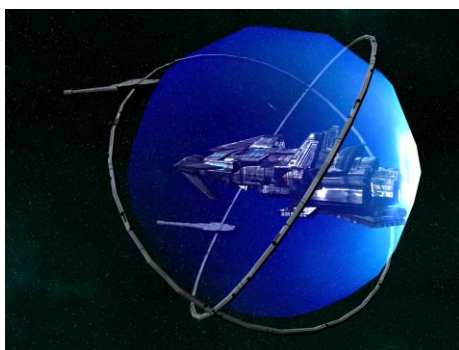
The quoted yield is actually the equivalent explosive yield it would require to physically blow up the massive station. ('massive' is used in the sense of containing megatonnes of matter). It is obvious why the mechanism is both secret and extremely will protected.

Section 3: Defence

Shield Matrix Field Technology

Background: [Relativity](#) + [Quantum Theory](#)

Shields are designed to stop emr beam and mass effect weapons as well as missile explosions. A strong electromagnetic field is used to deflect particle weapons. As well as defence against weapon fire this part of the shield prevents damage of high speed travel through space (dust - micrometeorites etc) The second part of the shield field matrix employs a modification of the space-time field in a 3D arc centred on the shield projector. This employs graviton particles. The two effects are calibrated so that they are contiguous (both in exactly the same place)



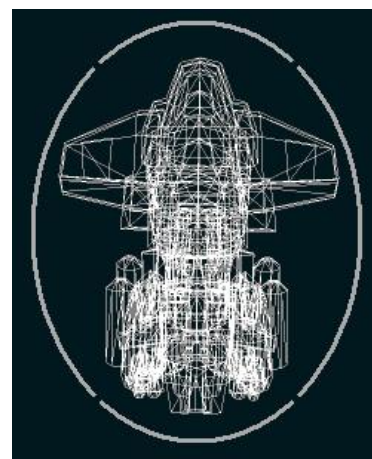
Impacts on the shield field matrix causes Cerenkov radiation (see above) to be released, often perceived as a flash of blue which 'lights up' the shield, rendering it briefly visible.

To an observer it appears that the intruding object, plasma packet or mass slug bounces off the shields - in fact the gravitational spatial distortion becomes so great that the path of the object is radically altered.

Shields operate by creating a layer, or layers, of energetic distortion containing a high concentration of graviton particles around the object to be protected. A graviton is the quantum exchange particle of gravity, much as a photon is a particle of light and is the exchange particle for electromagnetic force.

Capital ships, being so large, employ a network of 'grid' localised projector emitters laid out on the ship's surface. Shields are obviously essential equipment on all ships.

On capital ships, the shield is created in six sections; fore & aft and starboard & port and dorsal & ventral. This is commonly called; front-rear / left-right / top-bottom. Smaller ships like the ones used by Mercenaries have four shield generators which wrap around the ship; fore & aft and starboard & port. In Mercenary ships the shield energies are emitted from Neither matter nor highly-concentrated energy can normally penetrate a shield. When shields are energized at a high level, most matter or energy that comes into contact with the shields will be harmlessly deflected away. This is important in combat, as shields are essential for hull protection. If the shields don't fail, hull damage is negligible.



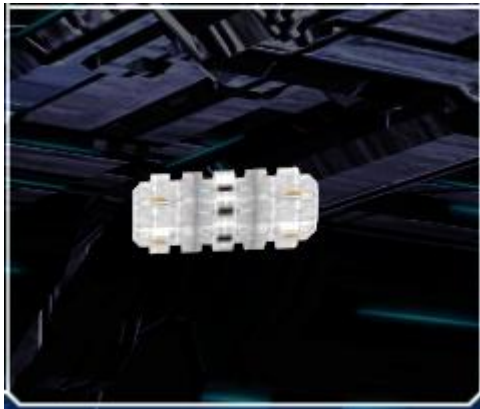
Continuous or extremely powerful energy discharges can progressively dissipate the integrity of a shield to the point of failure. Shield capacities varied according to many variables, mainly the power available from the capacitor storage system and the shield energy generation modules. Universal calculations of how much damage a shield can take are difficult to make.

Therefore, during combat pilots need to continually monitor their shield strength, usually as a percentage of total effectiveness, with 100% meaning that the shields are at full capacity, and lower percentage scores indicating weaker shield conditions. Mercenary ships are fitted with a bar chart of the four shield modules. Most pilots also fit a HUD display that shows amber/yellow when some shield damage is done and red immediately prior to shield failure. The info is displayed around the central tactical HUD display and hence can be seen without having to look away from the main cockpit/HUD view.

In combat some sections of the shield grid are subject to more damage than other sections, and hence can be reinforced by shunting additional power reserves from fully charged shield sections. Shields are said to be 'holding' if damage is not sufficient enough to compromise ship safety and allow hull damage; if the shields are 'buckling' or 'failing,' then a total loss of shield protection is imminent.

The central HUD shield strength display can also flash to indicate the direction of incoming fire - useful extra information in a combat situation.

Shield Boosters are the power storage part of the shield system.



They are a series of capacitors that store energy for each shield array. A single cell provides basic storage capacity for the shield system. It is possible to fit up to five of these booster cells

The Shield Array Recharger works as an energy transfer system and provides additional energy to shield arrays that become critically depleted.

This is done by routing power from the main energy system to the shield system. For additional defensive capabilities, particularly for heavy transport ships with fewer offensive options, this can be a very effective device. Since it is competing for main system energy there is obviously a limit to the amount and duration of energy transfer possible.



Shield Packs provide a significant charge boost for a ship's shield system..



They raise arrays power levels by about 50%.

Thus a shield array reduced to 50% would be boosted to 75% using one shield pack and to 100% using two shield packs consecutively.

Defensive Equipment

The Anti-Missile System is a semi-effective beam weapon that targets an inbound missile as it approaches your ship. It fires an (invisible) beam of X-ray frequency laser (coherent) energy at the missile to heat it up and cause it to explode before it reaches its target. Since the system is automated it doesn't emit need to emit any visible light that could act as a tracer and an aid to manual sighting.

If you turn away from the incoming missile, you give the system more time to be effective and hit the missile with more energy before it hits your ship. Also, since this system operates independently of the countermeasure system, you can also bombard the missile with CM energy for additional protection, which is particularly effective against multiple inbound missiles.

There are major issues with energy conflicts between AMS and fitted stealth generators (as opposed to one-shot stealth packs) making them incompatible



The Automatic CM Launcher does exactly what the name implies. It will begin launching CM's as soon as a missile approaches effective countermeasure range.



It can be wasteful with CM's, so pilots should train to use this system most effectively to minimize CM loss. A relatively unsophisticated (and hence affordable) AI core modules tracks incoming missiles and makes pessimistic decisions about the timing and number of CM units to release. The design criteria are based on the premise that a pilot would rather have to replace CM units more often than die!

The CM units used are quite simple. Chaff can't be used because it doesn't disperse rapidly enough in a vacuum and at space combat speeds ships leave chaff shadow very quickly

anyway. Electronic jamming or emr pulse generation systems (as used in the Leech missile) were considered. However the individual pulse generators are too bulky and too costly for the rate they would be deployed in a typical combat situation. There is also risk taking out the electronic systems of the ships in the vicinity (including the ship that fired them!)

Each CM unit is 'fire and forget' (FaF), non-tracking and passive. It releases a spherical wave of microwave frequency energy that heats the missiles and eventually causes their detonation. Several CM's are usually required, though competent combat pilots tend to develop an excellent sense of timing and can take a missile out with one CM (if they haven't already shot it out of the sky with cannon fire!)

One Shot Stealth Device

&

Sensor Probe



These are not technically weapons but their main use is in combat and so are included here. They work in a similar way to their big brothers. The stealth device has a limited power supply and lasts for around 60 seconds - it doesn't deplete your shields. The sensor probe is equivalent to the deployable Sensor Array (see below) but again, its low energy capacity gives it a limited period of operation.

The stealth system, be it the one shot, short life unit or the much more expensive permanent unit which are also very difficult to find on sale. They work in the same way.

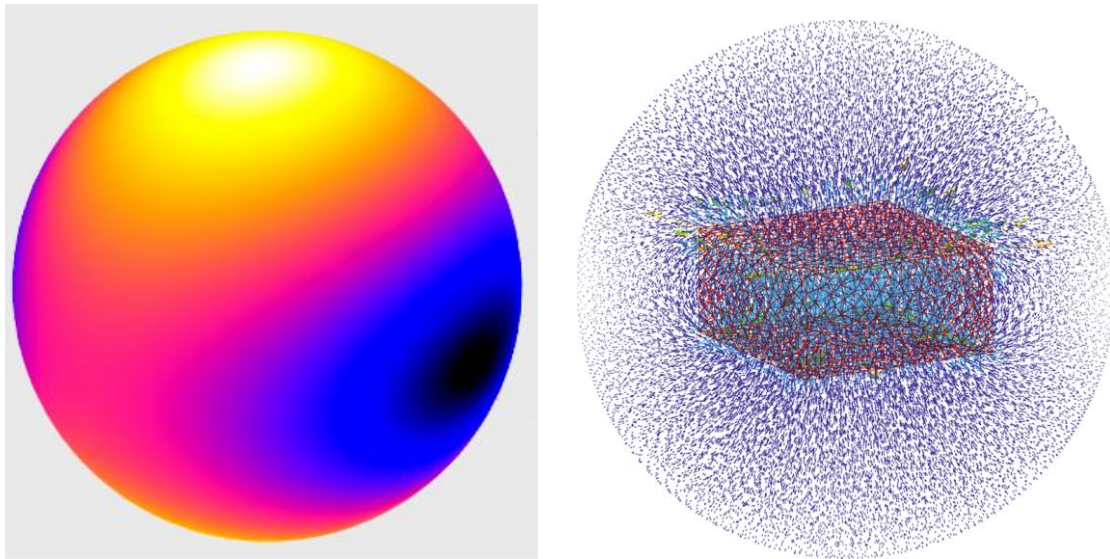


one shot stealth unit

permanent stealth field generator

Virtually all detection technology used in space utilises electromagnetic radiation (emr). The generators create a field that warps space-time so that all electromagnetic radiation (emr) bends round it completely. Looking at a cloaked object from any angle lets you see an undistorted view of what is behind it.

The first image is a false colour simulation of the outer surface of the generated distortion field; the second image is a computer simulation of the distortion field lines that allow the emr to be moved around the ship. Obviously, if real images could be created the stealth field wouldn't be a stealth field!!



The generator also masks the heat signature of the ship. Heat is infra red emr, but the stealth field generator has to deal with it being created inside the field. This is hard to do with 100% efficiency. Use of the afterburner both overloads the energy drain of the ship's energy core and creates too much heat for the stealth system to handle.

The designers considered disabling the afterburner system, but decided that a pilot would only use an afterburner when stealthed in emergencies. As a result, activating your afterburner switches off the stealth system, allowing shield recharge to begin immediately - hostiles would spot you anyway from the heat signal that leaked through the field.

The ship has to use passive 'radar' whilst stealthed or its presence would be detected.

The big disadvantage of the stealth system is that it is incompatible with the shield system. When the stealth generator switches on the shield collapses. The manufacturers have used this conflict to make the generators smaller and cheaper - they tap into the energy sources normally used for the shield.

When the stealth generator is switched off again it takes a significant amount of time to recharge the shields to a level where they can protect the ship. It also means that until the shield system fully recharges the generator can't be used again! Shield packs can be used to quickly recharge the system

If there is any shield energy depletion at all the stealth generator will not start, so pilots need to activate it prior to being hit in the combat zone. They also need to leave the combat zone before switching off the generator to avoid being unshielded 'sitting ducks'. You are advised to channel energy from weapons to shields until they recharge.

The other big downside of using a stealth system is that weapons systems are taken off line when the stealth field is active. A pilot dreaming of sneaking up on someone's six, 'uncloaking', firing and 'reclouking' is in for a very big disappointment!! However, used carefully they are very useful for scanning contracts in hostile space. You can ambush someone using stealth but you need to be able to guarantee delivering a killing blow before your target can respond and also be able to vacate the area before his wingman can retaliate!

Armour

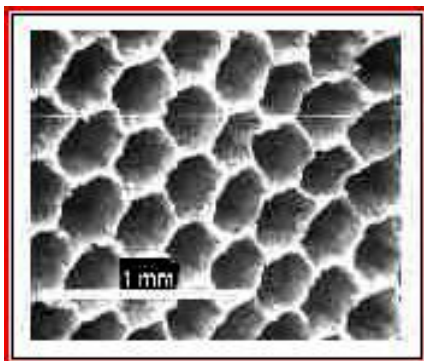
Armour is a somewhat valuable commodity constructed from metal ore. It can be built at constructor stations from mined metal for higher trade values. Nickel/Iron asteroids often contain traces of rare metals such as vanadium, chromium and titanium along with platinum. Mixtures of these metals creates very strong, dense metal alloys. When processed at a molecular level to optimise their performance the resultant armour is very resistant to damage.

It is well known that military frames have better technology than civilian frames. In military frames the construction metals are processed using nanotechnology to create materials with zero defects making the metal alloy armour as strong as it can theoretically be. However the military have also experimented with alternative armour types.

Reflective Armour The Evoch-C is the next generation of Alliance military fighter technology. Its reflective armour offers slightly better protection against particle cannons compared to the Wraith. Reflective armour is more properly known as *electric reactive armour* (also known as *electromagnetic reactive armour*, or colloquially as *electric armour*). This armour is made up of multiple cells of two or more conductive plates separated by some space or by an insulating material, creating a high-power capacitor.

In operation, a high-voltage power source charges the appropriate armour cell. The armour utilises the fact that plasma packets can have their trajectories deflected by a magnetic or electric field. The armour, being a ferrometallic alloy capacitor can have an intense local magnetic field induced in it. The cell is also charged so as to repel incoming packets of charged plasma. Due to the speed and energy of the plasma packets full deflection cannot be achieved but there is benefit in a direct line hit being deflected in to a more 'glancing' hit.

Composite Armour The ply-carbon plate armour is an advanced example of composite armour. Most composite armour are lighter than their all-metal equivalent, but instead occupy a larger volume for the same resistance to penetration.



The outer armour is a composition of regular plates of standard dimensions with the outer ablative covering that is made by a lamination of low thickness (28mm) layers of amorphous Silicon nitride, saturated with boron whiskers and 50mm layers of multicellular titanium metal foam.

This external layer is followed by layers of a sintered diamondoid crystal/metal nanoparticle matrix composite and by a third, thick layer of a 3-D mesh of carbon nanotubes in a Beryllium-Titanium alloy matrix (Commercial name: 'Plasteel'). All this is bonded to the structure of the hull.

This stratification enhances the internal elasticity and kinetic resistance, without sacrificing the energy resistance and so is more effective than simple thick hard alloy plate against the conventional energy and kinetic weapon attacks; the external laminate is lost through an ablative process, in the attempt to sacrifice as much as possible of the outer armour and hence preserving the inner hull.

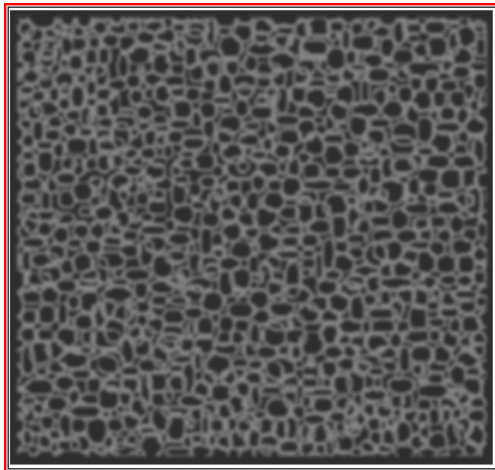
The external layer, being modular, allows easier repair and, in case of a close thermonuclear explosions, reduces the thermal stress on the structure, due to the dilatation room in the joints of the modules. The Boron based ceramics are highly refractory, and the beryllium is very likely the best heat sink and ablation resistant conventional material known.

This type of protection is a vast advancement respect to the old scheme, being more resistant against the 'conventional' attacks and improving the behaviour against the antimatter/anti-neutron beams. The large percentage of carbon nanotubes create an excellent material from the structural point of view, and a good 'energy dissipator'.

The modules of the later series have improvements in the materials (nanofabrication manufacturing of the fibres, introduced in all the variants actually produced and a rhombus design of the modules, that is more elastic, giving an higher degree of mechanical resistance, and with safer and more reliable thermal dilatation joints.

Improved composites - Chimera armour: The Chimera is the result of numerous experiments and design concepts to produce the ultimate heavy attack spacecraft. As the military have shown in the Chimera it is possible to design composite armour stronger, lighter and less voluminous than traditional armour, but the cost is prohibitively high for normal deployment.

The Chimera's armour is based on creating a layered sheet structure from graphene nanotubes. Each sheet has all the tubes aligned and has great impact resistance along the direction that the tubes are aligned. The armour is create monolayer at a time and has the direction of the nanotubes' orientation rotated by 15 degrees between each sheet. The resulting sandwich of millions of such layers results in armour that can dissipate the energy of hits outwards from the impact point. along the direction of the tubes



This nanotechnological armour is a formidable defence against the energy weapons, but has limited structural strength, and needs to be used in union with another type of protection: the combination of the nanotechnological sheet when it is sandwiched between metal alloy armour plates and layers of nanofoam between them has shown an exceptional effectiveness.

The final arrangement is

1. *alloy plate*
2. *nanof foam*
3. *carbon nanotube sheet*
4. *nanof foam*
5. *alloy plate*

When struck by a plasma packets, some of the impact energy is dissipated into the inert inner layer, and the resulting high pressure causes a localized bending or bulging of the plates in the area of the impact. As the plates bulge, the point of plasma impact shifts with the plate bulging, increasing the effective thickness of the armour. The foam expands to fill the bulge this maintaining its energy dissipation function within the deformed area.

The cost of producing the '***non-explosive and non-energetic reactive armour***' (***NERA/NxRA***) is exorbitant - it has been estimated that the hull and armour makes up more than 70% of the total cost of a Chimera. However it is the elite ship of any Evochron Naval Taskforce and the ultimate 'must have' for appropriately qualified mercenary pilots.

Section 4: Stations

These come in three fundamental types:

1. Built stations, found mainly in charted (gated) systems.
2. Constructed stations have the same shell as built stations but require the inside volume for AI modules, structural integrity field generators and auto-fabricators. They have no living occupants when created, but have got a small amount of living space for pilots wishing to stop over plus some accommodation for service and maintenance crews.
3. Deployed stations are much smaller, not permanent and have limited, specialised functionality.

Built Stations

Found in all the developed 'charted' systems with jump gates; they have also to be found in a few uncharted systems. Built stations are occupied by real people (and several alien species in some systems). The Trade Stations contain a large permanent population who work there and a large transient population of Mercenaries, traders, naval personnel etc. For many of the 'permanent' population, it is 'home' - they were born and grew up on the station and will live there unless they choose a life as a Mercenary. Built trade stations come in a variety of designs.

You will also see stations that carry adverts and that you cannot dock unless you have the appropriate clearance and identification beacon. These stations belong to major industrial players requiring zero gravity research and development and/or fabrication facilities. They are also more easily protected from attempts at industrial espionage. Like all built stations they have very strong defensive shielding and are able to withstand FT's and station detonators.

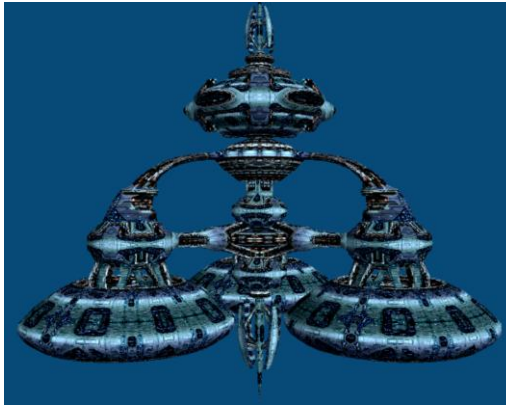
In uncharted systems, and only very occasionally you might stumble across an anonymous station that will warn you away when you get too close. These are the private residences of those very rich and powerful people who value their privacy greatly - you would be well advised to stay clear!

Constructed Stations

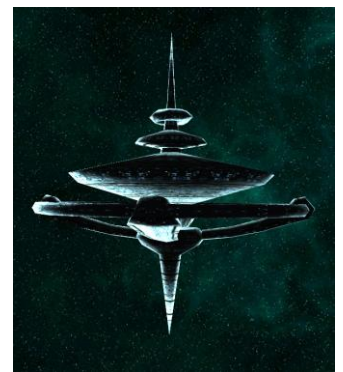
A build constructor unit actually doesn't build the station. The shipboard installed constructor unit sends coordinates to a central control facility in Sapphire. The plan for the particular construct required is used to create a shell plus the fabrication equipment for the items stocked by the station. The AI core modules are also created along with energy generators etc. These sections are delivered via a WH to the coordinates and self assemble within the station shell using energy extracted from the quantum vacuum foam surrounding your ship using a QVee module in the constructor.



Trade Stations are similar to permanent trade stations found in gated systems. They provide similar facilities and trade opportunities but do not have the same permanent large populations of residents. They are unable to withstand Station Detonators, though they are impervious to Fulcrum Torpedoes. As a permanent residence for civilian population they are too risky given the occasional vicious clan wars that break out across Evochron



Research Stations utilise AI cores and quantum computers to provide a rapid and sophisticated data analysis capacity within the system. This is a streamlined version of the distributed computing networks first seen in the late twentieth century. The result is an increase in the star system's technical ability - it also provides an attractive site for R&D development.



Energy Stations are a combined QVee system and construction facility, specialising in providing energy products for use in other stations and equipment. The speed of development of a system is directly related to availability of energy and the facilities needed to harness it and use it

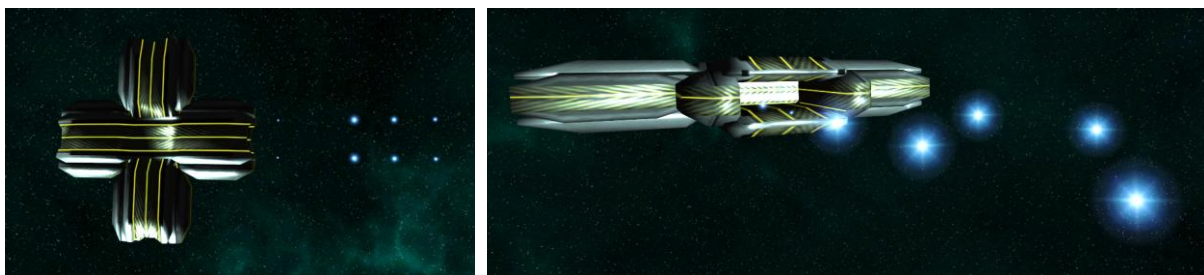
Ore Processors

These perform basically the same functions. Constructor stations are more specialised and limited but they are accessible to pilots. Ore processors are automated and meet the needs and demand from trade and other stations and cities that require 'parts' for their construction industries

and



Constructor Stations

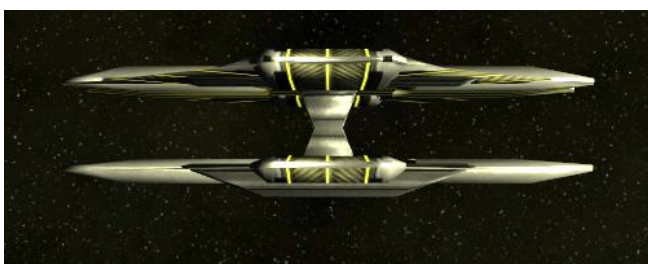
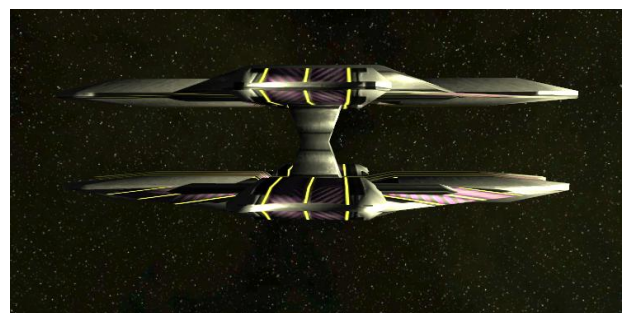


where mercenaries can have a variety of raw materials converted into technological artefacts, worth more than the raw materials would fetch on the market.

Deployed Stations

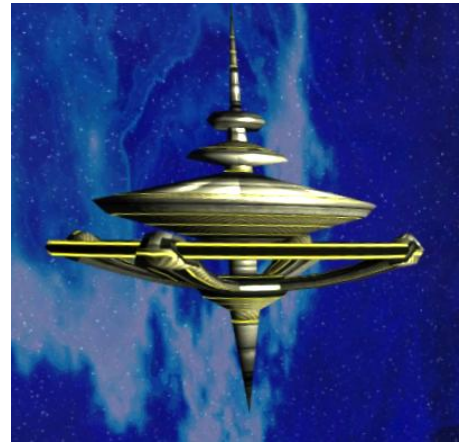
These are smaller and have a limited functionality - each has a single function and will all types self destruct (scuttle) when you leave the sector.

A **Fuel Processor** contains a small singularity at the core of its QVee unit which sifts matter particles out of the matter/antimatter virtual particle pairs of the quantum foam. The antimatter particles are converted into fuel. Ironically controlling the process is energy intensive and so the ships core generators are used to power the control system, Hence the continual charge/discharge cycles as fuel is 'made' in 5 units 'chunks'



An **Energy Station** works in a similar way to a fuel processor but doesn't process the extracted energy into a storable fuel - it feeds it into all of your ships systems simultaneously for an instant boost. Similar units are fitted into constructed and built trade stations.

The **Shield Array** is a bigger and much more powerful version of the unit in your ship (or a scaled down version of the unit in a real trade station!). It uses IFF technology to allow friendlies in and to keep hostiles out. To ensure safety if hostiles do manage to bypass the IFF identification protocols, the field also suppresses all weapons systems on all ships inside the shield sphere. If hostiles do manage to get in they cannot do much damage. However, pilots need to be aware of the tactic of physically bumping a ship out of the shield sphere so that you are no longer protected!



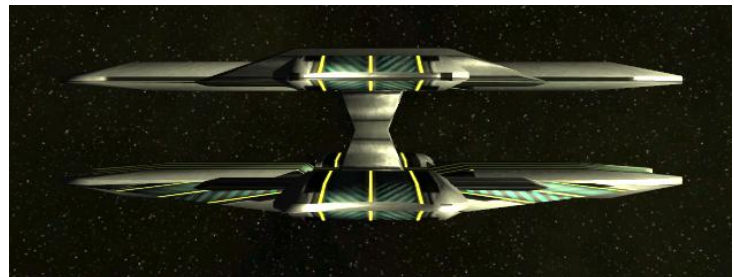
With judicious positioning it is possible to piggy back a shield array onto a fuel processor so that you can sit in safety for the time it takes to refuel. No more disturbed coffees or meals during the refuel cycle!



Sensor arrays auto ping a sector using passive and active sensor technology and record the position of **every** ship they find. It also registers any lost, abandoned or hidden containers within range. The information is transmitted to all parts of the sector and displayed on the nav map of **every** ship in the sector! Be warned - you can 'see', but can also be 'seen'. Ships are identified by coloured dots - green for friendly, and so on. Other members of your clan will also have their *ID Tag* shown

Smaller one-shot versions are available - they have a small power store and hence a limited active time - they are fitted into the standard secondary weapon slots.

The **Repair Station** is a masterpiece of design. An AI core analyses the damage to your ship and uses nanotechnology assemblers to create the necessary items. It uses converted CDM as its raw material and a small QVee energy extraction system to power everything that needs to be done. Similar units are fitted into constructed and built trade stations.



Repair, energy and refuelling stations can be identified by the colour of their stripes - all are yellow plus a secondary colour

Mining Probe: Mining is carried out by [nanobots](#) - for a more detailed explanation see the section on resource gathering and fabrication in the section on station fabrication (below). Basically the deploy constructor sends nanobots to the asteroid. The five-phase extraction process runs whilst at the same time an assembler is built to fabricate the containers. Therefore you see nothing happening until the end of the mining phase and then five containers of mined product appear nearby! You cannot specify what is mined so you may get metals, diamond or platinum or even silver and gold from an asteroid. etc. The nanobots are obviously more efficient than a simple mining beam!

Do not destroy the asteroid whilst you are waiting! If you get bored, you can mine another asteroid nearby.

Creating Build and Deploy Stations

Introduction

We take for granted the ability to create Build and Deploy stations almost on demand and wherever we need them. The technology behind this apparent simplicity is one of the more extreme developments of science and engineering in Evochron.

The industrial complexes fabricating enormous stations and city buildings faced an increasing problem as more and more systems in Evochron were discovered and colonised. Physical transfer of completed stations over very long distances wasn't considered to be feasible due to the limited size of gate wormholes. On-site construction was also very expensive due to the large amount of expensive equipment that had to be transported into a system and then taken away again at the completion of the project. It was simply too expensive to have manufacturing facilities in every system, especially in the early stages of colonial development and because the demand was limited. Demand for temporary (Deploy) stations and permanent research and processing stations grew. A solution was urgently needed if systems were to be able to develop and grow.

Over a period of decades an amazing manufacturing and deliver system was developed and refined. The main parts of the system are automated remotely programmable nanobot manufacturing facilities, linked to the central control facilities by micro-wormhole communication technology. This allows long distance communication (see section on FtL Communications (below)). Large 'delivery' wormholes are created between the manufacturing facility and the delivery point - these wormholes can be stabilised (at least for the time they are required) on a moment by moment basis - a task that requires extremely rapid and extremely delicate AI control systems.

The final and perhaps most awesome part of the whole construction chain is the location of the resource manufacturing facility and its resupply with raw materials all of which had to be fully automated.

The first two stages are described below; the creation of the delivery wormholes large enough to handle a completed trade station required much (expensive) research but was finally cracked using electromagnetic and graviton fields under AI control in place of 'exotic matter' to stabilise the wormhole mouths. The stability control, despite much research, has not as yet become reliable enough to allow the safe transport of living things through it. Leaked reports suggest that it is unlikely ever to be so.

Where are stations made?

background: [Superstring theory](#) - [Relativity](#) - [Quantum Theory](#)

The manufacturing facilities are not located in Evochron! They are in fact not located in our universe!! They are located a nearby parallel membrane universe of the multiverse. Hints to the solution of several problems were provided by implications of the mathematical equations describing String Theory and Relativity Theory.

String Theory (actually Superstring Theory that was developed from it) showed that ours isn't the only universe. When melded with Relativity Theory the equations show that wormholes can link our universe with parallel universes - the 'Brane Multiverse'. The parallel universes bears no 'historical relationship' to any other universe - there *isn't* an alternative you living an alternative life in a parallel universe. Instead, the laws of nature are simply different than those in our own.



Probes were designed to survey alternate universe, carrying as wide an array of data gathering technology as possible. They were programmed to automatically return when the multi-terabyte data stores were full.

Most didn't return and most of the universes from which probes did return were unrecognisable. It was soon realised that sending a probe into a universe in which, say atoms could not form meant that the probes were destroyed before they could collect much information and were unable to return anyway.

In order to keep expenses at an economic level and to sample more universes more rapidly, a new generation of small, simplified probes were built. These microProbes could be sent through smaller wormholes (saving energy and expense) in vast numbers thus increasing the chances of discovering a suitable universe.

The microProbes were developed to report back continuously for the first few minutes, whilst still protected by a rapidly dissipating bubble of our universe's space-time, measuring the universe's fundamental constants. Knowing the value of universal physical constants allows scientists to calculate the underlying space-time physics - what the universe would be like. When the bubble destabilises, if the universe is inimical to normal matter the probe is destroyed and that's the end of that exploration!



Only the most important constants can be measured in the limited time available and include:

strong nuclear force constant determines how strongly the nucleus is bound together overcoming the strong repulsion of positively charged protons - if it were 2% stronger than it is while the other constants were left unchanged diprotons would be stable and hydrogen would fuse into them instead of deuterium and helium. The existence of the diproton would short-circuit the slow fusion of hydrogen into deuterium. Hydrogen would fuse so easily that it is likely that all of the Universe's hydrogen would be consumed in the first few minutes after the Big Bang leaving no raw material for star formation. *if smaller*: no elements heavier than hydrogen (which only has a single proton) would form

weak nuclear force constant changes one type of quark into another

It is crucial to the structure of the universe in that the sun would not burn without it since the weak interaction causes the transmutation protons into neutrons so that deuterium can form and deuterium fusion can take place. It is also necessary for the creation of heavy elements.

if larger: too much hydrogen would convert to helium in big bang; hence, stars would convert most matter into heavy elements - an major plus

if smaller: too little helium would be produced from big bang; hence, stars would convert too little matter into heavy elements

gravitational force constant determines the strength of gravity;

if smaller: stars would be too cool to ignite nuclear fusion; thus, many of the heavier elements would never form

electromagnetic force constant determines how strong electrostatic and magnetic forces are. The electromagnetic force holds atoms and molecules together. In fact, the forces of electric attraction and repulsion of electric charges are so dominant over the other three fundamental forces that they can be considered to be negligible as determiners of atomic and molecular structure. Even magnetic effects are usually apparent only at high resolutions.

if greater: chemical bonding would be disrupted; elements more massive than boron would be unstable to fission

if smaller: chemical bonding would be insufficient for the production of heavier elements that we require for manufacturing

we can then use the **ratio of electromagnetic force constant to gravitational force constant:**

if smaller: all stars would be at least 20% less massive than the sun, thus incapable of producing heavy elements

mass density of the universe:

if smaller: insufficient helium from big bang would result in a shortage of heavy elements

density of galaxy cluster

if denser: galaxy collisions and mergers would disrupt the stellar orbits making it unlikely that solar systems could form - it would lead to a needle in a haystack search for resources

average distance between stars

if larger: heavy element density would be too sparse for rocky planets to form

if smaller: planetary orbits would be too unstable for solar systems to survive; the galaxy would be dominated by stars that have mopped up all gas and dust in their vicinity

fine-structure constant α , characterizes the strength of the electromagnetic interaction

if α was increased by 4%, stellar nuclear fusion would not produce carbon or higher elements.

If α were > 0.1 , stellar fusion would be impossible and no heavier elements would be formed

ratio of exotic matter mass (dark matter) to ordinary matter mass

if larger: universe would collapse before solar-type stars could form

if smaller: no galaxies would form

mass of the neutrino

if smaller: galaxy clusters, galaxies, and stars would not form

if larger: galaxy clusters and galaxies would be too dense to be stable - galaxy collisions and mergers would disrupt the stellar orbits making it unlikely that solar systems could form - it would lead to a needle in a haystack search for resources

Analysis of the returned data allows us to determine whether it is worthwhile sending one of the more complex (and hence bigger and more expensive) full spectrum probes to make a more detailed survey.

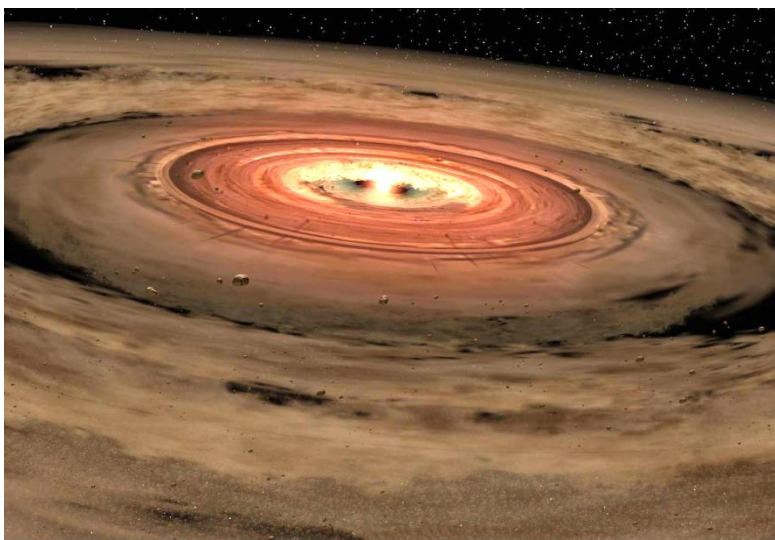
One probe's data stream confirmed that even the way time flows in a parallel universe may be very different from ours; one probe returned after a microsecond with its internal data store full and its internal clock suggesting that it had been gathering data for several months. The time had passed very differently for the probe and the research team.

Hundreds of thousands of microProbes were dispatched to different alternative universes, leading to a shortlist of just five candidates being surveyed in more detail. It is fortuitous that the probes discovered a universe containing the raw materials we need but in which time moves more quickly than in ours, though at a rate the construction engineers could exploit - several days pass in U-42X for each hour in our universe. Against all the odds the fundamental constants in U-42X are very close to those in our universe.

They are similar enough to allow matter to form and stars to develop. However they are different enough for the evolution of U-42X from its Big Bang to be somewhat different - U-42X contains second generation stars (required to create heavier elements from hydrogen and helium) but only has around 42 elements, around a third of the number of elements found in our Periodic Table (which numbered 128 at last count).

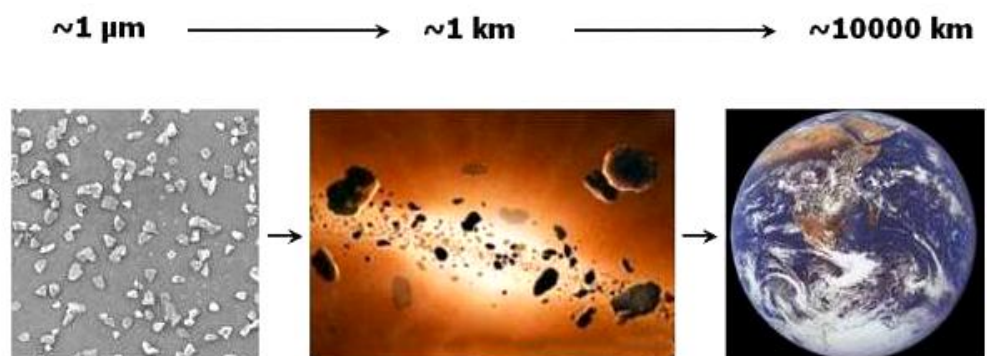
Importantly the most valuable element for our manufacturing needs - carbon - is available and in large quantities. The metals required (mainly gold, platinum and iron) are rarer there than here, making mining somewhat more difficult but not impossible since only relatively small quantities are required.

A manufacturing facility (codename: Cornucopia) was fabricated and transferred to U-42X close to the same universe coordinates as Sapphire here. On Sapphire is the Central Control Complex. It receives construct requests from the Build and Deploy Constructors around Evochron, processes them and sends instructions via the communications mini-wormhole to the fabricating complex in U-42X.



Though this is situated in same galactic location as Evochron. but star formation is rare and very few planets have formed around the stars that have formed.

However enough gaseous and dusty material has condensed sufficiently to form **planetisimals** and asteroids. The galactic stellar evolution is so slow that a typical third generation star system is still in the middle phase.



The manufacturing complex is located on one of the larger asteroids (1000km in diameter).

The whole facility is shielded to protect it from the constant bombardment by the 'rubble' orbiting the proto sun. Although such large shields are prohibitively expensive in energy use to be of practical use in Evochron, the vast energy resources available in U-42X and the fact that relatively few shields are required allow them to be deployed in U-42X.



There is a limit to how far the delivery wormhole can reach. Stability control gets harder as the delivery wormhole gets bigger and/or longer. There is therefore a limit to how far across Evochron the larger stations can be delivered. Build stations are significantly more massive and physically larger than Deploy stations and so within the equipment resources available, Build Stations can only be delivered to within around 20K sectors of Sapphire. Building several more fabrication complexes spread across the mirror of Evochron space in U-42X would extend this limit, but the economics do not make it feasible. All the major charted systems are covered and most (though not all) of the uncharted systems are within the 'delivery zone'.

By design, Deploy stations are physically smaller and less massive because they are single function units and are not required to have the long lifespan a build station will have - they self destruct when the Deploy Constructor moves out of range which in practice means leaving the sector. Because of this it is possible to stabilise the (smaller) wormhole required for delivery over much longer distances for the short time required to deliver the constructed station. No-one has as yet reached the limit of the range of deploy construction.

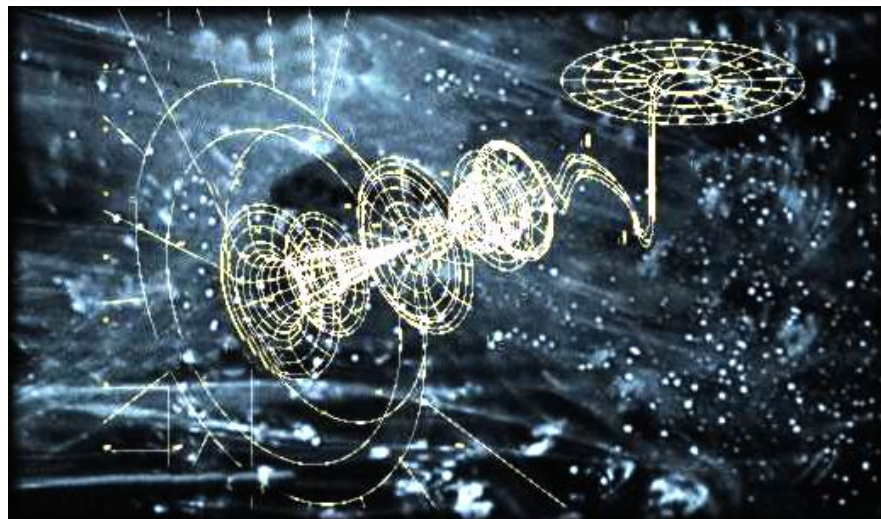
What actually happens when I Deploy or Build a station?

1. your Constructor communicates your order to the Control Centre in Sapphire
2. the Control Centre sends instructions to the Fabrication Facility in U-42X through the communications mini-wormhole to create the specified type of station and deliver it to a specified location



3. the Control Centre creates a Coordinate Marker used to accurately locate the wormhole mouth in our universe - this appears in your HUD as a green flattened cylinder at heading zero from your position - the location is identified by a coded signal transmitted by the constructor on your ship.

4. the Fabrication Facility either assembles the station from prefabricated parts that it has stockpiled or utilises one of its prebuilt stations (it is running non-stop and stockpiling parts and completed smaller stations)
5. the Fabrication Facility creates the delivery wormhole linking itself to the required delivery coordinates and transfers the station through.



6. At the moment of delivery you see the blue flash as the wormhole mouth is created in our universe
7. Your ordered station appears at your location!

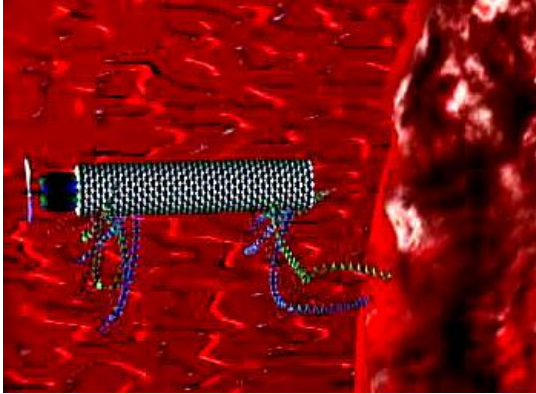
Deploy stations, being smaller and simpler and due to the time differential between our universe and U-42X appear virtually instantly. The larger and more complex Build stations tend to be assembled on demand and hence require a few minutes to appear!!

How are the stations fabricated?

background: [nanotechnology](#)

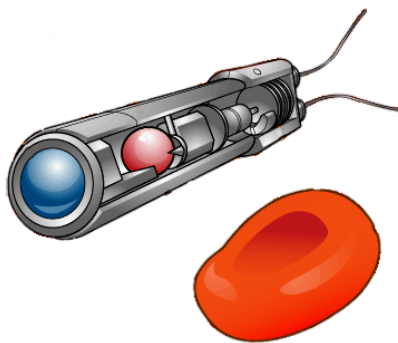
Mining raw materials

There are three designs of specialised nanobots employed in collecting raw materials plus one type of microbot



Nanobot Type 1 - fluidiser

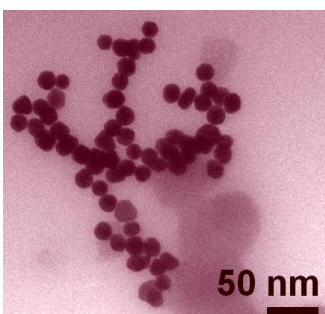
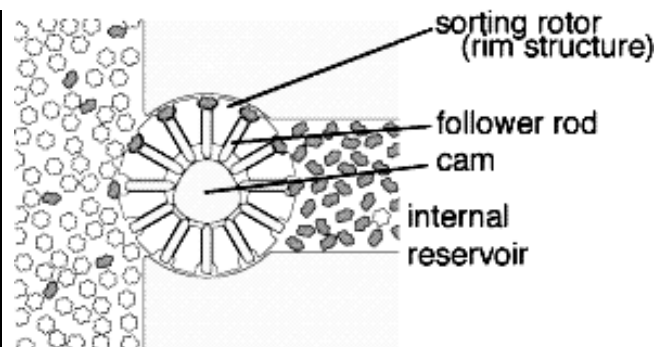
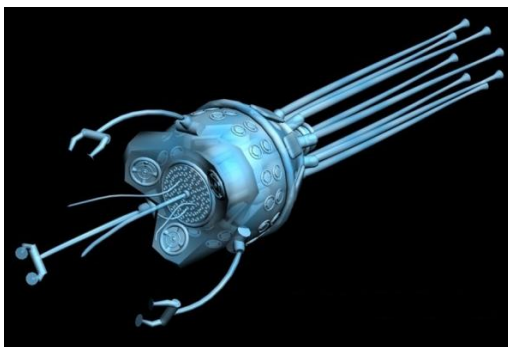
The function of these bots is to dismantle the material of the asteroid down to an atomic level working from the surface inwards. They are the most numerous of the three types of nanobots. The resulting atomic 'sludge' can be traversed by the other two type of mining nanobot and the microbots that form the final stage of resource extraction



Nanobot Type 2 - element identification

The micro-spectral analyser at the front (blue) identifies the particular type of atom the nanobot is programmed to retrieve. the identification data pattern is stored in the red sphere, just in front of the signal transmitter. It signals to an atomic collector . . .

Nanobot Type 3 - atomic collector

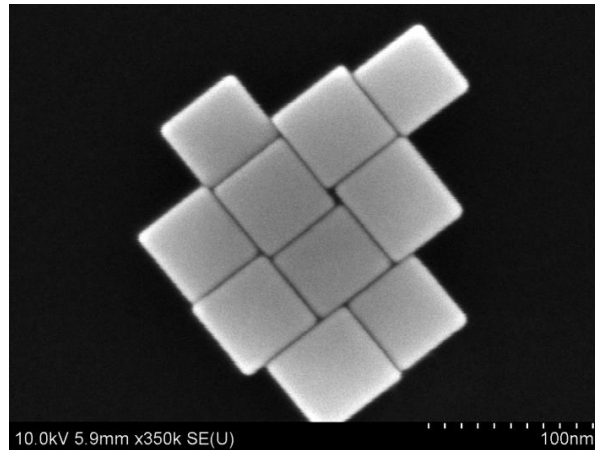


These pick up the individual atoms using a precisely positionable grip, and stores them in a reservoir. When full the nanobot excretes the metal as a spherical nugget

Microbot



Specialised microbots take over the next stage of resource collection. These microbots collect the excreted metal nuggets produced by the collector nanobots. Being bigger they can contain the identification technology as well, making them autonomous and therefore more versatile. In a similar way to the collector nanobot, this microbot collects and stores the spherical nuggets but excretes much larger cubic nuggets. The shape of the nuggets makes them more likely to aggregate with each other, making them easier to separate in the next (filtration) stage.



The processed slurry is filtered through an extractor. The microbots roll up into spherical capsules (for protection) and are extracted from the slurry in the first stage of filtration and returned to the slurry after the main stage of filtration. The cubical metal nuggets extracted are sent for further processing. The nanobots and the smaller (not yet collected) spherical nuggets are too small to be filtered out and are returned along with the microbots to the asteroid.

Fabricating the stations

The goal of molecular manufacturing to build exactly what we want at low cost has been achieved. Many if not most of the things that we want to build are complex (like a molecular AI computer). Adding programmed positional control at the precision required at such a small scale lets us construct a truly broad range of macroscopic molecular structures. To add this kind of positional control, however, requires that we design and build what amount to very small mechanical robotic manipulators. If we are to make anything of any significant size with this approach, we need vast quantities of these manipulators. The ability of nanobot assemblers to manufacture other general purpose manufacturing device lets us build extremely large numbers of such devices at low cost. This general approach has let us develop a low cost general purpose molecular manufacturing capacity.

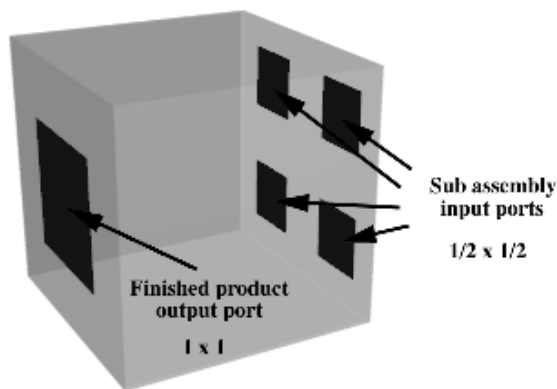
Nanotech can make very big things as well as very small things. An attractive approach is to use *convergent assembly*, which can rapidly make products whose size is measured at the metre scale starting from building blocks whose size is measured in nanometres. It is based on the idea that smaller parts can be assembled into larger parts, larger parts can be assembled into still larger parts, and so forth. This process can be systematically repeated in a hierarchical fashion, allowing the creation of artefacts spanning the size range from the molecular to the macroscopic.

The limitation of this approach is obvious - although the fabricated items can have complex structures they are made up of repeat units of these structures. However this is exactly what is needed for the manufacture of structural spars, tubes and sheet materials. With modifications it also works for electronic circuits.

Convergent Assembly - how it works

The following description uses simple sizes and times so that it is easy to follow the argument. Real assemblers work at much faster speeds!

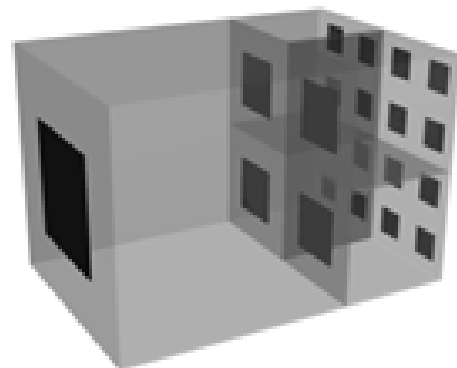
It's common to make bigger things by assembling them from smaller things. To make a cubic assembly one metre per side, we'd need to assemble eight smaller cubes, each of 0.5 metre in size. This relationship holds approximately for many products. A one metre sheet would require four half metre sheets.



The fabricators themselves are modular. In the example a single assembler is able to accept subassemblies from the four input ports to the right, and produces a finished assembly to the left through the single output port.

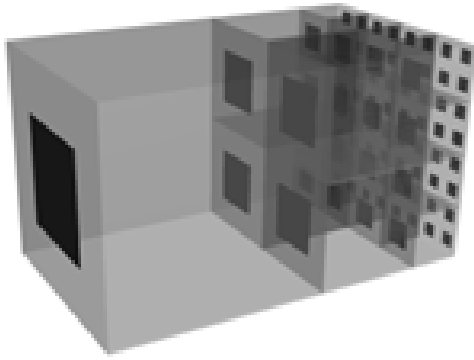
If the output port has a size of one metre by one metre, each input port would have a size of 0.5 metres by 0.5 metres. We could assemble our eight subassemblies into a finished assembly by using one or more robotic arms (or other positional devices).

This process could be repeated. We might take 64 sub-subassemblies, each with a size of about 0.25 metres, assemble them into 8 subassemblies, each with a size of about 0.5 metres, and finally assemble the 8 subassemblies into the finished assembly, with a size of about 1.0 metre.



*We describe an assembler by the size of its **output** port. The actual module size is larger. In this case, the 1.0 metre assembly module has a size of 2.0 metres. This additional size provides sufficient room to handle subassemblies and the final 1.0 metre assembly. In the following paragraph the actual timing isn't critical - we are simply describing the relative time relationships between the sub-assembler parts.*

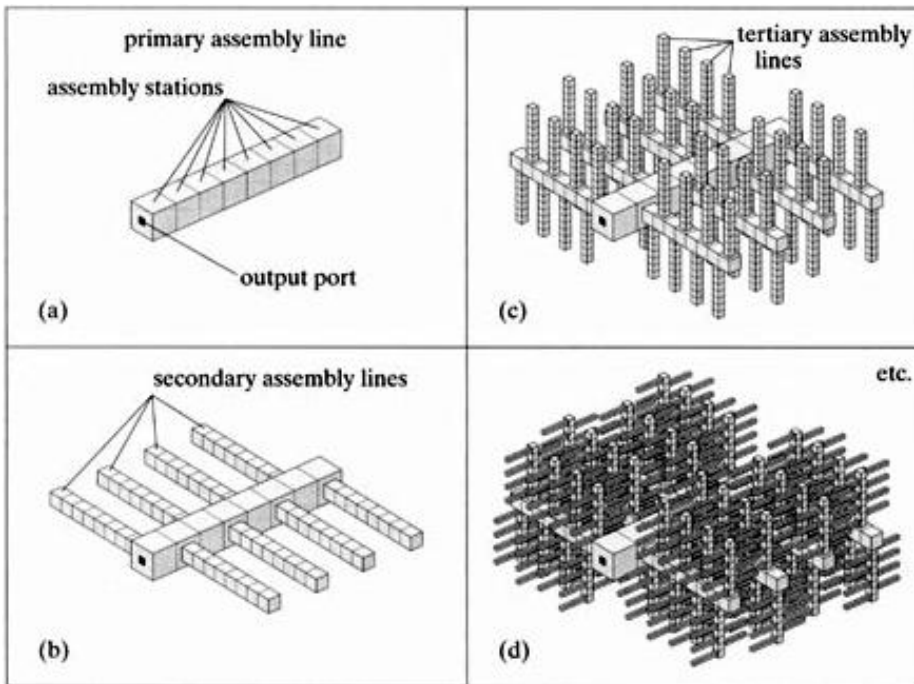
Say that the final stage of the assembler (which assembles the final product) takes about 10 seconds. Therefore the 0.5 metre assembler needs to complete one sub-assembly in 5 seconds, i.e. twice as quickly. *(An object which is half the size can finish a movement of half the length in half the time: it's frequency of operation is doubled!)* Each 0.5 metre assembler can therefore produce two subassemblies in 10 seconds. Therefore we need four 0.5 metre assemblers to finish eight subassemblies in 10 seconds; both the final 1.0 metre assembler and the four 0.5 metre assemblers must work for 10 seconds to produce the final product. This is the reason that only four 0.5 metre assemblers are required to 'feed' the 1 metre assembler.



This process can be repeated at each smaller step.

This diagram illustrates three stages of this process, in which 512 x 0.125 metre sub-sub-sub-assemblies are assembled in 16 x 0.25 metre assembly modules, making 64 sub-sub-assemblies; these 64 sub-sub-assemblies are assembled into 8 sub-assemblies in 4 x 0.5 metre assemblers. Finally, the 8 sub-assemblies are assembled into the final product in the single 1.0 metre assembly module.

In reality we aren't limited to cubes or even symmetrical components - any object that can be created from sub-units can be fabricated.



Take a deep breath . . . each 0.25 metre assemblers operate twice as fast as the 0.5 metre assemblers, and four times as fast as the 1 metre assembler. The 16 x 0.25 metre assemblers can make 64 sub-sub-assemblies in the same time that the 4 x 0.5 metre assemblers can make 8 sub-assemblies, which is the same amount of time that the single 1.0 metre assembly module takes to produce the finished product.

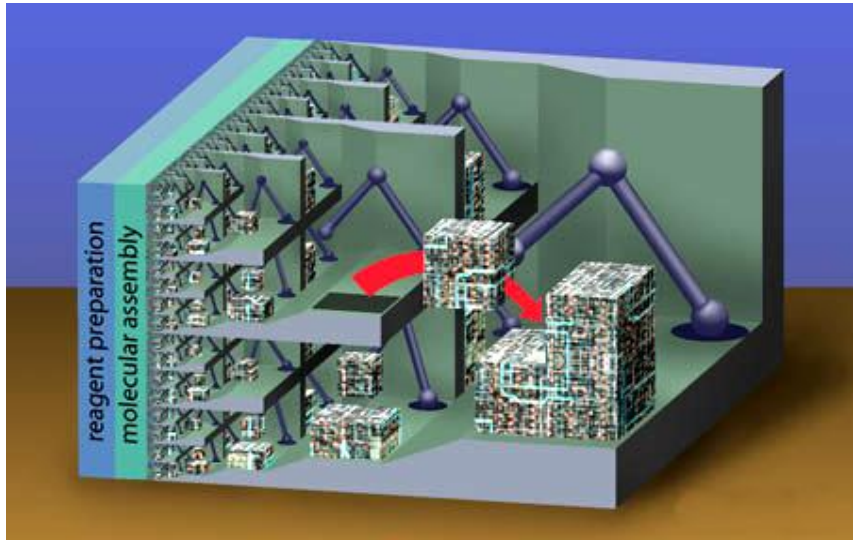
Where we require larger components we can of course extend the assembler system in the other direct with four 1 metre assemblers feeding a 4 metre assembler and so on.

We can keep adding stages to this process until the inputs to the first stage are as small as we require and the output stage is as large as we require. **In reality these initial inputs are about one nanometre in size.**

The timings given in the illustration are deliberately long to prevent us having to use very small time descriptions at the smaller end of the assembler chain and to make it easier to follow the description.

A typical 30 stage system currently available should be able to produce a single metre-sized panel or strut in one hundredth of a second. It should be able to produce a steady stream of metre-sized products at a rate of roughly one hundred new products every second. Given the large number of multi-assembler fabricators available plus the time differential between the two universes, creating a station and maintaining an adequate stockpile is nor too challenging!

Control is an issue in terms of size at the smaller end of the chain since it is under nanobot control. The solution proved to be quite elegant; the first stages employ hard-wired automation, eliminating their flexibility. When the fabrication line is required to change the product produced (for example if a newer improved version is designed) the assembler packages must be physically swapped out and replaced with new assemblers with new programming. Since the assembler packages involved can be fabricated quickly in advance this process is itself very quick and cheap.



The larger assembler units which would be slower to swap out are large enough to contain their own reprogrammable control systems. By combining a relatively modest number of standard 100 nanometre parts we can make a remarkably wide range of products.

Convergent assembly is most useful in the manufacture of relatively rigid structures made from rigid components. This includes computers with a large number of molecular logic gates densely packed into a three dimensional volume (e.g. processor cores and high density memory cores); structural elements useful in load bearing applications in stations and city buildings, etc.

Convergent Assembly - Conclusions

Convergent assembly is based on the idea that smaller parts can be assembled into ever larger parts. The fabricator designs used are able to produce multi-metre-sized products in a fraction of a second from nanometre-sized parts while going through about 30 stages. At each stage the parts are approximately double the size of the parts from the previous stage and half the size of the parts in the succeeding stage.

Section 5: Mining

Materials worth mining

Diamonds in (carbonaceous) asteroids are both rare and microscopically small. Diamonds are a high value commodity used in a variety of applications ranging from cutting tools to optical equipment. Beam-mined diamonds are also a useful resource for diamond sheet fabrication. Although nanotech mining extracts a purer raw material, diamond microcrystals obtained by mercenary miners using mining beams **is pure enough to act as an excellent raw material for graphene, fullerene nanotubes and diamond sheet** fabrication.

Paying Mercenaries to mine is also significantly cheaper than nanotechnology mining, which is consequently used in limited situations - or when mercenaries think they can turn a profit using mining probes. Microcrystalline diamond is almost always in demand and is a primary incentive for mining. Contrary to popular rumour, asteroid mining doesn't net 'gem quality' stones! The luxury jewellery trade is serviced by individual prospectors manually mining asteroids

Platinum is generally the most valuable raw material commodity in Evochron due to its inert nature giving it longevity and also for its excellent conductive properties. It is used for electronics, primarily in the computer and weapon systems of spacecraft. (Consider jettisoning your existing cargo to recover platinum). There are rumours of platinum asteroid fields in Evochron. It is also in demand within the luxury jewellery market

Gold remains a very valuable commodity. It is useful in the production of electronics and their radiation shielding. Like platinum it is chemically inert and has excellent electrical conductivity. It is also used as money in some economies and is valuable to jewellery industries.

Silver is generally less valuable than gold, although it has many uses that make it valuable in most economies. Certain digital and solar technologies also keep it in high demand. Although a good electrical conductor it is less resistant to corrosion than gold and platinum, unless alloyed with either or both of them.

Metal alloys are a relatively low value commodity that provides the raw material needed for manufacturing. Delivering this item doesn't usually provide much profit unless there is a temporary demand for it. You need to keep a close eye on market information for the system you are in. There is the opportunity to make a profit by converting metal alloy into armour at a construction station - armour has a much higher market value.

Mining/tractor beams are a dual purpose system

Firstly they are used to extract and collect metals, water, oxygen *etc* from asteroids and the atmosphere, land and seas of planets. They also extract raw materials for fuels from nebulae and the corona of stars.

Secondly they function as a 'tractor beam' to move mined material into containers in a cargo bay. They are capable of tractoring containers and rescue pods as well.



The tractor field part of the mining beam is generated by graviton manipulation to literally lift the processed bits of the asteroid crust into the cargo bay. Similarly it can manipulate rescue pods and cargo containers

When mining asteroids the beam control system recognises that it is aimed at raw materials and creates a lower energy plasma beam. This beams ablates the asteroid and mass spectrograph analysers identify the material (metal ores, diamonds *etc*) being released by analysing the light emitted in the vaporisation of the asteroid surface. The material is concentrated and then transferred into cargo containers. Initially, to save weight and cost, the beam was generated using the beam cannon plasma generator. However there is some doubt about the effectiveness of beam weapons and some pilots do not have them fitted and so early versions of the mining beams wouldn't work. Complaints lead to the production of a self contained system

In nebulae & star coronae (for fuel gathering), planetary atmospheres and oceans *etc*, the simple AI unit controlling the beam unit automatically recognises that the plasma beam is redundant. The AI unit recognises rescue pods and jettisoned containers and automatically moves into retrieval mode.

Recent improvements in the AI core's ability to discriminate have resulted in the production of specialist mining beams that recognise a specific material (diamond - platinum - gold - metal ore) and ignore the rest. The beams can still be used for pod/container retrieval. A pilot should think carefully before choosing a specialised beam - it isn't difficult to either 'prime' cargo bays with the chosen material or to eject mined material until the correct one is found - as one pilot put it "Hell is a diamond mining beam in a platinum asteroid field!"

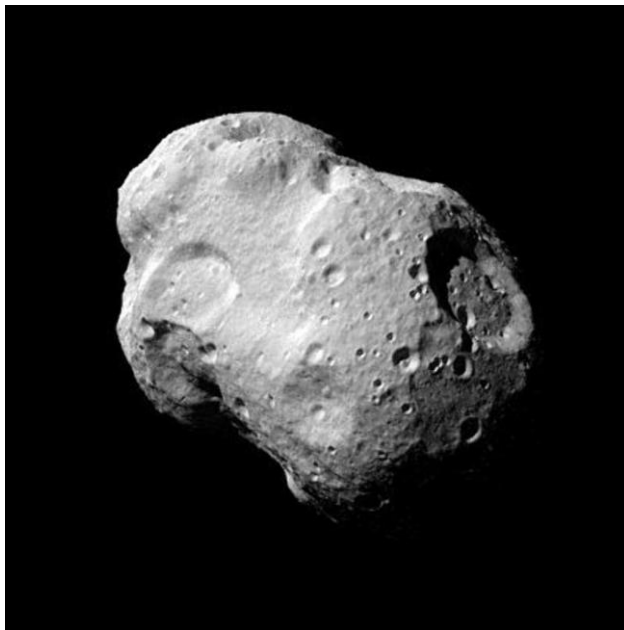
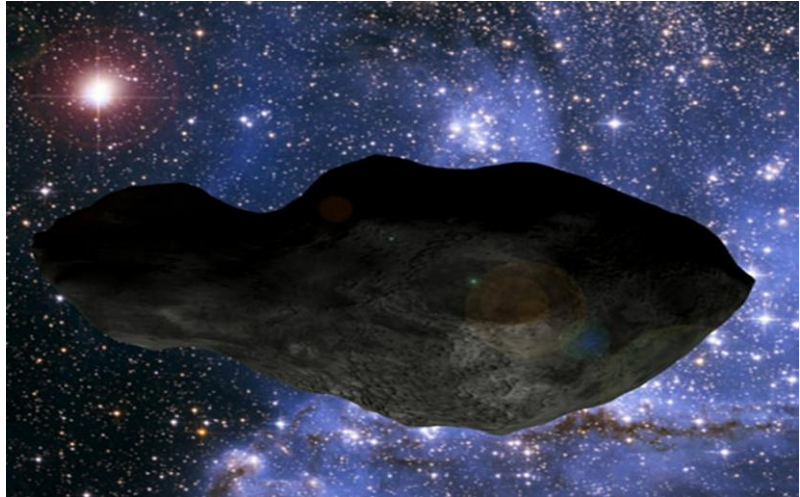
See also [Nanotechnology Resource extraction](#)

Nanotechnology mining techniques are superior to beam mining in terms of the purity of the materials gathered but are very expensive to deploy on small asteroids (a few hundred metres in diameter). The only uses of nanotech mining known are in Deployed Mining Probes and the Fabrication Complex in alternative universe U-42X where Build and Deploy Stations are fabricated to order. In the former case the technology is used when ultra pure samples are required and in the latter the fact that humans cannot live in U-42X due to the differential rate of time passage coupled with the extremely hostile environment - this is reflected in the cost of Build Stations.

Asteroids

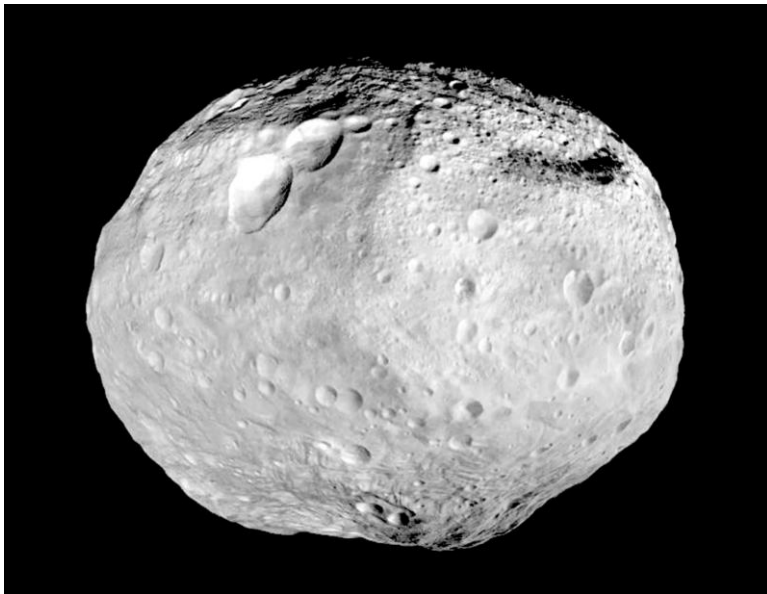
There are four common types of asteroids: carbonaceous, siliceous, metallic and water ice. The latter are more commonly known as comets.

(C-type) Carbonaceous asteroids (stony and darker than coal) are the commonest and contain many complex organic molecules and form raw materials for much of Evochron's chemical industry, creating medicines, plastics and resins and fibres and elastomers, solvents, detergents, dyes and pigments, paints and varnishes and other coatings, adhesives, lubricants and coolants, gels *etc.* Carbonaceous asteroids also contain diamonds.



(S-type) Siliceous asteroids (bright, stony bodies which contain metal) are the next most common. Composition is metallic iron mixed with iron- and magnesium-silicates. They are rich sources of 'metal alloys' with traces of platinum and diamond

(M-type) Metallic asteroids (exposed metallic cores of much larger bodies) mainly consisting of nickel/iron and often contain traces of rare metals such as vanadium, chromium and titanium along with platinum. Mixtures of these metals creates very strong, dense metal alloys. When processed at a molecular level to optimise their performance the resultant armour is very resistant to damage.



Water ice asteroids (commonly called **comets**) exist in the outer most part of star systems as 'leftovers' of the systems formation.

While the ice asteroids are in the outer system the cliché description is actually very accurate for the vast majority - they are 'dirty snowball'.

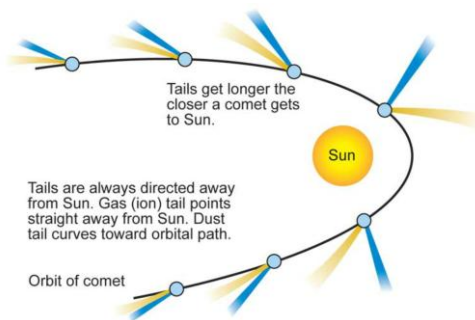


Periodically comet's orbit is gravitationally perturbed and it begins a long fall 'in system' towards the star. Some are evaporated before they reach the inner parts of the system, some don't survive their swing around the star and some pick up gravitational energy from the star and are flung out into space. They form a major source of water for many remote arid systems. As the comet core approaches its star the ice sublimates. The core becomes unstable and prone to asterquakes.

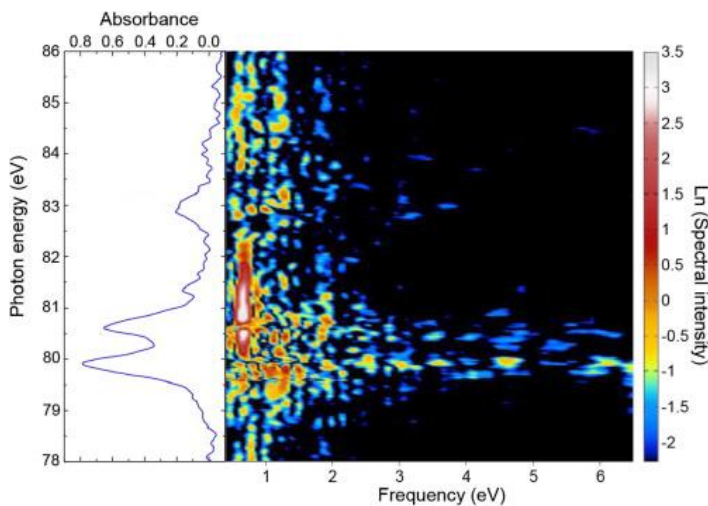
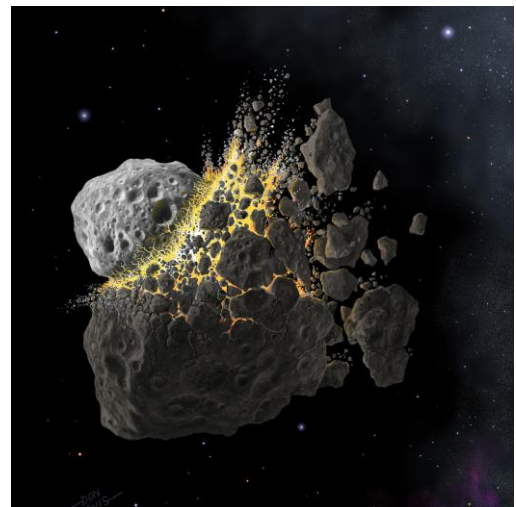


During the closest approach to the star, comets develop their characteristic twin tails.

Harvesting asteroids to provide water for arid planets had allowed the colonisation of a number of resource rich systems. The asteroids are not mined - the whole asteroid is transported to the planet



In asteroid fields collisions between these large chunks of brittle materials leads to their fragmentation, mixing and reformation, resulting in asteroids that contain metals, ice, organic carbon materials and diamonds.



It is often difficult to tell asteroids apart - ice asteroids can be coated with carbonaceous dust and metallic and carbonaceous asteroids often look quite similar. When mining a spectrographic sensor system in the mining beam unit analyses the light created and can therefore selectively tractor in different materials.

Section 6: FtL Communications

Background: [Quantum Theory](#) - [Relativity](#)

When mankind first travelled to another planet, as opposed to the Moon, they chose Mars. Electromagnetic radiation (EMR) includes light and radio waves. It takes between 3 minutes and 22 minutes to travel between the two planets, depending on their relative positions in their orbits.. Imagine the early morning exchange (using an average 10 minute delay) between **Mars Control** on Earth and the **Mars Habitat** in the **Timoshenko crater** near **Tempe Fossae** in **Tempe Terra** lowlands of Mars

All times given as Earth UCT

Time	<i>Earth Mission Control</i>	<i>Mars Habitat</i>
8:00	"Good morning Mars"	
8:10		hears Mission Control greeting
8:11		"Hi MC - everything is good here"
8:21	hears Mars' hello	
8:22	"Good - here's the latest on your request . . ."	
8:32		hears their request.
8:50		sends response
9:00	hears Mars Habitat's response	

It made conversations impossible. Pluto was even worse with an average of a four hour delay. A method of sending signals FtL was urgently needed! Three basic ideas researched based on Quantum Theory and Relativity.

The first method involves the creation small (atomic or nano-sized) paired wormholes dedicated to communication by means of a laser whose pulses traverse the wormhole at the speed of light thus achieving FtL transmission speeds. This is basically a microscopic version of a jump gate. Present theories of wormhole formation suggest they would **not** become 'time-holes', thus allowing FtL communication without the additional complication of allowing communication with the past or the future! Some sections of the science community and the military are sorely disappointed. The **Evochron Lottery** organisers are greatly relieved.

Since jump technology was already being developed, and because of problems with the technology involved with Quantum entanglement and the fragility of the entanglement of the photon pairs, WH communication is the technology used in human controlled space in Evochron. Prototypes of the transmitter created a wormhole between itself and the receiver. Only these two communication units could communicate via the WH created. This has the advantage of very secure communications (and is still used by the military for passing ultra secret information). The disadvantage is that multi-person communications and general universe wide broadcasts can't be made.

The issue of these broadcast problems was solved by creating a network of satellite relay stations throughout Evochron. The communicator in a ship creates a WH to the nearest relay station. The relay stations are linked to each other in the network via permanent micro-WH's. The message has encoded in it the recipient's **receiver identification code** and sends the message to the nearest relay station in the network to the receiver. This relay then creates a WH to the intended recipient's communicator.

If multiple person communication or general broadcasts are required then the relay stations create WHs to either each of the appropriate persons' receivers or all the communicators within their range.

However, there is still a short delay in the transmission of the message, though it is very much faster than gate jumping because the messages don't need to be accelerated first like ships do. There is also an issue with bandwidth - verbal communication requires a *much* higher bandwidth than typed speech. Consequently ship to ship messages are typed into a 'chat' window. The general experience is acceptable but it can be amusing to see two conversations going on between two or more people at the same time! In general, multiple person broadcasts, there are often several conversations mixed together!

The second method employs (faster than light!) tachyons. It is rumoured that Vonari use tachyon based communications for real-time communication over long distances at a very high bandwidth. Some affluent mercenaries have also managed to acquire adapted Vonari technology which allows them to use speech communication.

This is called **TSpeak** or **TachyonSpeak**. There are some issues about signal breakup (garbling their messages) and a very high AI decoding requirement which can at times interfere with the AI management systems of the ships fitted with the technology; data screen updates can become a little (or a lot!) 'laggy'!

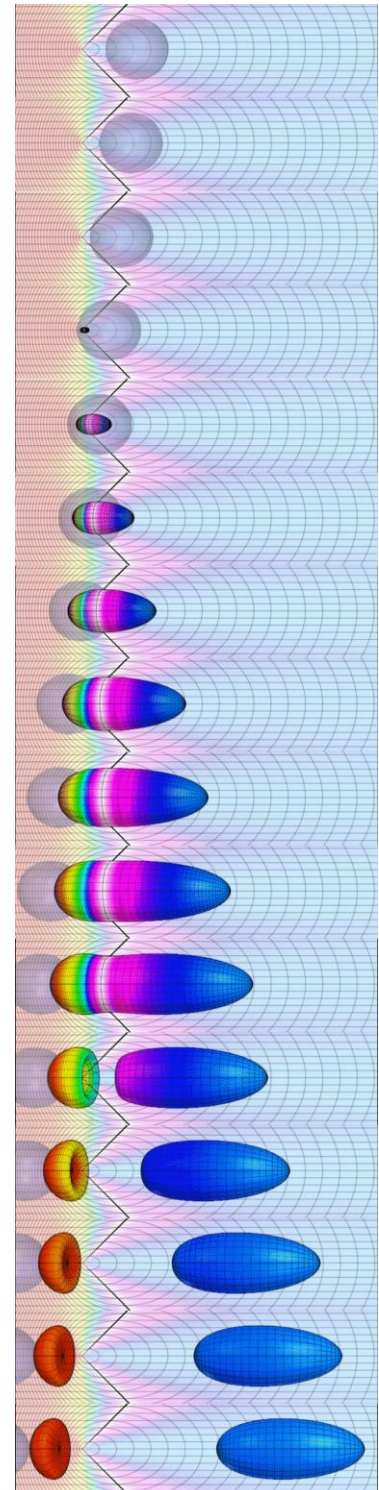
Since a tachyon moves faster than the SoL we cannot see it approaching. After a tachyon has passed nearby, we would be able to see two images of it, appearing and departing in opposite directions. The black line is the shock wave of Cherenkov radiation (see above), shown only in the diagram at one moment of time.

There is a good animation of these still images at

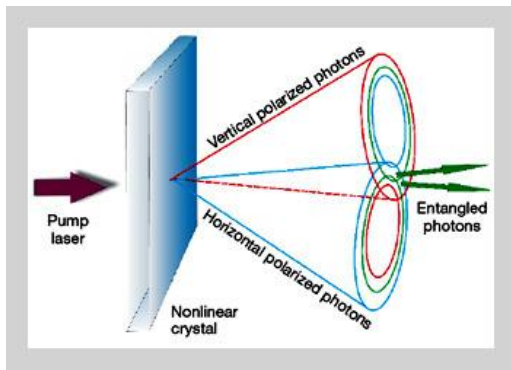
<http://en.wikipedia.org/wiki/File:Tachyon04s.gif> or

<http://www.message-to-eagle.com/images/Tachyon04s.gif>

Due to quantum particle/wave duality whereby particles have wavelike properties and vice versa, the tachyon stream can have its wave train frequency modulated to behave like a FtL equivalent of a FM radio wave used for short range communications.



The third method utilises the properties of quantum entangled particles, a technology that is used in the quantum computers utilised in the highest power AI modules.

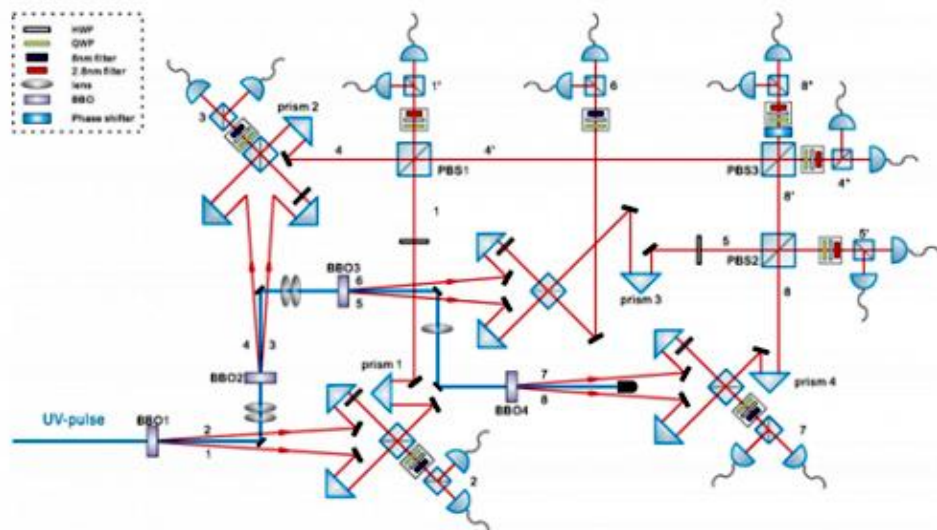


The method is based on the creation of pairs (or pairs of pairs or pairs of pairs of pairs etc) of quantum entangled photons using a quantum cloning system.

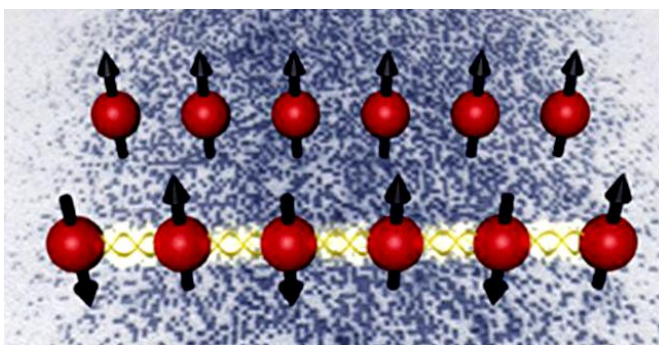
The entangled photons are captured in photon traps (which can be seen as the green and orange cylinders in the centre of the 'entangler'). In this experimental entangler photons are entangled in fours - the other two traps are on the other side of the cylinder.



The experimental schematic for an entangled octuplet look like this . . .



. . . which demonstrates the complexity of a scaled up system given that thousand photon entanglements would be required



One of the entangled photon tubes is transported to each station of the communication network. Collapsing the quantum state of one of the entangled particles instantly causes the collapse of the all the others regardless of how far away they are. Each particle can be used to transmit only one 'bit' of data and so a typical very short message requires around 10K entangled photons.

Efficiency can be increased by coding the messages so that one symbol stands in for a word or sentence or even a phrase. Effectively the message is encoded, but there is a delay as the encoding and decoding take place.

The problem is that the particles can only be separated after they are made in entangled pairs or groups and have to travel to their destination using methods that are less than the SoL or via expensive wormholes. One way around the limit is to create a network of prepared entangled photons that must be set up in advance and then be kept 'topped up'. This would be used in conjunction with distribution via a network of relay stations similar to that built for WH communication to minimise the number of entangled clusters required. This is a technically and practically difficult solution, since the entanglement is fragile.

However, research continues because it would allow near instant communications across the universe. The military and large corporations are attracted to the inherent strong data protection to guard against eavesdropping of sensitive data streams.

Section 7: Portable Energy Resources including emergency boosters

Background 20th & 21st Century physics

Fusion cells are also a high end energy source, but are much easier to produce. They feature a very long lifespan and usually provide a high price for shipping. These employ 'cold fusion' cells and hence don't need the complex magnetic containment 'bottles' required for hot fusion that recreates conditions in the centre of a star (temperatures of 15 000 000 K or more!)



Cold fusion was first reported in the late 20th Century by Stanley Pons and Martin Fleischmann. It was the most heavily hyped science story of the Century, but the awed excitement quickly evaporated amid accusations of fraud and incompetence. When it was over, Pons and Fleischmann were humiliated by the scientific establishment; their reputations ruined, 'Cold fusion' and 'hoax' became synonymous in most people's minds. However many reputable scientists continued to play with cold fusion and in 2025 Pons and Fleischmann were completely vindicated, when they shared the Nobel Prize for Physics for their discovery.

Cold fusion systems are still based on the basic same system reported by P&F in 1989. Their system had produced excess heat in quantities that could only be explained in terms of nuclear processes. They further reported measuring small amounts of nuclear reaction by products, including neutrons and tritium. Their small tabletop experiment involved the electrolysis of 'heavy water' using palladium electrodes. Heavy water is water in which the two hydrogen atoms are replaced by the isotope of hydrogen called deuterium. Hydrogen atoms, the simplest atoms, contain one proton and one electron; deuterium atoms have one proton and one neutron in their nuclei plus an electron in orbit. Palladium is a member of the platinum group of metal elements in the periodic table along with platinum (!), rhodium, ruthenium, iridium and osmium group. They are all excellent catalysts.

Modern 'Low Energy Nuclear Reaction' (LENR) cold fusion units utilise the Mossbauer effect, a process isomeric nuclear transitions in a chemically bound crystal structure solid. The regular array of the crystal both increases the fusion efficiency greatly but also allows a finer degree of control.

Deuterium-Tritium mixtures are used as the 'fuel' with dendritic palladium hydride electrodes. The fractal dendritic structure increases the surface area to volume ratio of the palladium electrodes by a factor of 10 000.

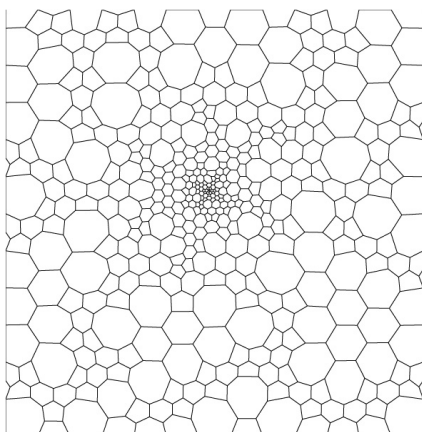


Diagram of a dendritic fractal structure

Anti-matter cells are a high end energy source that are extremely expensive to produce and provide a very long lifespan. As a result, a premium is paid for these devices to anyone who can deliver them.



Antimatter cells use a micro-QVee unit to extract antimatter from the quantum vacuum. This is used in nanogram scales in a matter/antimatter reaction cell, releasing very high quantities of energy. The antimatter extractor isn't very efficient but given the amount of matter released by even a gram of antimatter in contact with matter, it is more than adequate for its purpose. It is also much safer since the energy can be produced at a controlled rate and there is little chance of a significant amount of antimatter leaking out at any given time.

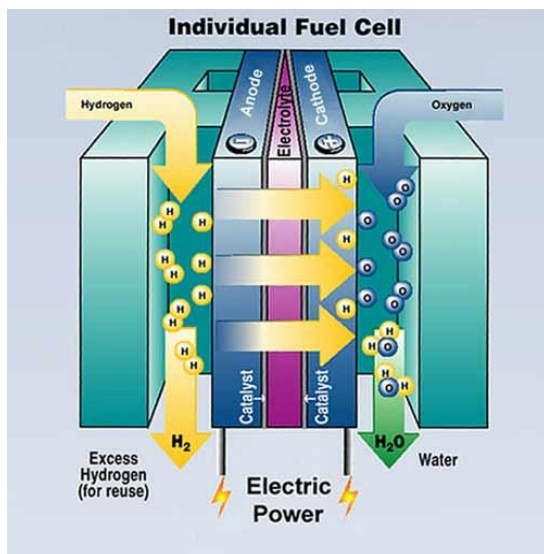
Fusion cells are not available to domestic users!

Hydrogen Fuel Cells are a common medium level energy source that some systems use for general purpose electrical power needs. Their moderate value makes them a popular shipping choice.

Basically, a fuel cell converts the chemicals hydrogen and oxygen into water and in the process it produces electricity. It is similar to another electrochemical device with which we are very familiar with - the battery. A battery has all of its chemicals stored inside and it converts those chemicals into electricity, the battery eventually goes dead and it is necessary to either re-charge it or after awhile it is defunct and needs to be thrown out.



With a fuel cell, the chemicals constantly flow into the cell so it never goes dead. The fuel cell creates a direct current voltage that can be used to power motors and electrical appliances.



To do this it uses hydrogen as a fuel to combine with the oxygen, converting them into water while producing the heat and electricity - the cell has two electrodes, an anode and a cathode, separated by a membrane. Oxygen passes over one electrode and hydrogen over the other. The hydrogen reacts on contact with a catalyst on the anode. The hydrogen gas is converted into negatively charged electrons (e^-) and positively charged ions (H^+). The electrons flow out of the cell to be used as electrical energy. The hydrogen ions move through the electrolyte membrane to the cathode electrode where they combine with oxygen and the electrons to produce water.

The **catalyst** facilitates the reaction of oxygen and hydrogen. It is manufactured from platinum nanoparticles coated onto a graphene sheet. The catalyst is rough and porous so that the maximum surface area of the platinum can be exposed to the hydrogen or oxygen.

Hydrogen fuel cells are available in a variety of power capacities. They are self-contained units and for domestic use aesthetically designed. Those intended for 'industrial' environments incorporate valued characteristics of simplicity of maintenance and robustness.

Domestic cells can be refilled with hydrogen gas under pressure - industrial cells maintain this option but the majority tend to employ a continuous hydrogen feed which is replenished by the most appropriate of several classes of hydrogen generator/extractor available, depending on the location and application involved;



Emergency energy/fuel boosters:

Charge Packs provide a single full recharge to a ship's energy reserves.

They can be installed on secondary hardpoints

Fuel Packs provide 200 units of fuel each. They are used to extend the range of a ship without the need to stop and refuel at a station, city or carrier

They can be installed on secondary hardpoints.



Section8: Miscellaneous Technologies

Background: [nanotechnology](#) + 20th & 21st Century physics and engineering

Terrain Walkers



The IMG-TR Terrain Walker (TW) is a multi-purpose planetary exploration and recovery platform. They are designed to allow mercenaries to explore planetary surfaces up close without the need to use expensive spacecraft fuel. They also provide several important functions via standard equipment that normally has to be purchased and installed separately on ships. Terrain walkers are often available in high technology systems, but are generally very expensive. They are installed as an equipment item.



Most planets require a degree of terraforming to make them inhabitable - the process can take decades, even centuries. Terrain walkers are designed for protecting the pilot against the harsh environments of most planets outside colony buildings or cities. They utilize a nuclear power source generating enough electricity to power an extensive life support and environment system. Various electric actuators and motors handle movement and rotation while remaining power is devoted to available combat systems. Terrain walkers also utilize the surrounding atmosphere for life support and cooling. As a result of these dependencies, **they can't be used in the vacuum of space or on the surface of moons with no atmospheres or asteroids or inside stations.** For safety a TW will not deploy over water or if the ship is on a city docking station (or any other city building!)

While primarily designed for exploration and recovery (they are similar in size to your ship) terrain walkers also come equipped with powerful particle cannons and shield arrays. These are higher spec than the ones fitted to ships (TW's being newer technology!) As a result a terrain walker can generally protect itself effectively against one or two attackers flying spacecraft.

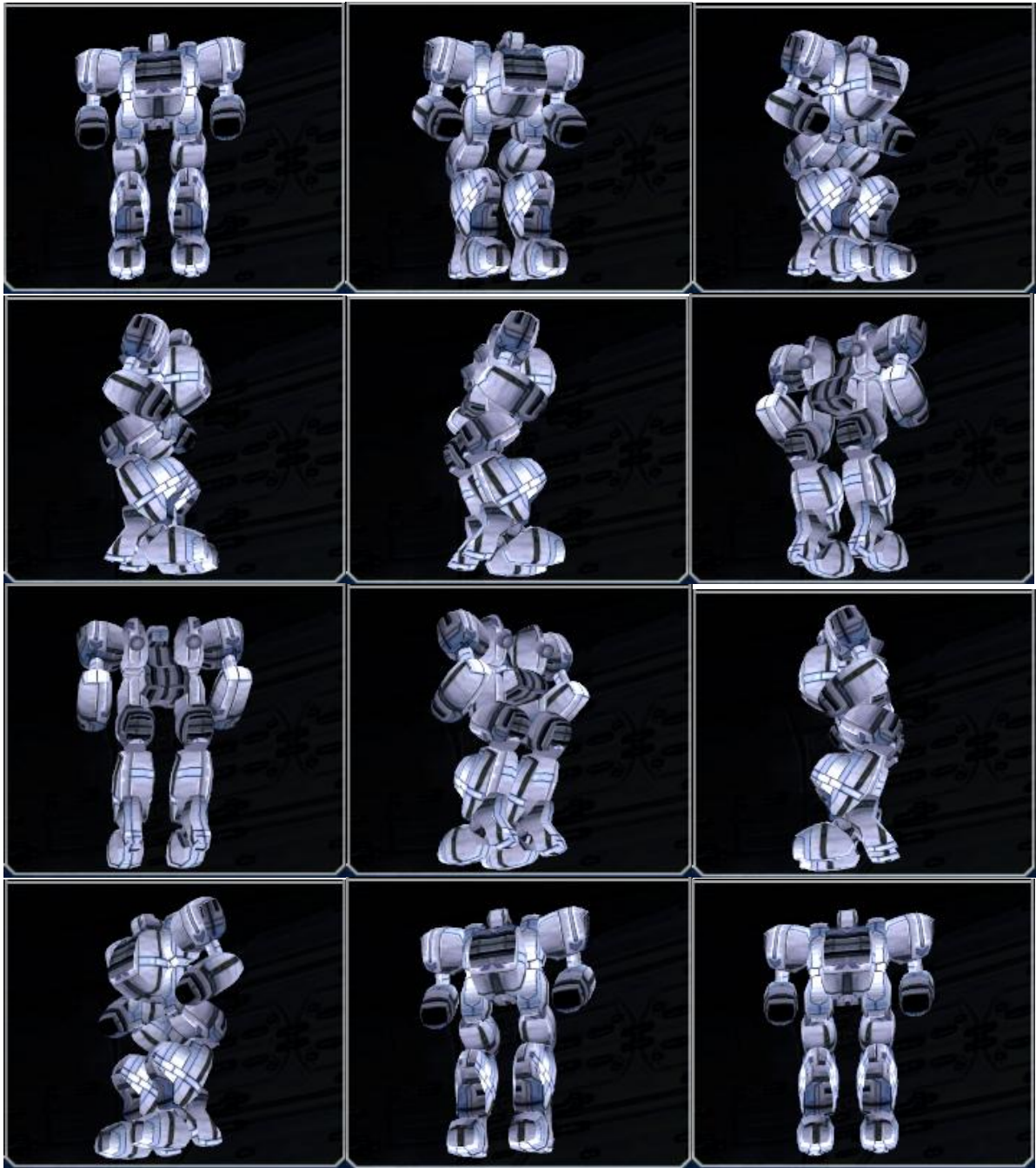
TW's are capable of functioning underwater - an enhanced image mode automatically cuts in when you enter a sea or a lake similar to ship carried units used in asteroid caves

At present TW's are not capable of accepting upgrades.

Terrain Walkers are equipped as standard with;

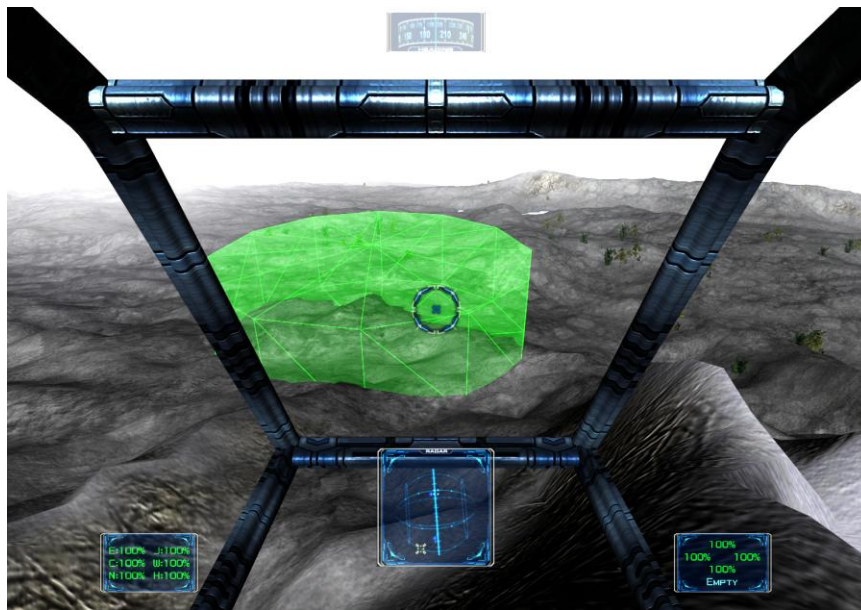
- shields (like a ship) - four projectors cover front, rear, left and right
- a pair of particle cannon of a higher spec than the best off-the-shelf cannon available from trade stations, carriers etc
- short range jump jets enabling fly in short bursts. They can provide a quick escape and a way to quickly reach the tops of mountains and buildings. The jump jet's fuel system utilizes materials extracted from planet atmospheres and recharges after use.
- a mining/tractor beam - mercenaries are often hired to recover a full load of a specific material due to their faster mining rate (roughly 5X as fast as a typical spacecraft mining system).
- one cargo bay
- a high powered cargo scanner allowing them to retrieve details about container contents at long range for example from canisters that have been abandoned or dropped from space
- advanced 3D imaging equipment designed for close range surveying. Some energy companies are known to hire mercenaries with terrain walkers to survey an area before construction or mining projects.

Combined with their built-in mining beams, terrain walkers make a valuable addition to the toolset of mercenaries interested in cargo salvage and planetary surface exploration



This image gives a full 3D surround view of a TW.

The HUD is significantly simpler than the one fitted into a ship. It includes a



- target reticule
- compass
- radar globe
- shield readout
- cargo bay readout
- scanner readout
- status display of hull integrity, navigation system integrity, engine/motor integrity, cannon integrity and energy reserve, jump jet energy reserve, shield integrity etc

The LHS display is arranged as;

Engine damage level (%)	Jump Jet energy level (%)
Cannon damage level (%)	Cannon energy level (%)
Navigation System damage level (%)	Hull damage level (%)

A linked stealth device comes standard with every terrain walker, giving mercenaries a way to hide and protect their ship while they travel around in the walker. A green HUD marker is left behind to guide pilots back to where they left their ships. They simply need to return to the marker and park their walker inside it. They can then deactivate the walker, returning it to its compact state in an equipment slot, then continue to fly their ship.

The radar globe always displays a blue icon that shows the position of the stealthed ship. It can also show the location of canisters and ships (with the usual hostility level colours). The compass and radar globe are linked to the galactic disc - **not the planet**. It must be emphasised that the radar globe does **not** show the planet and the compass reading of zero does **not** point North! Set waymarkers will also show, but be aware that because they are fixed in relation to the galactic plane and not the planet surface. the waymarker will appear to drift as the planet rotates! You cannot use a waymarker to identify the location of a city for example!



Terrain Walkers are about the same size as your ship!! The walker and ship in this picture are close enough for the walker's shield to be activated by bumping.

When not deployed, they fold into a package unit small enough to fit into a ship's equipment slot. When activated (default ' K' key), the walker core extracts itself and uses the detailed design specs to compile its various structures into the complete design with legs, arms, centre torso, and head. As is usual the QVee extracts atomic matter from the quantum vacuum and nanotechnology systems create the appropriate extensions onto the core.



The deployment and recovery is virtually instantaneous; this sequence of photographs taken on a high speed camera shows what happens on deployment. As can be seen, the ship reorientates, and starts to drop. The deployment of the walker occurs at the same time as the ship is stealthed. The walker is lowered to the ground on a tractor beam and activated.

Fuel Converters are remarkable pieces of equipment that can transform high energy photons from solar corona or nebula clouds into fuel. It connects to the tractor beam system and fuel tank to directly deposit the converted fuel into the tank.



Cargo containers have a programmable radio frequency identification (RFID) tag built into their structure. RFID tags are intelligent 'barcodes' that can talk to a networked automatic cargo handling system to track every product that is put into a cargo container.

These passive RFID tags can store up to 2 kilobytes of data and are composed of a microchip, antenna and, in the case of active and semi-passive tags, a power source. The tag's components are enclosed within tough tamper proof polymer envelope within a cavity within the container wall. This is to maintain compliance with Evochron custom and tax laws.



At a basic level, each tag works in the same way:

1. Data stored within an RFID tag's microchip waits to be read.
2. The tag's antenna receives electromagnetic energy via a pulse from an RFID reader's antenna.
3. Using power from its internal battery or power harvested from the reader's electromagnetic field, the tag sends data via modulated radio waves back to the reader.
4. The reader picks up the tag's radio waves and interprets the frequencies as meaningful data.

An RFID will broadcast the contents of the container when interrogated by an appropriate electronic transmitter. RFID technology became common in the late twentieth century and has proved to be useful and reliable. This facility is primarily designed for automated cargo handling between different stations, ships and trade stations and between ships in space. Cargo scanners are a modification of this technology that allows the detection of the identity of cargo (either in open space or in a ship's cargo bay) at a much longer range of between 500 and 2500 Dm, depending upon the scanner's class.

Repair Devices automatically repair subsystem and hull damage in-flight. Installing one of these means you don't have to dock and pay for repairs. Subsystem damage can be repaired fairly quickly, but hull damage takes a long time to repair. Class 1, 2 and 3 devices are available, with increasing speed of repairs. Military ships are rumoured to be fitted with even higher classes.



An AI core module analyses the damage to the hull and internal systems. A QVee module creates the solid materials required and provides the energy for fabrication of various replacement components. Nanotechnology in the form of nanobots carry out the fabrication.

Given the size limitations of a shipboard repair system the process is relatively slow. Many pilots use the facility if they have some free time or no access to a station - otherwise deploying a repair station or using the facilities in a trade station can get a pilot back into the action far more quickly!

The matter extracted from by the QVee from the quantum vacuum is used to repair hull damage - it doesn't repair the 'paint job'. You can fly and fight again but everyone knows you got burned!

Structural Integrity Fields









The main function is to increase the structural integrity of large, relatively weak structures such as trade stations.



This field is a modification of the combat shield and is projected through the structure of a station essentially turning the material into a cross between matter and force field. This increases the strength and rigidity by orders of magnitude, allowing the materials to withstand the stresses associated with their mass (megatonnes), size and operations.

One of the functions of the Station Detonator is to destabilise the SIF generators







Appendices





Appendix 1: Ship Frames (Civilian - Alliance)

 <p>Talon</p>	<p>The Talon is a scout class frame that provides a basic platform for new mercenaries. It is inexpensive to build and operate. While the weapon options and defensive capabilities are limited, the Talon frame is the fastest platform and most manoeuvrable. While its design possibilities are limited, it can be optimized effectively for particular advantages.</p>
 <p>Pulsar</p>	<p>The Pulsar frame expands on the original and provides more assembly resources with a minimal reduction in performance and manoeuvrability. It also includes substantially more armour and is a more flexible platform from a design options standpoint.</p>
 <p>Saber</p>	<p>The Saber is a fighter class frame, although it is also used as a scout by many mercenaries. Its reinforced armour and efficient power system provide a high level of protection for such a small frame. Like the Raven, the Saber frame is considered to be the best choice for light and medium combat duties by most mercenaries and is very affordable.</p>
 <p>Raven</p>	<p>The Raven frame expands on the Saber design. With a larger size, it offers more assembly resources and armour at a similar level of performance. Named after the Alliance combat spacecraft that fought in the first Alliance-Federation war, the new Raven provides a solid platform for mercenaries looking for a capable combat frame with amazing performance and manoeuvrability.</p>
 <p>Striker</p>	<p>The Striker frame is a unique compact design that uses blended metallic composites for very effective armour protection and advanced technology to keep its overall size small compared to other frames. Its rounded shape and powerful energy system allow it to have a high level of assembly resources and support for energy hungry shield systems. An excellent multi-role frame.</p>
 <p>Phoenix</p>	<p>The Phoenix class frame is a revised version of the Striker, offering a much larger structure with more assembly resources and armour. These improvements are available with a minimal reduction in agility. Most mercenaries who prefer the advantages of the Striker frame choose the Phoenix as the best version.</p>
 <p>Hunter</p>	<p>Designed to survive intense large scale battles and protect valuable cargo from even the most powerful adversaries, the Hunter class frame boasts triple layer metallic composite armour and plenty of assembly resources for high end components. It's main drawback is limited agility and speed, but it is ideal for mercenaries who require high end offensive and defensive capabilities.</p>
 <p>Renegade</p>	<p>The Renegade class frame was built as a combat oriented upgrade to the Hunter frame. It sacrifices some agility for a larger size with 25 more assembly resource points and another layer of armour. It also features a compression capacitor in its engine management module, which helps to minimize the loss of speed, resulting in a reduction of only 50 MPS base speed compared to the Hunter frame.</p>









 <p>Centurion</p>	<p>Considered the battleship among mercenaries, the Centurion frame commands attention and respect. Only wealthy mercenaries can afford to buy and operate this ship, but the reward is a commanding lead over other frames in most combat situations. It can be designed to also be an effective transport, offering a level of cargo safety far above what other ships are capable of.</p>
 <p>Leviathan</p>	<p>Several private mercenary groups pooled their resources together to develop the Leviathan class frame as an answer to the Centurion which had dominated much of Evochron for a long time. The Leviathan offers an unequalled level of assembly resources and armour. It usually takes a skilled group of pilots to defeat one of these ships.</p>




Appendix 2: Ship Frames (Civilian - Federation)

 <p>Arrow</p>	<p>One of the first Federation frames made available to mercenaries operating in Alliance space, the Arrow frame offers remarkable agility. While not quite as fast as the Alliance built Talon, its powerful thruster system gives it a manoeuvrability level that's over 20% higher.</p>
 <p>Scorpion</p>	<p>The Scorpion offers a robust platform for a light frame. With a higher design capacity than most other light frames coupled with agility that matches the Arrow, it is a very capable platform for light transport and combat duties. This frame is also popular for racing.</p>
 <p>Panther</p>	<p>The Panther is a sleek design offering high speed and moderate assembly capacity. It's not quite as agile as the lighter Federation frames, but can hold its own against the Alliance Talon and Saber frames. With its higher design capacity and high speed for its size, this frame is a popular choice for mercenaries who trade in moderate to hostile space.</p>
 <p>Mirage</p>	<p>The Mirage frame is a very capable medium combat platform. Complementing its thick armour is a high power shield core similar to the design used on the military's Aries fighter. It's not quite as fast as the comparable Alliance Raven frame, but it has an edge in agility and design capacity. This frame is a popular choice among skilled combat pilots.</p>
 <p>Venture</p>	<p>The Venture was designed for moderate transport duties. It has a relatively high assembly capacity for its size along with a multi-coil shield core. While its additional bulk does limit its velocity and acceleration, powerful manoeuvring thrusters help it match the agility of the lighter Mirage frame, even with its heavier hull armour.</p>
 <p>Sentinel</p>	<p>Named after the defensive combat role it was built for, the Sentinel is often used in escort and support duties. It has earned a reputation of being able to take a hit. With its moderate assembly and design capacities, it can also be made into a formidable offensive combat spacecraft. Mercenaries often devote its available resources to weapons and shields.</p>

 <p>Guardian</p>	<p>The Guardian is based on the Sentinel's design, but adds significantly more armour, assembly and design capacity, and shielding. Its ability to carry a much higher payload comes at a price, its speed and agility are significantly less than the lighter Sentinel. However, many pilots consider its additional protection well worth the price.</p>
 <p>Legacy</p>	<p>The Legacy frame is designed to provide a high cargo and weapon capacity in one of the fastest and most agile heavy designs. It features much better agility compared to a similarly configured Renegade frame along with a slight speed and acceleration advantage. Because of its agility, this frame is often used in heavy combat roles.</p>
 <p>Mammoth</p>	<p>Designed to be a heavy transport, the Mammoth offers enough design capacity to carry many of the most advanced equipment upgrades at the same time. While it's slightly slower than a comparable Centurion, it is significantly more manoeuvrable. This ship is often the preferred choice for surviving in hostile space.</p>
 <p>Starmaster</p>	<p>Little is known about this frame. The Starmaster is rumoured to be built in only a few secret locations and is generally only owned by the wealthiest of mercenaries.</p>

Appendix 3: Ship Frames (Military)

 <p>Ferret</p>	<p>The Ferret is a lightweight scout spacecraft designed for high speed reconnaissance. It carries a basic internal missile rail of 4 hardpoints. The Ferret has minimal armour, but its high agility and speed makes it very effective at evading missiles and gunfire.</p>
 <p>Aries</p>	<p>The Aries is categorized as a scout but provides sufficient armour and speed for it to be effective in light fighter roles as well. This spacecraft is often used for training combat fighter pilots. It is also often used for patrols and scout duties that require more range than the Ferret can provide.</p>
 <p>Shadow</p>	<p>The Shadow is the Alliance's primary light attack fighter. For its size and agility, this spacecraft carries a remarkably high payload limit. It also features a shield core with nearly the same output capacity as the Wraith. Its wing design also gives it an advantage in atmosphere manoeuvrability while its composite armour offers good resistance against direct hull impacts.</p>
 <p>Wraith</p>	<p>Considered to be the front line fighter in the Alliance Navy, the Wraith is a multi-purpose medium range strike fighter with extreme speed and agility. With 8 hardpoints and moderate armour, it's a well rounded fighter package capable of filling a variety of combat roles.</p>
 <p>Evoch-C</p>	<p>The Evoch-C is the next generation of Alliance military fighter technology. It includes a manoeuvring system based on reverse engineered Vonari spacecraft and unique ion-pulse engines that together provide the most agile and fast spacecraft known to exist. Its reflective armour offers slightly better protection against particle cannons compared to the Wraith.</p>
 <p>Evoch-E</p>	<p>The Evoch-E is a heavily redesigned version of the C model. This platform essentially takes the original Evoch design and improves it in virtually every area. It is faster, more manoeuvrable, and better armoured than the original. The only drawbacks to this design over the C model are higher fuel use and cost. This new fighter is considered the latest in technology.</p>
 <p>Lamprey</p>	<p>The Lamprey is based on the Evoch-E platform, but is modified to perform a more strike oriented role. What it lacks in speed and agility, it makes up for in armour and shielding. It's unique forward swept wing is combined with a powerful thruster set which provides excellent agility in planet atmospheres and open space.</p>
 <p>Firestar</p>	<p>Considered by many to be the best overall strike spacecraft, the Firestar is an all-new design built to replace the aging Avenger. It offers a significant speed advantage over the Avenger while being barely slower than the Lamprey. It's also much more agile than the Avenger with a minimal reduction in armour. As a result, this design is also capable in a dogfight.</p>

 <p>Avenger</p>	<p>The Avenger is designed to be a heavy interceptor and strike spacecraft. Its thick armour coupled with high speed and agility for its size give it a distinct advantage in many heavy combat roles and strike missions against powerful capital ships. The Avenger is the primary strike and intercept spacecraft of the Alliance Navy.</p>
 <p>Shrike</p>	<p>The Shrike is a major redesign of the Avenger platform. It is a heavy attack spacecraft optimized for capital ship engagements. Its reactive armour and powerful shield core provide an effective defence against flak cannons and particle gun impacts. The Shrike also has the highest speed of its class, allowing it to reach its target quickly.</p>
 <p>Predator</p>	<p>The Predator is generally regarded as the Alliance Navy's most powerful heavy attack spacecraft. It has the heaviest armour of any military spacecraft and provides agility that exceeds even the lighter civilian Centurion and Leviathan frames. It is used sparingly due to its high construction and repair costs, but is the spacecraft of choice when the objective involves high numbers of powerful enemy forces.</p>
 <p>Chimera</p>	<p>The Chimera is the result of numerous experiments and design concepts to produce the ultimate heavy attack spacecraft. Its high fuel burn rate and extreme cost limit its practicality and accessibility. But with its decent agility and speed, immense shield core, and ply-carbon plate armour, it is a force virtually no one wants to go up against on the battlefield.</p>

Appendix 4: Ship Stats

Originally created by Marvin - updated for Expansion by DaveK & Busch

CIVILIAN SHIPS - BASIC CONFIGURATION (original data provided By Marvin)					
NOMENCLATURE	ASSEMBLY	CAPACITY	AGILITY	ARMOR	BASE SPEED*
Talon	200	7	80	90	558
Arrow	225	8	100	85	545
Scorpion	225	9	100	105	519
Pulsar	225	8	75	110	525
Saber	250	10	72	130	505
Panther	275	10	74	125	492
Raven	300	11	70	140	479
Mirage	325	12	70	145	459
Striker	350	12	65	180	459
Venture	375	14	70	170	440
Phoenix	400	14	55	190	413
Sentinel	425	15	58	185	413
Hunter	450	18	50	210	361
Renegade	475	19	35	225	328
Guardian	500	18	55	200	374
Centurion	500	21	30	250	262
Legacy	525	20	50	220	348
Mammoth	550	21	45	240	256
Starmaster	550	22	40	280	243
Leviathan	550	22	25	300	262

* Ships speed when fitted with an Illumine MK I Engine.

CIVILIAN SHIPS - STANDARD ASSEMBLY COMPONENTS* (Original data provided By Marvin)

NOMENCLATURE	HARD POINTS	CM PACKS	EQUIPMENT SLOTS	CREW SLOTS
Talon	2	1x25	3	1
Arrow	3	1x25	3	1
Scorpion	3	1x25	4	1
Pulsar	2	1x25	4	1
Saber	4	1x25	4	1
Panther	4	1x25	4	1
Raven	4	1x25	5	1
Mirage	4	1x25	5	2
Striker	5	1x25	5	1
Venture	5	2x25	5	2
Phoenix	8	1x25	4	1
Sentinel	5	2x25	5	3
Hunter	8	2x25	5	3
Renegade	8	2x25	5	4
Guardian	8	2x25	5	3
Centurion	8	4x25	5	4
Legacy	8	3x25	5	4
Mammoth	8	4x25	5	4
Starmaster	8	4x25	5	5
Leviathan	8	4x25	5	5

* Assembly components can be modified and adjusted within the ships capacity range.

MILITARY SHIPS* (Provided By Marvin)

NOMENCLATURE	ASSEMBLY	AGILITY	ARMOR	HARD POINTS	MAX SPEED
Ferret	400	94	120	4	814
Aries	400	90	135	4	788
Shadow	420	95	145	8	821
Wraith	420	95	155	8	821
Evoch-C	440	100	180	8	880
Evoch-E	440	105	200	8	900
Lamprey	470	92	220	8	801
Firestar	470	90	240	8	788
Avenger	500	70	270	8	755
Shrike	500	55	285	8	722
Predator	500	50	310	8	689
Chimera	500	52	375	8	709

* All military ships are fitted with eight equipment slots and 4x25 CM Packs and 1 cargobay.

Appendix 5: Engine data

Originally created by Marvin - updated for Expansion by DaveK & Busch

ENGINES (Original data provided By Marvin)				
NOMENCLATURE	ASSEMBLY	THRUST	FUEL USAGE	INCREASE*
Illumine MK I	15	150	36	0
Illumine MK II	25	300	60	32
Voyage MK I	45	450	84	65
Voyage MK II	70	600	108	98
Richton Ion	90	750	132	131
Clan Richton Ion	115	900	144	164
Neptune MK I	145	1050	156	197
Neptune MK II	155	1200	168	230
Quantum Ion MK I	170	1350	180	262
Quantum Ion MK II	200	1500	192	295

* Amount of increase (+/-0.5) to a Ships Base Speed.

Engine Class 1 Illumine Mark I Engine While merely an entry level engine, the Illumine is ideal for Scouts that are designed more for shipping, mining, cleaning, trade, and other non-combat objectives. The engine is known for its low cost of operation, being the most fuel efficient type of engine available to mercenaries.

Engine Class 2 Illumine Mark II Engine This upgraded version of the Illumine engine provides adequate performance for light combat duties, but is generally considered to be best for non-combat objectives. It's small design, low fuel consumption, and modest output provides a good first upgrade for rookie mercenaries flying light spacecraft.

Engine Class 3 Voyage Mark I Engine Designed to provide a high level of power with minimal assembly use, the Voyage class engine is the ideal choice for small spacecraft that need assembly resources for other critical components. It also includes twin vertical stabilizers to improve atmospheric control.

Engine Class 4 Voyage Mark II Engine The Mark II offers remarkable power output for its size and assembly resources. It's considered by most mercenaries to be the best choice for light and medium class spacecraft. It also offers close to the power output of a Richton engine with a substantially lower assembly resource requirement.

Engine Class 5 Richton Ion Engine The military research division in the Richton system developed this engine for use in interceptor class combat spacecraft and was soon made available to mercenaries looking for a propulsion system that balances fuel consumption with power output. The Richton is a good overall choice for a variety of combat and non-combat roles.

Engine Class 6 Clan Richton Ion Engine The CR Ion Engine Improves the power capacity of the original Richton version with a very small increase in fuel consumption. Not generally recommended for smaller spacecraft, the Clan Richton engine is a good fit for medium sized spacecraft.

Engine Class 7 Neptune Mark I Engine The Neptune is a well armoured and efficient propulsion system. For its power, the Neptune is relatively fuel efficient. It's generally a better choice for larger ships requiring powerful engines and with a high level of assembly resource needed to accommodate its size.

Engine Class 8 Neptune Mark II Engine The Mark II Neptune is substantially larger and more powerful than the Mark I. It also includes a much larger cooling system with bigger heat vents for improved efficiency and reduced exposure to damage. The Neptune is also well shielded and is a popular choice for mercenaries who frequently engage in heavy combat.

Engine Class 9 Quantum Ion Mark I Engine The Mark I Ion engine is the civilian version of a classified military propulsion system offering far more power than other engine types. It includes 2 compression cells which improves performance for rapid speed changes and 4 sub-outlets for stability.

Engine Class 10 Quantum Ion Mark II Engine The Mark II is essentially two Mark I engines joined together. It includes 4 compression cells and 8 sub-outlets. While not the most fuel efficient engine by any measure, its output is unmatched and provides remarkable speed even for the heaviest spacecraft.

Appendix 6: Wing data:

Please note that in the following descriptions taken from manufacturer's technical sales literature, 'thruster coils' is the name for the combination of the plasma acceleration coils and electromagnetic focussing lenses

Wing Class 1 (assembly points: 10) The *StarGlider* is the standard entry level wing system. It provides moderate performance for small ship frames and requires a very low level of assembly resources. Combined with a low cost, its features result in this wing and thruster set being a common choice for pilots who want to compromise on agility. This system includes the weakest thruster set available to mercenaries.

Wing Class 2 (assembly points: 20) The *Archer* wing system is a minor increase in overall performance compared to the StarGlider, but it does offer its improvement at a minimal cost in assembly resources and credits. It works best on smaller frames, but is also useful on larger frames to recover needed assembly resources for pilots who want to reduce manoeuvrability for other options.

Wing Class 3 (assembly points: 35) The *Raptor* wing is unique among small class wings. It provides a much higher level of performance and stability compared to other wings in the same class and even some in higher classes. It's twin pylon design for its 4 tail fins only needs to be attached to a frame at the front two wings, which keeps assembly resource consumption to a minimum.

Wing Class 4 (assembly points: 55) The *Falcon Mark I* wing is ideal for light and medium frames. It provides improved thruster performance needed for heavier frames and doesn't require a lot of assembly resources. It's original application was on Alliance military spacecraft and is now being sold in the free civilian markets of Evochron.

Wing Class 5 (assembly points: 70) The *Falcon Mark II* wing adds a one piece tail section to the original design, further improving agility. A good upgrade for small and medium frames.

Wing Class 6 (assembly points: 80) The *Falcon Mark III* wing adds two middle fins to the Mark II design along with additional thruster coils further improving agility. Recommended for small and medium frames.

Wing Class 7 (assembly points: 95) The *Razor Mark I* wing is a good choice for medium frames as it includes two thruster packs to assist the inertial dampening system for improved manoeuvring performance. It's additional weight and connections for the thruster system do require substantially more assembly resources, but most pilots consider the advantages it offers to be worth it.

Wing Class 8 (assembly points: 110) The *Razor Mark II* wing adds vertical stabilizers to the wings for improved performance. Not an essential upgrade, but a minor improvement for frames with a few assembly resources remaining.

Wing Class 9 (assembly points: 120) The *Razor Mark III* wing adds a tail section, offering additional thruster coil space for improved performance and stability. Another minor improvement to the Razor design.

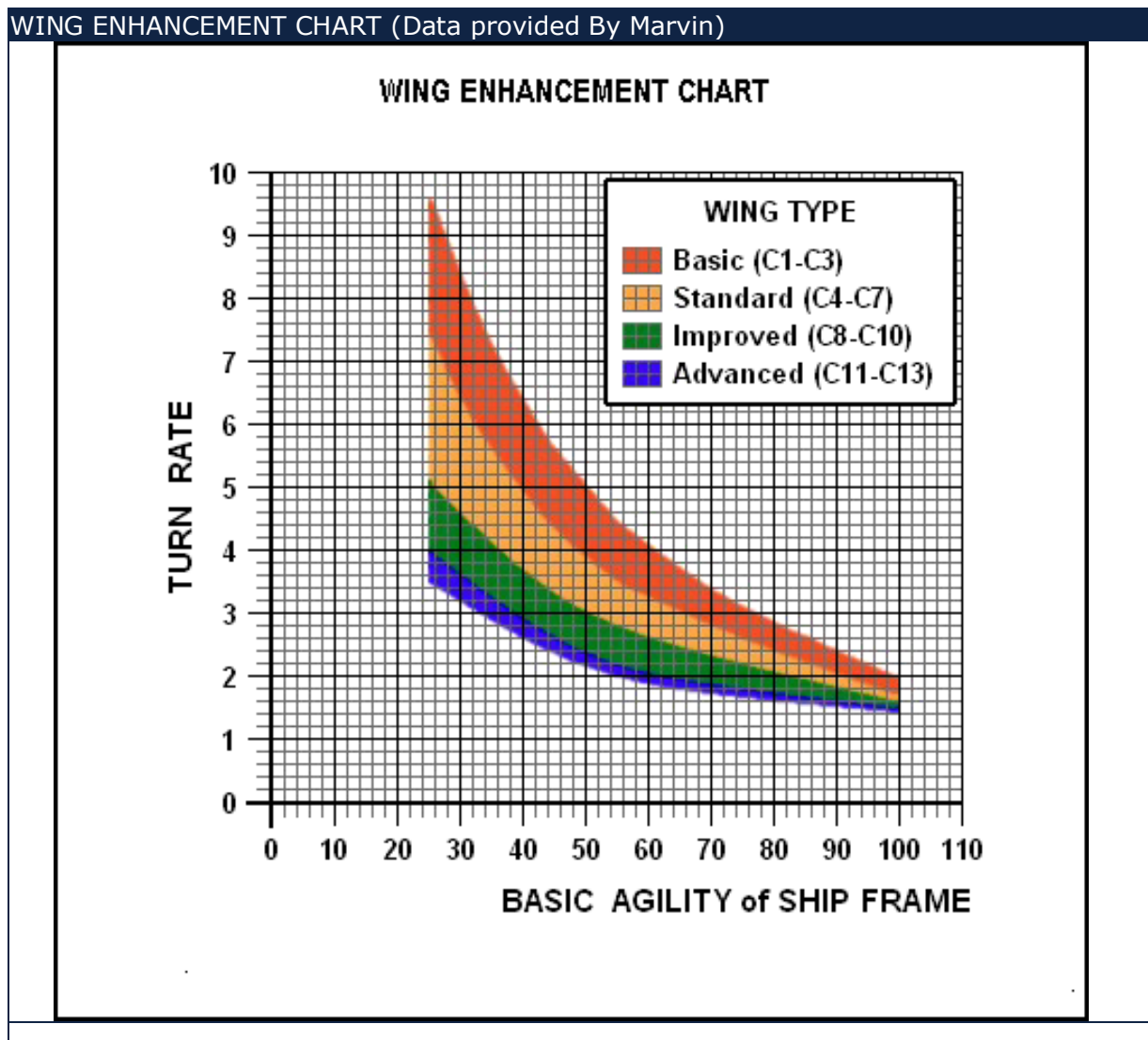
Wing Class 10 (assembly points: 135) The *Razor Mark IV* wing adds two middle stabilizing wings. While the individual enhancements offer minimal improvements, collectively they provide a substantial upgrade compared to the MKI design.

Wing Class 11 (assembly points: 150) The *NightHawk Mark I* wing may look very small in comparison to other wing designs, but it features a revolutionary advancement previously only used in military applications. Mounted on each wing is an anti-gravity pod that is used to generate additional power and agility. It's design provides a higher level of performance than even the bulky Razor.

Wing Class 12 (assembly points: 170) The *NightHawk Mark II* wing adds rear vertical stabilizers to the original design, offering additional stability and anti-gravity emitters. It retains the same low visual profile and overall size as the Mark I design.

Wing Class 13 (assembly points: 180) The *NightHawk Mark III* wing adds middle stabilizer wings to the Mark II design, offering additional stability. It continues to provide a low profile appearance with its stealthy design. This wing is generally considered the best performing model available to mercenaries.

The graph is in the process of being revised for changes made in the Expansion - However, preliminary tests have shown that the basic patterns and shape of the graph will be the same - the actual turning rate will be a little different.



Appendix 7: Weapons Data

Originally created by Marvin - updated for Expansion by DaveK & Busch

Particle Cannon

Name	Yield	Cycle Rate	Range
C1: The FlareBeam particle cannon is a rapid fire, low energy, low yield weapon used by new mercenaries. It packs a decent punch for its low cost and energy use.	10	12	830
C1: The IceSpear particle cannon offers a higher yield than the FlareBeam and the same firing rate with only a slightly shorter range.	15	12	710
C1: The FireFury particle cannon provides nearly the same level of damage as the StarGuard cannon with a slightly longer range. Although its firing rate is comparable to lower class weapons, it's shorter range is a compromise.	24	14	680
C1: The StarGuard particle cannon is the most powerful class 1 weapon available. It's still a lower powered plasma based weapon, but it offers near class 2 level yield with a longer range.	32	14	650
C2: The Stalker particle cannon is a class 2 weapon designed for efficient energy use in exchange for a lower yield and shorter range.	38	20	630
The Eclipse particle cannon is a kinetic weapon designed to disrupt a target's ability to maintain a consistent orientation, making it more difficult for the target to effectively counter attack. It offers a low yield, so it is best used in conjunction with other weapons or in a defensive role.	25	20	620
C2: The StarForge particle cannon is a moderate class 2 weapon that provides an even balance between yield, energy use, and firing rate.	45	22	660
C2: The Maxim-R particle cannon is a powerful, long range class 2 weapon designed for medium to long range fighter engagements. It features the rapid firing rate of a class 2 design while including the long range of a class 1 design. It has the highest energy use of any class 2 weapon, but also the highest yield.	50	22	780
The SunRail particle cannon is an energy depletion weapon . It's best used with other weapons or in a defensive role to limit the attack capabilities of a target. Several hits from this cannon can deplete the primary energy reserve of a target ship.	20	25	630
C3: The Razor particle cannon is a short range weapon designed for close combat. While it is limited by the shortest range of any particle cannon, it also uses the least energy of any class 3 weapon.	55	25	530
C3: The Predator particle cannon is effectively the same design as the Razor, but optimized for a slightly longer range and higher yield. The only significant drawback to this variant of the design is its higher cost.	58	25	560
The Trebuchet particle cannon is a specialized weapon designed to deplete the shields of a target . This weapon is best used with other support spacecraft nearby ready to attack with other weapon types. It is also most effective when used with a beam weapon.	28	28	630

continued . . .

Particle Cannon (continued)

Name	Yield	Cycle Rate	Range
C3: The Atlas particle cannon is a high yield, short range, class 3 weapon designed to inflict maximum damage with each shot. Its high energy use and low firing rate can limit its effectiveness in certain roles, but with sufficient energy, it is a powerful weapon for capital ship strikes and other larger ship engagements.	70	28	580
C3: The Phantom particle cannon builds on the Atlas design by extending the range and yield. Its only drawbacks are its higher energy use and cost.	75	28	650
The Banshee particle cannon is a high powered kinetic weapon designed to knock a target off course. It is best used in a support or defensive role, although it does also do moderate class 2 level damage.	40	28	600

Beam Cannon

Name	Class	Yield	Range*
C1: The Refractor laser beam cannon is a low power weapon using basic technology. It uses very little power, but also inflicts the least amount of shield damage.	C1	28	Linked
C2: The Metal-Vapor laser beam cannon uses a low level of energy and has a low yield against shields.	C2	35	Linked
C3: The Coil laser beam cannon uses a moderate level of energy and has a moderate yield against shields.	C3	42	Linked
C4: The Neodymium laser beam cannon uses a high level of energy and has a high yield against shields.	C4	49	Linked
C5: The Fusion laser beam cannon offers the highest level of shield damage, but also uses the most energy.	C5	58	Linked
<i>* The range of a beam weapon is linked to its particle weapon counterpart.</i>			

Missiles - standard, available at all trade stations, carriers etc

Name	Yield	Range	Speed
C1: The Echelon missile is the fastest and longest range individual missile available. It's yield is also the least of any missile, but several of these can inflict significant damage and their cost is minimal.	1000	3800	1400
C2: The Viper missile is a long range, low yield design that inflicts a higher level of damage than the Echelon at a minimal reduction in range & speed.	1200	3500	1200
C3: The Rockeye missile is designed for medium range small craft combat. It offers a balanced mix of range, speed, and yield.	1400	3400	1000
C4: The Starfire missile is a multi-role, medium range, moderate yield design that works well in combat situations ranging from small ship dogfights to large ship escorts and intercepts. It generally commands a higher price for its versatile design.	1800	3000	900
C5: The Exodus missile is a short range, high yield design optimized for capital ship strikes and large ship engagements. They are best used at close range to leave little time for a target to use countermeasures.	2500	2400	700
The Leech EMP missile is designed to knock out a target's weapon and navigation systems . It's electro-magnetic pulse can disrupt a ship's sub-systems for several seconds, but it must detonate on contact with the target to work.	200	3500	1000
The Excalibur Pack is a regenerative missile system that constructs and fires eight missiles at a time. It takes a few minutes to reload after firing each salvo. The missiles themselves are relatively weak, but can be effective when collectively fired on individual targets.	800	4000	1800
Fulcrum Torpedoes are devastating weapons primarily intended for capital ship destruction, although they have also been used for fighter suppression. Due to their indiscriminate destruction, the Mercenary Guild considers the weapons contraband.	110000	2000	250
The Lynx missile targets a ship's engine system . Overall impact damage is relatively low, but the missile can critically damage a ship's engine system.	900	2700	800
The Rage missile targets a ship's weapons system . Overall impact damage is relatively low, but the missile can critically damage a ship's weapon system.	950	2800	850
The Cyclone missile is a medium range, medium yield weapon that also inflicts a kinetic burst on a target.	1500	3100	1000

Other Offensive Weapons

Name
Proximity Mine: Proximity mines explode when a ship approaches them at close range. When activated, a range indicator will be displayed on the HUD of the ship that places it. Data: ~2000 range, ~100,000 yield
Station Detonator: Specifically created to destroy Build Trade Stations and has no other offensive use. Yield - around 8 000 000. The SD's uses are for clearing redundant station clutter from systems and during Clan Wars where clans destroy opponent clan's stations to create space to build their own

Offensive Boosters

Name
The Cannon Heatsink helps keep primary particle cannons cooler during their firing cycles, allowing them to fire at significantly faster rates.
The Cannon Relay System doubles the energy capacity of your primary weapon system and adds two additional gun barrels to an installed particle cannon. It works by storing extra power in a network of capacitors between firing cycles, supplying sufficient energy for firing both sets of barrels per cycle.

Defensive Boosters

Name
The Anti-Missile System (AMS) is a semi-effective beam weapon that targets an inbound missile as it approaches your ship. It fires an invisible beam of laser energy at the missile in an attempt to heat it up and cause it to explode before it reaches your ship.
The Automatic CM Launcher (ACML) does exactly what the name implies. It will begin launching CM's as soon as a missile approaches effective countermeasure range. It can be wasteful with CM's, so pilots should train to use this system most effectively to minimize CM loss.
Shield Packs provide a significant charge to a ship's shield system. They can be installed on secondary hardpoints and raise all arrays by about 50%. Two packs should raise the shield reserve to 100%
The Shield Array Recharger (SAR) works as an energy transfer system and provides additional shield energy to arrays that become critical by routing power from the main energy system to the shield system.

Other Defensive Equipment

Name
Stealth / Cloaking Device cloaks your ship from sensors and visual detection for a brief period of time (around 60 seconds). They are installed on secondary weapon hardpoints and can only be used once.
Sensor Probe provide location data for objects within spherical range of around 25,000 Dm on the NAV console. Once deployed, a circle will be displayed on the nav map indicating the range of the probe.
The Stealth Generator is a reusable piece of equipment that uses a ship's shield arrays to generate a stealth field. The stealth generator cloaks the ship visually and prevents it from being detected by sensors for up to around 180 seconds. They are installed in the equipment points
Charge Packs provide a full recharge to a ship's energy reserves. They can be installed on secondary hardpoints.

Appendix 8: Charted System Coordinates (four versions)

Table 1 has the gated systems in alphabetical order

Table 2 has them arranged alphabetically but divided into quadrants

Table 3 has them arranged scanning left to right (W to E) across the core

Table 4 has them arranged scanning top to bottom (N to S) across the core

Table 1 - alphabetical

Agate	-2200	3620
Agate Hub	-2198	3520
Alpha Centauri	1300	-3700
Andromeda	2000	28000
Aquila	1400	-2700
Aries	-3500	2000
Atlas	1000	1500
AWZ(Pearl)	3500	-1500
Capella	2000	-1000
Cerulean	2400	2100
CWZ	2420	2500
Cygnus	-1700	1250
Deneb	3500	-3500
Emerald	-3200	-550
Fauston	-500	800
Iota	-2500	-1500
Lambda	-1250	-400
Lost Rucker	5500	-1000
Merak	-2000	2500
Olympus Prime	1250	500
Onyx	3500	1000
Orion	-1000	-2400
Pearl	3500	-1800
Pices	1800	-300
RiftSpace	7000	9500
Rigel	-3200	-2500
Rucker	1800	-2000
Sapphire	0	0
Sierra	-2200	3500
Sirius	-2300	-3700
Sol	-1050	-5050
SWZ	-2200	3800
Talison	100	2000
Thuban	0	-500
TWZ	100	2550
Vega	500	-2200
Virgo	700	-1250
Vonari	1000	5000
WolfZone	5550	5550

Table 2 alphabetical within quadrants

NW	Agate	-2200	3620
	Agate Hub	-2198	3520
	SWZ	-2200	3800
	Sierra	-2200	3500
	Aries	-3500	2000
	Talison	100	2000
	Cygnus	-1700	1250
	Merak	-2000	2500
	TWZ	100	2550
	Talison	100	2000
NE	Fauston	-500	800
	CWZ	2420	2500
	Cerulean	2400	2100
	Olympus Prime	1250	500
	Atlas	1000	1500
	Onyx	3500	1000
	Sapphire	0	0
SW	Emerald	-3200	-550
	Lambda	-1250	-400
	Iota	-2500	-1500
	Rigel	-3200	-2500
	Orion	-1000	-2400
	Sirius	-2300	-3700
	Thuban	0	-500
SE	AWZ(Pearl)	3500	-1500
	Pices	1800	-300
	Vega	500	-2200
	Capella	2000	-1000
	Virgo	700	-1250
	Pearl	3500	-1800
	Rucker	1800	-2000
	Aquila	1400	-2700
	Alpha Centauri	1300	-3700
	Deneb	3500	-3500
Misc	RiftSpace	7000	9500
	WolfZone	5550	5550
	Vonari	1000	5000
	Lost Rucker	5500	-1000
	Andromeda	2000	28000
	Sol	-1050	-5050

border

border

border

Table 3 West to East

Aries	-3500	2000
Emerald	-3200	-550
Rigel	-3200	-2500
Iota	-2500	-1500
Sirius	-2300	-3700
Sierra	-2200	3500
Agate	-2200	3620
SWZ	-2200	3800
Agate Hub	-2198	3520
Merak	-2000	2500
Cygnus	-1700	1250
Lambda	-1250	-400
Sol	-1050	-5050
Orion	-1000	-2400
Fauston	-500	800
Sapphire	0	0
Thuban	0	-500
Talison	100	2000
TWZ	100	2550
Vega	500	-2200
Virgo	700	-1250
Atlas	1000	1500
Vonari	1000	5000
Olympus Prime	1250	500
Alpha Centauri	1300	-3700
Aquila	1400	-2700
Pices	1800	-300
Rucker	1800	-2000
Capella	2000	-1000
Andromeda	2000	28000
Cerulean	2400	2100
CWZ	2420	2500
Onyx	3500	1000
Pearl	3500	-1800
Deneb	3500	-3500
AWZ(Pearl)	3500	-1500
Lost Rucker	5500	-1000
WolfZone	5550	5550
RiftSpace	7000	9500

Table 4 North to South

Andromeda	2000	28000
RiftSpace	7000	9500
WolfZone	5550	5550
Vonari	1000	5000
SWZ	-2200	3800
Agate	-2200	3620
Agate Hub	-2198	3520
Sierra	-2200	3500
TWZ	100	2550
Merak	-2000	2500
CWZ	2420	2500
Cerulean	2400	2100
Aries	-3500	2000
Talison	100	2000
Atlas	1000	1500
Cygnus	-1700	1250
Onyx	3500	1000
Fauston	-500	800
Olympus Prime	1250	500
Sapphire	0	0
Pices	1800	-300
Lambda	-1250	-400
Thuban	0	-500
Emerald	-3200	-550
Capella	2000	-1000
Lost Rucker	5500	-1000
Virgo	700	-1250
Iota	-2500	-1500
AWZ(Pearl)	3500	-1500
Pearl	3500	-1800
Rucker	1800	-2000
Vega	500	-2200
Orion	-1000	-2400
Rigel	-3200	-2500
Aquila	1400	-2700
Deneb	3500	-3500
Sirius	-2300	-3700
Alpha Centauri	1300	-3700
Sol	-1050	-5050

Appendix 9: System Descriptions (arranged into alphabetical order)

The **Agate** system was recently colonized by explorers from the Sierra system. While the economy is barely noteworthy, several powerful energy companies have diverted their main efforts to Agate recently. The Guild and Rebel colonists in the system are opposing these corporations. Through unknown paths, large amounts of the rare ores of gold and silver have been appearing on the black market in the system. The Alliance has stationed the carrier Verity in Agate, due to its relative proximity to the Vonarian sectors. There have not been any reports of Vonarian sightings, however, leading to the belief the Vonari are not (yet) aware of the Agate system.

Economy Classes: Energy

Faction Details:

Energy Companies - Strong presence, run by Agate Construction Corp.

Navy/Military - Strong presence, defends energy interests and trade lanes.

Rebels - Small presence, native colonists, opposing the ACC.

Guilds/Clans - Unknown presence, scattered, encounters are fairly rare.

Miners - Moderate presence, works with energy companies.

Alpha Centauri has the distinction of being the first system to be colonized outside of Sol. The open trade between this system and Aquila results in it having a strong exchange of energy for technology. The planet **AC528** is known for paying slightly more for most items. There are also no docking fees for most mercenaries in this system, giving it a cost advantage over both Aquila and Deneb. Most ships are friendly to outsiders, but occasional trade blocks and attacks do occur.

Economy Classes: Energy

Faction Details:

Energy Companies - Strong presence, primary faction with economic control.

Navy/Military - Strong presence, controlled by energy companies.

Rebels - Uncertain presence.

Guilds/Clans - Uncertain presence.

Miners - Light presence, short trade runs from asteroids to planet.

Aquila consists of one planet in orbit around a blue-white star. While it may seem like an empty system, it does provide a high paying trade location with several stations and a relatively strong technology based economy. It is the central trade location between Alpha Centauri, Deneb, and Rucker.

Economy Classes: Technology

Faction Details:

Energy Companies - Moderate presence, devotes production to technology.

Navy/Military - Moderate presence, high ship and weapon technology.

Rebels - Moderate presence, battles outsiders frequently.

Guilds/Clans - Light presence, shares common interests with energy companies.

Miners - No significant presence.

Aries is a hostile system where battles often rage for the few scarce resources available. Not much trading takes place here due to the system only having one planet with two stations, instead many mercenaries have resorted to fighting each other for the cargo they are carrying. Aries is considered to be one of the most dangerous systems in Evochron and generally best avoided. Why the system is home to so many mercenaries remains a mystery, it's quite possible there are resources available here that aren't in the charted part of the system.

Economy Classes: Unknown

Faction Details:

Energy Companies - Unknown presence.

Navy/Military - Unknown presence, likely scattered patrols.

Rebels - Unknown presence, likely a powerful local faction.

Guilds/Clans - Unknown presence, likely a powerful local faction.

Miners - Unknown presence.

Atlas has a very small population and is generally a quiet system. It's often a destination for mercenaries looking to escape for a while to enjoy some scenery and peaceful contracts. Due to its proximity to Cerulean and relatively stable economy, pay here is decent. Some mercenaries refer to this system as the vacation spot of Evochron.

Economy Classes: Unknown

Faction Details:

Energy Companies - Moderate presence, mostly solar/photon collection.

Navy/Military - Moderate presence, popular location for training.

Rebels - No significant presence.

Guilds/Clans - No significant presence.

Miners - Moderate presence, works with energy companies.

Capella: Although a known solar system for many years, Capella wasn't colonized until recently due to an apparent lack of resources. In their efforts to expand, Clan colonies from nearby Rucker decided to terraform the nearby planet and establish a base of operations in the system. Since then, security issues have resulted as attacks by clan forces from Capella to Rucker increased. This has resulted in an almost constant state of conflict in the system with Navy forces from Rucker trying to eliminate the Clan threat. Mercenaries are advised to avoid this system unless they are well equipped and trained to survive in such hostile space.

Economy Classes: Unknown

Faction Details:

Energy Companies - Light presence, primarily independent operations.

Navy/Military - Moderate presence, forces from Rucker.

Rebels - Strong presence, support clan efforts to attack Rucker.

Guilds/Clans - Strong presence, uses system as base of operations.

Miners - Moderate presence, often works for Clan forces.

Cerulean is known for its beautiful blue starscapes and planets. Trade between the two planets in this system is popular for quick credits with a short trip. Cerulean is currently under Alliance control and does not generally charge docking fees for mercenaries. Strong markets with high demand for commodities along with a relatively high technology level provide several unique qualities in this region of Evochron. High radiation conditions have resulted in a strong biological research division that is frequently attacked by local rebel/guild groups interested in acquiring important medicine and technology. This system is also part of the frontline region of the Human - Vonari war.

Economy Classes: Agricultural, Biological

Faction Details:

Energy Companies - Moderate presence, primarily focuses on local production.

Navy/Military - Moderate presence, protects bio-research interests.

Rebels - Light presence, occasional reports of trade interference.

Guilds/Clans - Light presence, often tries to steal biological resources.

Miners - Light presence, owned by energy companies.

Cygnus is the primary refuelling location for traders travelling between Fauston and Aries. Its low prices for fuel and equipment make it one of the most popular stops for travelling mercenaries in the entire upper region of Evochron. Docking fees generally apply here, except for Federation citizens and their allies. Cygnus is known for its strong industrial economy and interest in forming a single government with Fauston.

Economy Classes: Industrial

Faction Details:

Energy Companies - Strong presence, works to provide resources to industry.

Navy/Military - Moderate presence, well equipped, generally against Alliance.

Rebels - Moderate presence, fights for unification with Fauston.

Guilds/Clans - Light presence, joins with Rebels only to share resources.

Miners - Light presence, generally work for energy companies.

Deneb is a remote system that has only one gate exchange with Alpha Centauri. Resources are scarce, so premium prices are paid for commodities, but the system has very advanced technology. Deneb has admitted to having an advanced weapon research facility, but refuses to reveal the location. They've likely constructed it well outside the range of most navigation sensors and long range scanners. Political and faction disputes have resulted in frequent conflicts throughout the system. Outsiders are generally treated poorly.

Economy Classes: Agricultural, Industrial

Faction Details:

Energy Companies - Light presence, provides resources to agriculture.

Navy/Military - Moderate presence, advanced technology, monitors outsiders.

Rebels - Moderate presence, fights Federation control, rejects local laws.

Guilds/Clans - Light presence, shares isolation interests with Rebels.

Miners - No significant presence.

Emerald is arguably one of the most beautiful systems in Evochron. A bright green planet orbits a warm yellow star with a soft blue-green nebula backdrop. It's a peaceful setting for a system with a moderate level of conflict. Emerald offers good opportunities for independent ship owners, but reports continue to come in about attacks from rogue groups ambushing traders in the area. Emerald is also subject to high Federation taxes for local residents, which frequently drives away trade to nearby systems and has created a somewhat low end market for such a distant system. Emerald was one of the staging areas for the Alliance during the last war with the Federation. As a result, some military weaponry and technology occasionally makes its way into the market here.

Economy Classes: Technology, Agricultural

Faction Details:

Energy Companies - Strong presence and influence, involved in government.

Navy/Military - Light presence, little protection/defence capability.

Rebels - Moderate presence, occasionally attack local traders for cargo.

Guilds/Clans - Moderate presence, active in smuggling and attacking traders.

Miners - No significant presence.

Fauston borders on being a hostile system, but most ships generally leave each other alone. It's low level economy makes it an unpopular trade stop for selling, but a common one for buying and refuelling. Many new mercenaries visit this system first once they leave Sapphire and try some of their first combat contracts here. The level of technology is very similar to Sapphire, so most ships have limited capabilities and don't pose much of a threat to rookie mercenaries with entry level ships. Fauston is known for its amazing scenery, especially its icy blue world with liquid methane lakes, and is a significant supplier of medical supplies with a vast bio-research network.

Economy Classes: Biological, Agricultural

Faction Details: Energy Companies -

Light presence, primarily supplies military and research.

Navy/Military - Moderate presence, low level technology and lightly armed.

Rebels - Moderate presence, strongly against Alliance control and influence.

Guilds/Clans - Moderate presence, shares anti-Alliance interests with Rebels.

Miners - Minimal presence, mostly remain neutral.

Iota: Even though it is considered a Richton territory, Iota citizens consider themselves to be independent from any major government or military faction. Shortly after the system was colonized, the colonies asked for independence. Richton leadership initially denied the request, but due to their inability to enforce their rule as a result of the ongoing Federation war at the time, Iota was allowed to govern itself and has remained an independent system since that time. A strong economy and an advanced industrial manufacturing system provides one of the most high paying systems in the region where even raw metal ore is a valuable commodity.

Economy Classes: Unknown

Faction Details:

Energy Companies - Strong presence, supports manufacturing.

Navy/Military - Strong presence, well equipped.

Rebels - Unknown presence, scattered, encounters are fairly rare.

Guilds/Clans - Unknown presence, scattered, encounters are fairly rare.

Miners - Moderate presence, metal ore is generally in high demand.

Lambda is a lightly populated system, but was once the home of the Federation Military Command Centre. Most of the system's population departed in the late 24th century due to increasing living costs, high Federation taxes and the resulting decrease of opportunities for freelance mercenaries. By the turn of the century, most Federation companies departed the system and Lambda now primarily consists of just a few scattered independent colonies. While not a particularly hostile system, the quest for survival does lead to several small scale conflicts. A good buy can sometimes be found here, but Lambda is not considered a good place to make a profit. Although in Richton space, a division of Federation territory, Lambda is now mostly independent.

Economy Classes: Technology, Agricultural

Faction Details:

Energy Companies - Moderate presence and influence, main economic factor.

Navy/Military - Moderate presence, scattered and not well organized.

Rebels - Light presence, mostly lone groups that reject local leadership.

Guilds/Clans - Light presence, occasionally engage local forces for resources.

Miners - Unknown presence, likely a few scattered ships, not significant.

Merak is a system of devastation and desperation. It is the site of one of the largest battles against the Vonari where victory came at an immense cost. Countless lives were lost when the Vonari invasion reached this system and a massive battle unfolded to stop them here. As the battle began to favor the Vonari, a controversial decision was made to unleash numerous Fulcrum weapons. The counter-attack worked, but the destruction was vast, leaving the system shattered. Now only a handful of the population remains, often fighting each other for the few scraps of resources left. Those lucky enough to find passage on a ship often escape to other systems. But a few remain here, calling this system home, determined to restore it to its former powerful status.

Economy Classes: Unknown

Faction Details: Energy Companies -

Light presence, resourceful, but limited.

Navy/Military - Light presence, generally temporary operations.

Rebels - Strong presence, opportunistic hunters and salvage experts.

Guilds/Clans - Strong presence, working with Rebels who unite to work together.

Miners - Light presence, few mining operations.

Olympus Prime is often considered an extension of Sapphire. It is a large system that is used for repairing, reloading, and refuelling by many mercenaries who are travel to the upper Evochron systems. While not a particularly wealthy or advanced system, it is a good second system for new mercenaries looking to move out from Sapphire into a more profitable but mostly safe system with low level threats and plenty of job opportunities. Olympus has a strong industrial and energy production economy that exports many needed resources to nearby systems and is generally considered a safe system for mercenaries interested in mining, racing, equipment cleaning, and trade.

Economy Classes: Industrial, Energy

Faction Details:

Energy Companies - Strong presence, competition helps keep prices low.

Navy/Military - Strong presence, defends energy interests and trade lanes.

Rebels - Unknown presence, likely rare and avoids high traffic areas.

Guilds/Clans - Unknown presence, scattered, encounters are fairly rare.

Miners - Moderate presence, works with energy companies.

Onyx: As its name implies, Onyx is a dark system with a blank backdrop and cold rocky planets. It remains a mysterious system where frequent conflicts break out between local government supported energy companies and Rebels trying to take over the local asteroid sector. Military intervention has kept the Rebels from succeeding in their efforts, but the continuing battle has drained the local economy and created a lot of uncertainty for local colonies. Protecting the valuable asteroid clusters has become a top priority for the local government.

Economy Classes: Industrial

Faction Details:

Energy Companies - Strong presence, often hires mercenaries for protection.

Navy/Military - Moderate presence, fights to defend local asteroid clusters.

Rebels - Moderate presence, fights to take control of asteroid clusters.

Guilds/Clans - Moderate presence, occasionally joins with Rebels.

Miners - Moderate presence, struggles to continue harvesting resources.

Orion was one of the earliest Federation controlled systems, dating back as far as the late 23rd century. It has several well established colonies and companies that support its local economy. Orion is largely self-sufficient with most local mercenaries working for one of the energy companies, so there isn't much demand for outside assistance in trade. On the positive side, this means low prices for available items and ship construction is similarly affordable. This makes Orion a good location for buying and it's a fairly safe system for new mercenaries who may not be ready for more hostile systems with more advanced technology.

Economy Classes: Biological

Faction Details: Energy Companies - Strong presence, dominate political and economic force.

Navy/Military - Moderate presence, primarily protects energy interests.

Rebels - Light presence, mostly opportunistic explorers who remain reclusive.

Guilds/Clans - Uncertain presence, rumoured to patrol low traffic areas.

Miners - Moderate presence, works with energy companies.

Pearl is a large system consisting of several planets and is the site of the Arvoch Conflict that took place a few years ago. Abundant resources and numerous opportunities make Pearl a system with some of the wealthiest and best equipped mercenaries in all of Evochron. Even though resources are readily available, shipping them in this system is extremely risky, so premium prices are paid for even the most basic supplies and equipment. Survival here depends on skill, wealth, and a powerful ship. Rumours suggest there is a remote research facility in this system that provides the advanced and experimental technology.

Economy Classes: Biological, Technology, Energy, Agricultural

Faction Details:

Energy Companies - Strong presence, dominate political and economic force.
Navy/Military - Moderate presence, primarily protects energy interests.
Rebels - Light presence, mostly opportunistic explorers who remain reclusive.
Guilds/Clans - Uncertain presence, rumoured to patrol low traffic areas.
Miners - Moderate presence, works with energy companies.

Pices is a neutral system that is often used as a trade centre between Thuban and Pearl. Mercenaries looking for a central meeting point without the risks of attack common to both Thuban and Pearl often use Pices as the location to meet in. The economy is low here, but there are no docking fees for most mercenaries and expenses are equally low, including some of the lowest prices for fuel in the lower region of Evochron. It's industrial economy is one of the leading suppliers of low cost ship components and weapons in central Evochron.

Economy Classes: Industrial

Faction Details:

Energy Companies - Light presence, primarily serves industrial energy needs.
Navy/Military - Moderate presence, maintains peace between trade factions.
Rebels - Moderate presence, unaffiliated mercenaries, unpredictable.
Guilds/Clans - Light presence, mostly independent mercenary groups.
Miners - No significant presence.

The **Rigel** system is the primary trading centre between Sirius and Emerald. It is free of most Federation regulation, so many mercenaries from Emerald enjoy travelling to Rigel for tax free trade with local companies and other mercenaries from Sirius. Rigel is fiercely independent and does not identify itself as an Alliance or a Federation territory, so stations and planets here often charge docking fees and other fines to any outside mercenary regardless of where they came from. Most mercenaries agree that the minor cost in fees is largely offset by the higher market values found here.

Economy Classes: Industrial

Faction Details:

Energy Companies - Moderate presence, controlled by industrial factions.
Navy/Military - Moderate presence, defends local interests and traders.
Rebels - Moderate presence, hostile, well equipped, against Energy companies.
Guilds/Clans - Moderate presence, generally united with Rebels, oppose navy.
Miners - Limited presence, works with energy companies.

Rucker is named for the admiral of the Alliance fleet in the first Alliance-Federation war. It is a large system filled with asteroids, making jump drive navigation dangerous. While not a common stop for mercenaries due to the difficult navigation conditions, it does offer a moderate economy with no docking fees and low prices. It is considered a potential gold mine for well equipped mercenaries interested in mining due to its vast asteroid fields and its close proximity to the high paying Pearl system.

Economy Classes: Industrial

Faction Details:

Energy Companies - Strong presence, includes Miners for harvesting ore.

Navy/Military - Moderate presence, primarily protects energy interests.

Rebels - Light presence, occasionally seen joining with Guilds/Clans.

Guilds/Clans - Light presence, primarily opportunistic explorers.

Miners - Joined with energy companies for common energy supply goals.

Sapphire: This is the main trading centre in EVOchron and is firmly in Alliance control. It has jump gates to all four quadrants of the EVOchron quadrant. Sapphire is considered the launching point for new mercenaries due to its strong Alliance presence resulting in a well protected system with a positive reputation level. Few major conflicts ever occur in this system, mostly minor fighting between individual mercenary ships. Because of a saturated market, commodity values and contract pay is generally very low, but the safety of the system makes it a good starting point for new mercenaries to learn basic skills in trade, ship control, racing, equipment cleaning, mining, and other activities.

Economy Classes: Energy, Agricultural, Industrial

Faction Details:

Energy Companies - Strong presence and influence, main economic factor.

Navy/Military - Strong presence, central system of Alliance military.

Rebels - No significant presence.

Guilds/Clans - No significant presence.

Miners - Moderate presence, works with energy companies.

Sierra is another hostile system. It was recently reclaimed by the Federation, but the local leadership has fiercely fought for independence. Very little organized trading takes place here, although some traders travel from Talison for the higher selling values. It is one of the most recent systems to be colonized and as a result, doesn't have an established government or economy. The two planets in this system are also known for their bad weather, Sierra in particular has extremely windy conditions making atmosphere descents much more challenging.

Economy Classes: Limited Industrial

Faction Details: Energy Companies -

Light presence, mostly scattered after the last war.

Navy/Military - Light presence, no longer a single, well organized force.

Rebels - Strong presence, fights against Federation control.

Guilds/Clans - Strong presence, shares isolation interests with Rebels.

Miners - No significant presence.

Sirius is a distant system with a good economy similar to Rigel's. A few key difference between Sirius and Rigel are the low cost of operations (typically no docking fees) and high paying contracts with relatively easy objectives. The gate system between Sirius and Sol was destroyed in the last war and has not yet been rebuilt, cutting off the main supply line to this system. So supplies are somewhat scarce resulting in fairly high prices paid for needed commodities and equipment. The planet Sirius B is generally considered a very good trade location for selling.

Economy Classes: Energy

Faction Details:

Energy Companies - Strong presence, dominate political and economic force.
Navy/Military - Moderate presence, primarily protects energy interests.
Rebels - Light presence, mostly opportunistic explorers who remain reclusive.
Guilds/Clans - Uncertain presence, rumoured to patrol low traffic areas.
Miners - No significant presence

Talison has a moderate economy and technology level without docking fees for most mercenaries. This is an active trading location with ships coming from Fauston and Cerulean on a regular basis. Although the government of Talison considers itself independent, they were part of the Federation until just recently. Now without Federation supply deliveries, Talison offers good prices for most items and equipment. This is a popular location for mercenaries heading to Cerulean and Onyx for high value sales. Talison is also on the frontlines of the war against the Vonari. The system is used as a base of operations for Alliance military ships moving up to the nearby war zone.

Economy Classes: Industrial

Faction Details:

Energy Companies - Moderate presence, provides resources to military.
Navy/Military - Strong presence, supports war effort, escorts Alliance ships.
Rebels - Light presence, unknown interests.
Guilds/Clans - Light presence, unknown interests.
Miners - Moderate presence, frequently harvests ore from local asteroids

Thuban is the home of the Federation and although the war has ended, tensions remain high between the Alliance controlled system of Sapphire and Thuban. Local mercenaries here are known to attack ships from the Alliance without provocation. As a result, Alliance command continues to warn against travelling to this system. Thuban is often in conflict with various companies and military factions battling for control of the system's abundant resources. For well equipped mercenaries interested in combat roles, this system offers some of the most attack, patrol, and spy contracts.

Economy Classes: Energy, Biological

Faction Details:

Energy Companies - Strong presence, owned by military and government.
Navy/Military - Strong presence, aggressively attacks Alliance ships.
Rebels - Moderate presence, frequently attacks many civilian Thuban ships.
Guilds/Clans - Moderate presence, disrupts energy shipping, wants territory.
Miners - Limited presence, mostly independent ships.

Vega is one of the closest systems to Earth, being only 25 light years away. It remained an independent colony for many years, consisting mostly of scientific research teams. However, Rebel forces from Virgo recently invaded the system in an attempt to control its resources. While they failed in their efforts in Virgo, they achieved significant gains in Vega since the local population was not equipped to defend themselves from attack. Distress calls were sent to the Alliance and Navy forces were dispatched to fight off the Rebels and protect the system. The future of this system remains uncertain, it's currently still considered an undefined territory.

Economy Classes: Unknown

Faction Details:

Energy Companies - Light presence, primarily independent operations.

Navy/Military - Moderate presence, defending against Rebels.

Rebels - Strong presence, attempting to conquer the system.

Guilds/Clans - Moderate presence, united with Rebels.

Miners - Light presence, a few mining operations do occur.

Virgo is a lightly populated system of mostly colonists. While the system is technically in Federation controlled space, it was given independence in 2374 and has been almost entirely self-sufficient since that time. Its inhabitants pride themselves in their abilities to live off their own resources and typically discourage outside trade. As a result, they offer very little for most items and commodities. How this system has remained to survive for so long without outside assistance and do so well has been a continuing mystery. Rumours suggest they control a hidden world somewhere nearby that supplies resources they would otherwise not have access to.

Economy Classes: Agricultural

Faction Details:

Energy Companies - Light presence, serves agricultural industry.

Navy/Military - Moderate presence, limited ship and weapon resources.

Rebels - Light presence, elusive, mostly remain outside of traffic areas.

Guilds/Clans - Light presence, mostly remain outside of traffic areas.

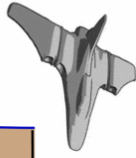
Miners - No significant presence.

Vonarion - The Enemy!: The Vonari system is home to the aggressive race that is responsible for several wars and continues to attack randomly. Mercenaries are advised to avoid this system entirely as the technology level of the Vonari is very advanced. The hidden Alliance outpost is still being operated, although a cloaking field protects it from detection. It has been a stop for a few brave mercenaries who have travelled to this system in their efforts to explore the area and test Vonari capabilities.

Appendix 10: Asteroid Cave Plan

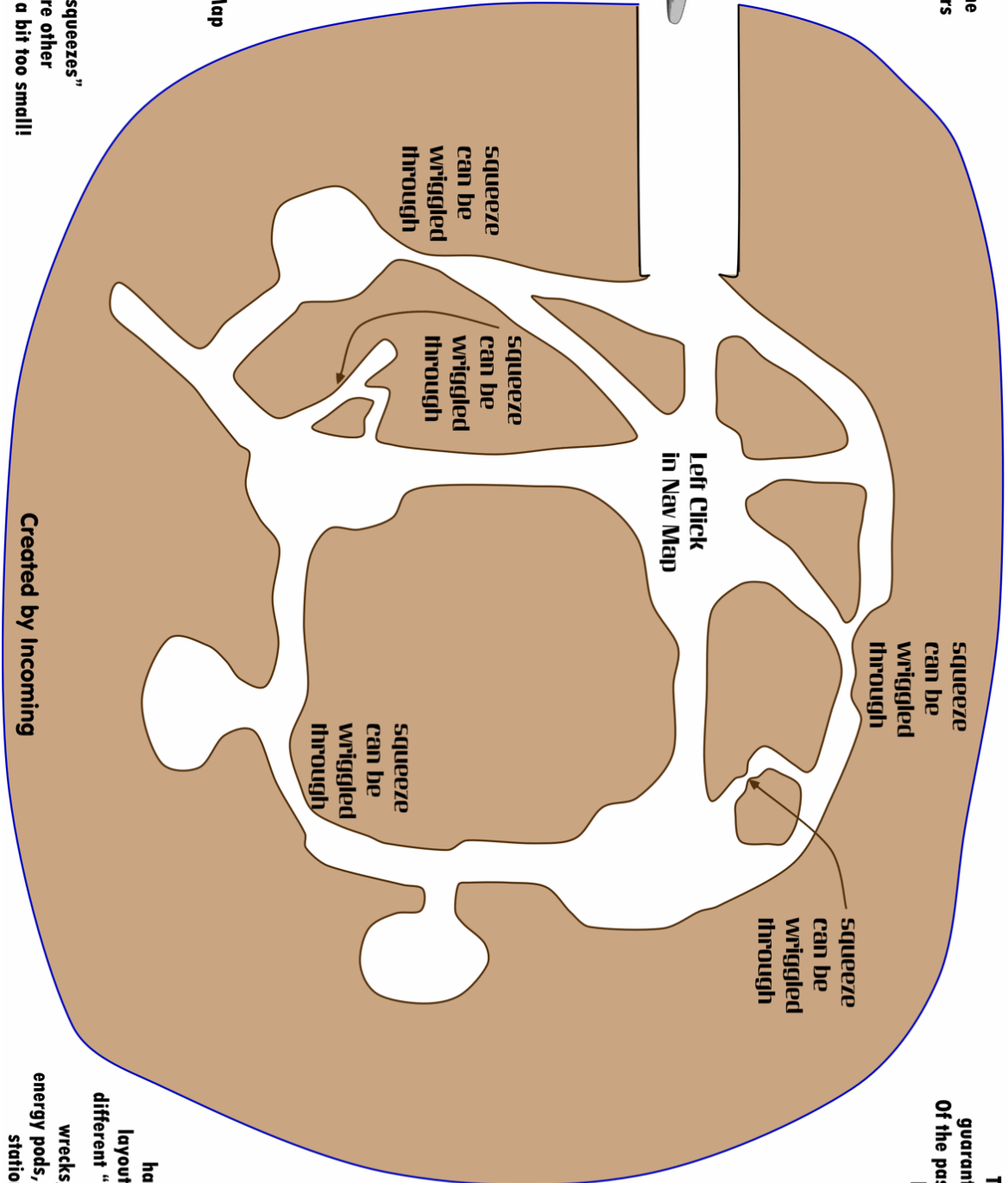
The cave is made of merged boulders so the passages and chambers are "lumpy"

The passages are 3D - the map can't show the Y coords



You can jump directly into the main chamber - left click in the NavMap But you need the correct heading

You can get through "squeezes" by wriggling - there are other "peep holes" that are a bit too small!!



There are no guarantees that all Of the passages have been found!

The caves have a similar layout but contain different "treasures" : wrecks, containers, energy pods, jump gates, stations and more

Created by Incoming

Appendix 11: Calculating Velocity when using Inertial Mode

(Acknowledgements to Vice for this explanation)

Think of it this way. If you move in any given direction 1.0 units, your distance travelled is obviously 1.0. Now if you start at the same point, but turn 45 degrees to the right, then move the same 1.0 units, your distance travelled is the same, but in relation to the original direction, you have not moved out as far on the Z axis (forward/reverse) as you original did at a heading of 0. Plus, you've moved farther out than just 50% of the distance even though you are halfway to 90 degrees. So in an exchange of velocity values for 3 direction values (XYZ), this factor has to be accounted for in the calculations.

If you were to start at a point and drew equal lines from that point around a full 360 degrees, you would wind up with the end of those lines forming a circle. To achieve the same distance at 45 degrees as you would at 0 degrees, your direction floats (the two velocity values referred to earlier) will each generally be at around 70% of the original speed value (for a speed of 1000, each at around 707). Perhaps this diagram will help:

