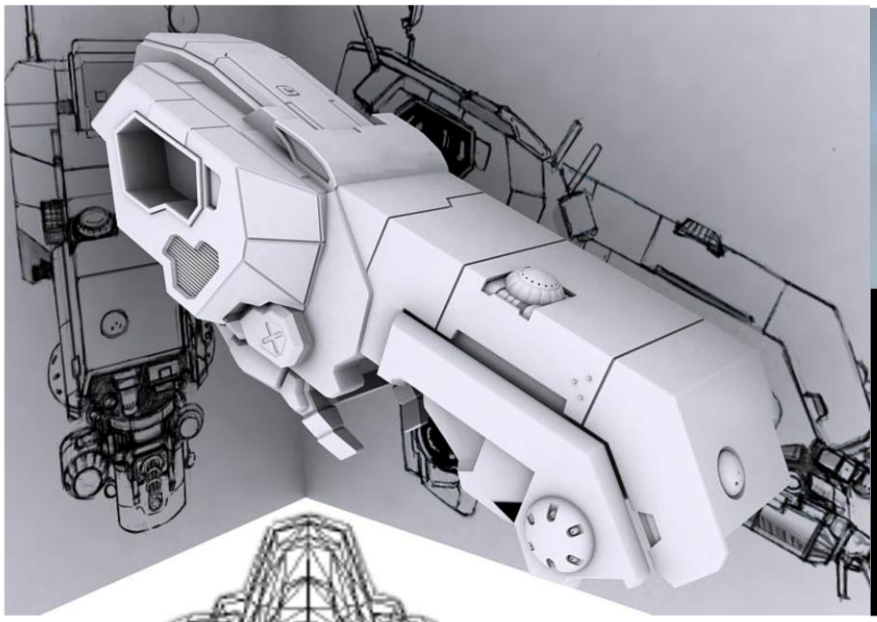
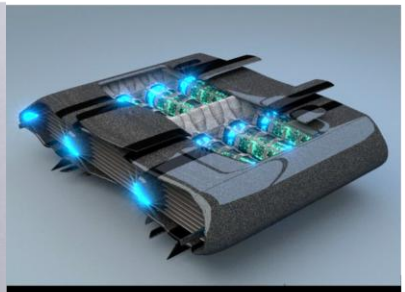
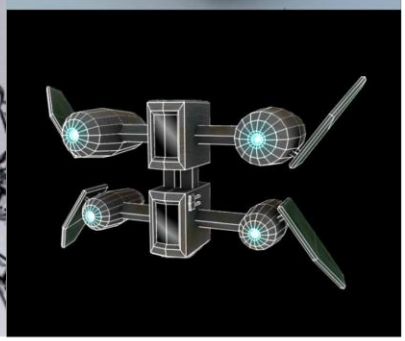
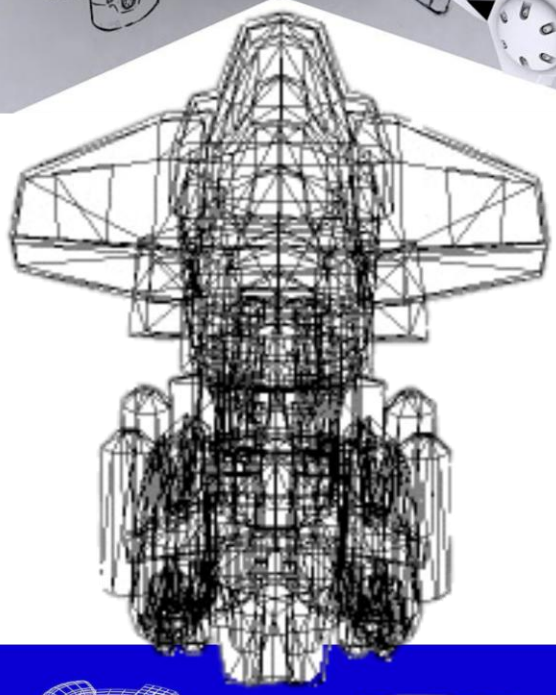
The Authorised Evochron Mercenaries' Technical Guide

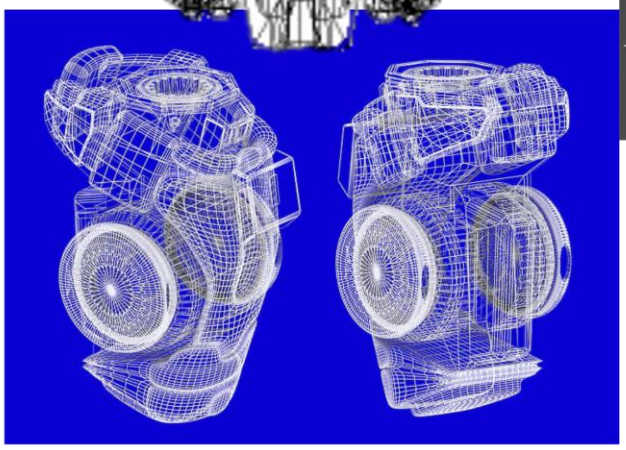
(or "How your equipment works")





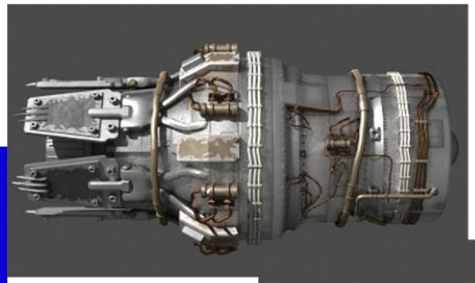






created by DaveK
(aka Incoming)

Expansion Edition



Revised April 2015

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 this Revised Expansion Edition

The following sections have been added

- Looking closely at the official History of Evochron timeline it became apparent that there are a few inconsistencies in dating, particularly with the development of Fulcrum Jump Technology.
- Several people have asked the unusual nature of the planets in Evochron – small, relatively smooth, shallow lakes and seas and the fact that humans require protection (usually terrain walkers) to move around on the surface – here's the cosmological and geological reasons.
- I've taken the opportunity to inform readers about the practicalities and difficulties of colonising Evochron. Most people alive today have forgotten what their great, great grandparents sacrificed to open up Evochron for settlement – here's the gen on founding a colony.
- There is little information on the technical background about one of the commonest career options available to merc's – trading and cargo haulage. There is now a detailed section on cargo transport covering the whole spectrum between ground haulers and capital cargo vessels.
- A common topic of debate in bars amongst merc's is the actual facts about capital ships. Given that most of us will never see the inside of a battleship or cruiser, I've taken the opportunity to access recently (unofficially) released papers (on EvoLeaks) to discuss the roles of the four capital ship classes and their primary, secondary and close-in protection weapons. There is a detailed section on the primary weapon systems – railguns and missiles.
- We all know that Vonari exist, though little detail is available. There are (lasting) rumours about two other alien species in the Evoverse. I was lucky enough to be given access to leaked information and have reproduced intel reports concerning the Vonari, Actarians and 'The Ancients'. I am actively seeking an original of the heavily redacted Vonari Report!
- We have become so used to living in underground cities or space stations or having the free, roaming life of a typical mercenary that we have on the whole forgotten about the long term plans for Evochron. I've now included a section of the terraforming options chosen to transform out planets so that our children's children's children will be able to grow up in the open under blue skies!

DaveK (Callsign Incoming)

Contents *(new sections are marked in red)*

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!

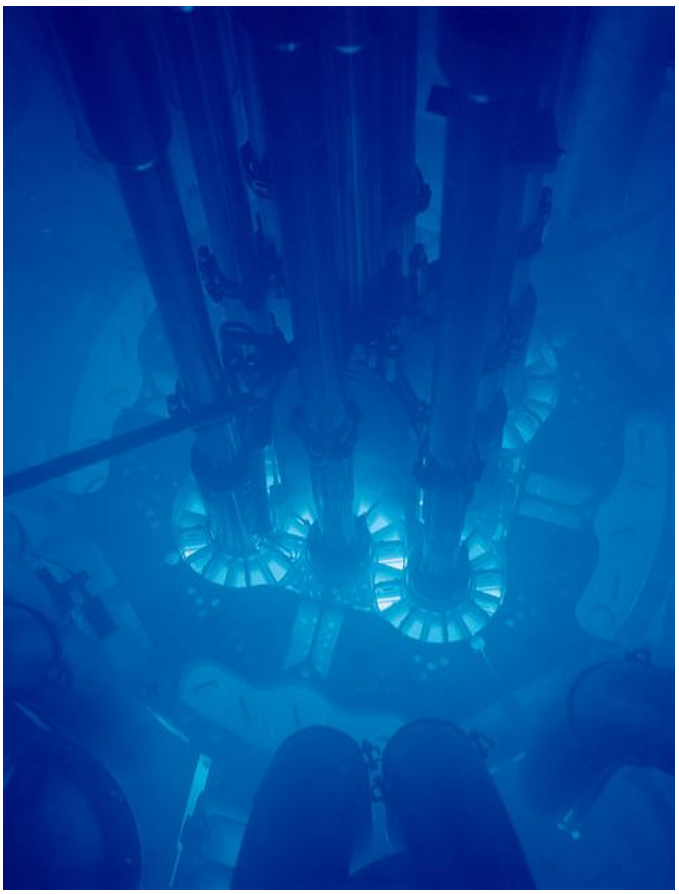
Part 1: The Background Theories

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.

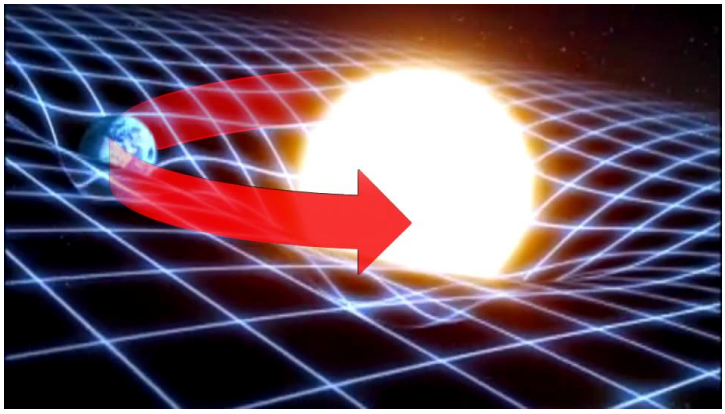
In early 20th century on Earth (in the Sol system), Albert Einstein developed his theories of special and then general relativity. Amongst many other consequences this put a 'speed limit' on the universe - the speed of light (SoL), or more properly the speed of all electromagnetic radiation. The SoL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



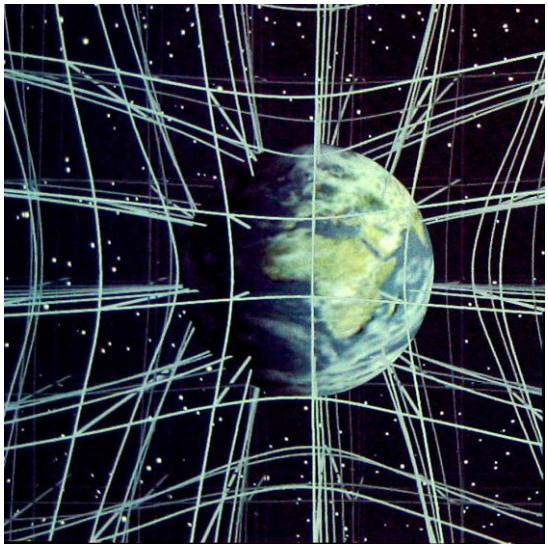
A neat illustration of this speed limit is seen in the nuclear pile at the centre of a nuclear power generator. As a result of beta decay, electrons are born in the nucleus and leave it travelling faster than the SoL. They instantly have to slow down. As they do so they emit their excess kinetic energy 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' that is the time that you are talking about.

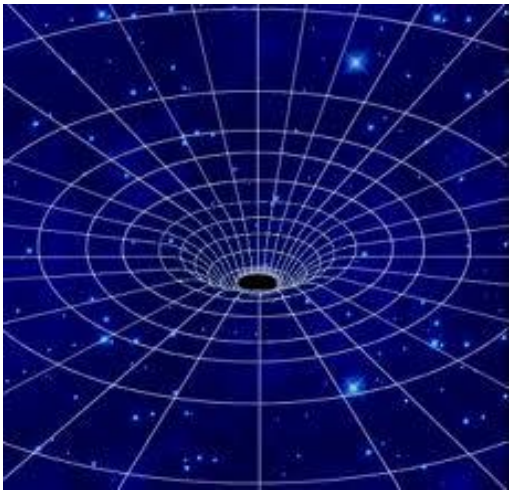


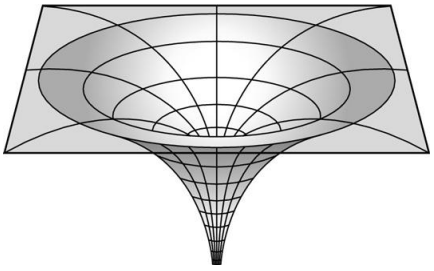
Mass 'bends' space-time like a bowling ball on a rubber sheet - the bigger the mass the greater the bending. Objects move across the sheet and like a marble passing near the bowling ball, curve around due to the dent in the sheet. Gravity is just the curve in space time causing planets to orbit their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

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

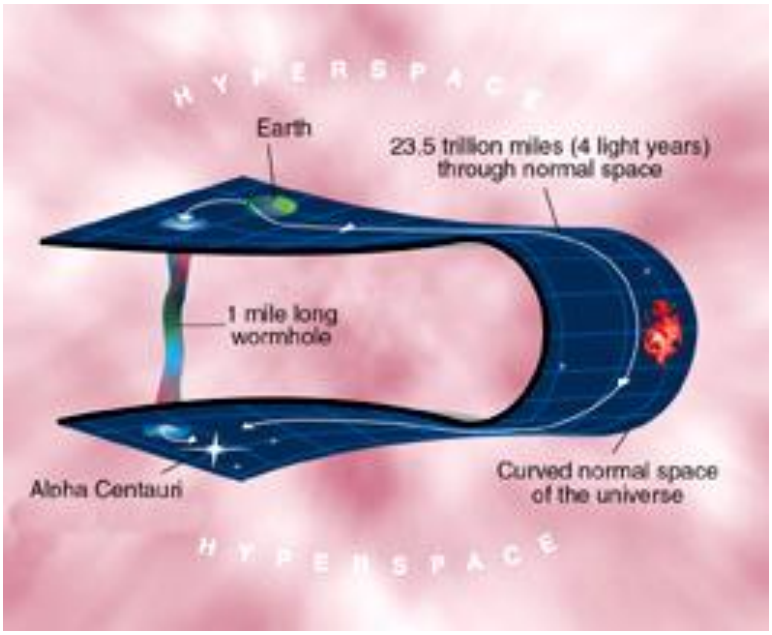


A second important consequence is that if the mass of an object is large enough the gravity causing it to contract can overcome all the forces of repulsion between sub-atomic particles (mainly proton - protons and electron - electrons) causing the object shrinks to zero size - a singularity. There is 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'!





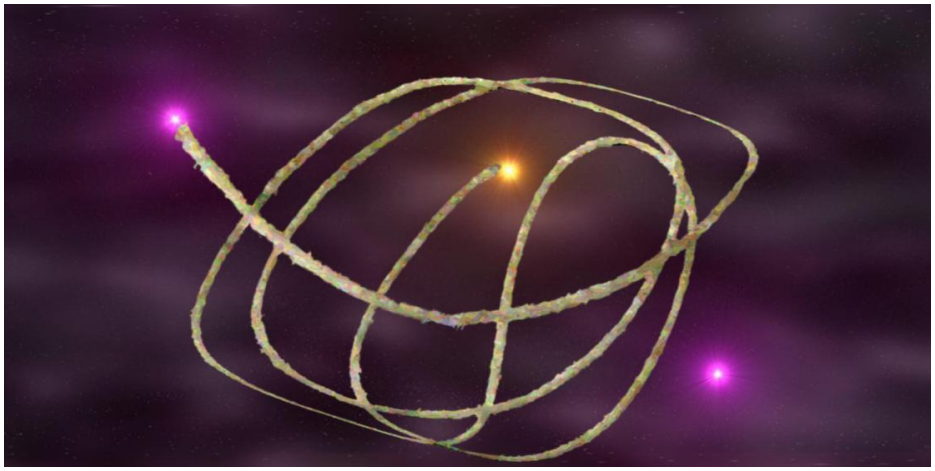
A blackhole has a massive distortion effect on the surrounding space-time and if large enough is able to create and stabilise a wormhole event horizon in it centre. Careful and skilful piloting allows a pilot to jump into the event horizon of the WH before being destroyed by the BH singularity. Even 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!



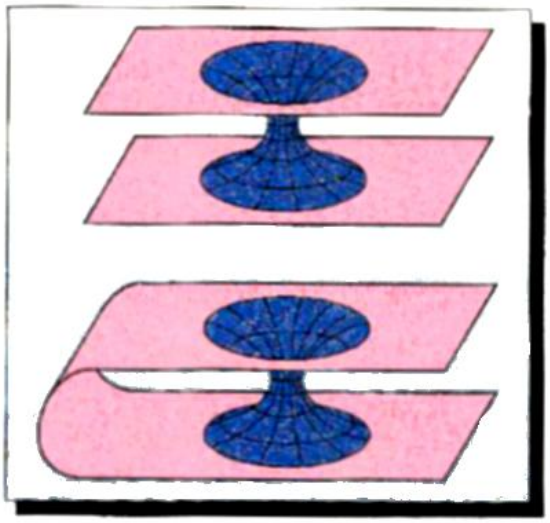
A wormhole is, fundamentally, a 'shortcut' through space-time. For a simple visual explanation of a wormhole, consider space-time as a two-dimensional (2D) surface. If this surface is folded along a third dimension, it allows one to picture a wormhole 'bridge' between the two sides of the fold.

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 lower left picture)

They also, in theory allow travel between universes in the multiverse (upper 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

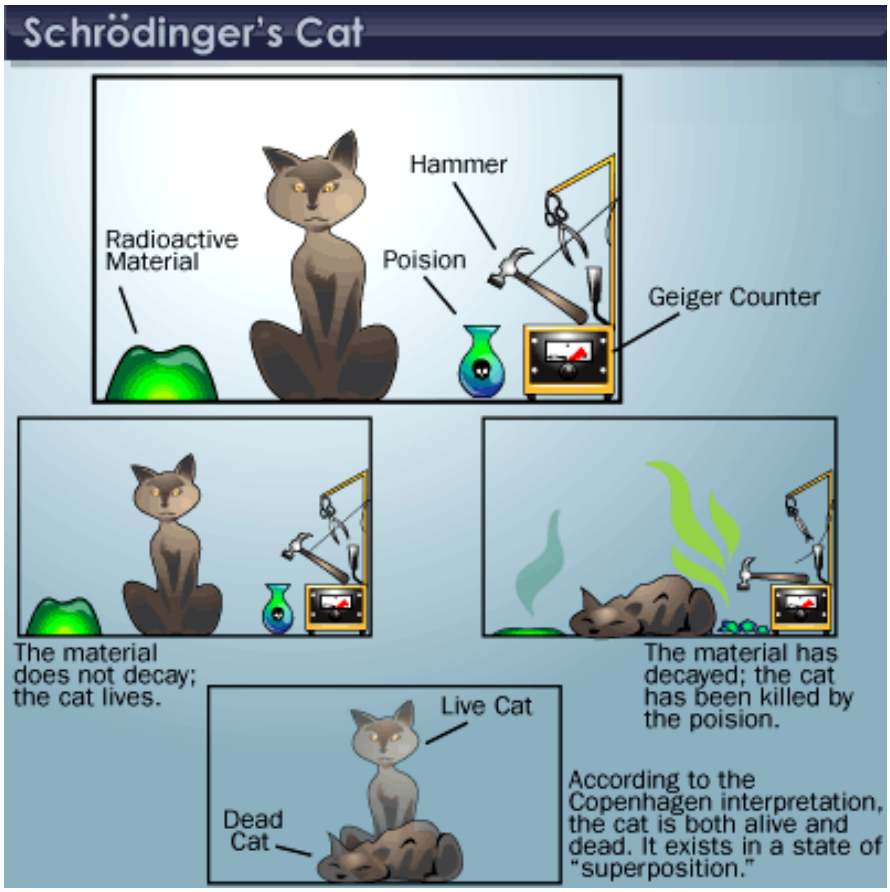
The standard explanation of what takes place at the quantum level is known as the Copenhagen-interpretation. This is because much of the pioneering work was carried out by the Danish physicist Niles Bohr, who worked in Copenhagen. Quantum theory describes the behaviour of very small objects, generally 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:

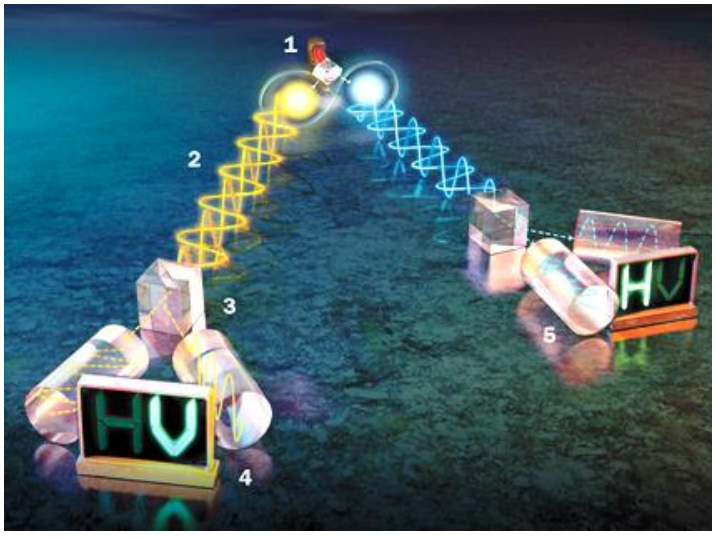


The EPR Paradox is so named because it was a thought experiment devised by Albert Einstein, Boris Podolsky and Nathan Rosen. As with Schrodinger's cat-in-the-box thought experiment's it was devised to expose the 'foolishness' of the Copenhagen-interpretation. The experiment focuses on the phenomenon 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 kilometres 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

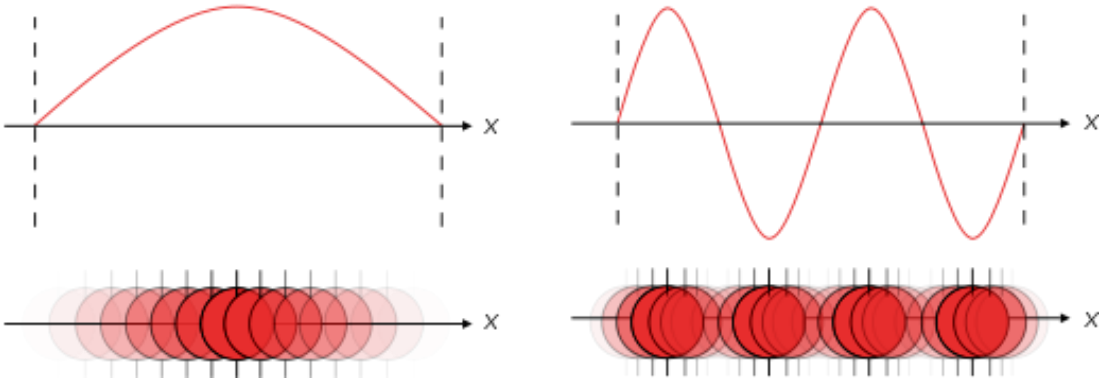
Technology has proved Einstein wrong; faster than light speed, at least in the quantum world, is a reality. However, in classical physics - at sizes above that of atoms - relativity still remains unchallenged, nothing has been detected at faster than light speed.

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.

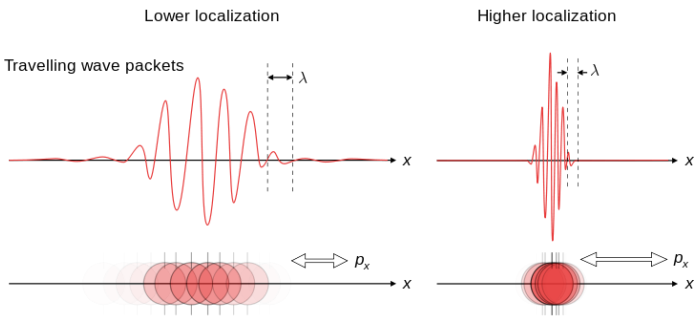
The principle of Uncertainty showed that all knowledge is limited, that there is no such thing as absolute certainty. This leads to some extraordinary outcomes. At an atomic level particles have wave-like properties and waves (like light) have particle like properties - particle-wave duality. Hence light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

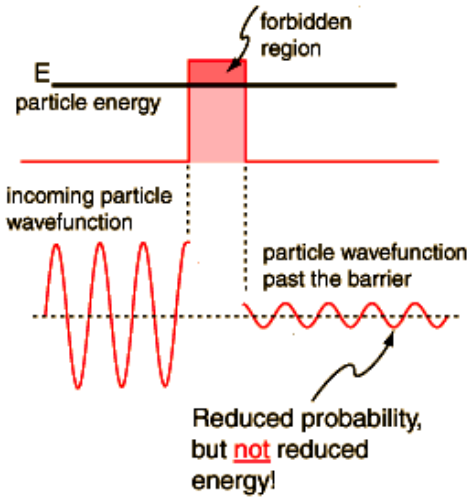
If we have a travelling wave/particle packet, for example an electron we get:

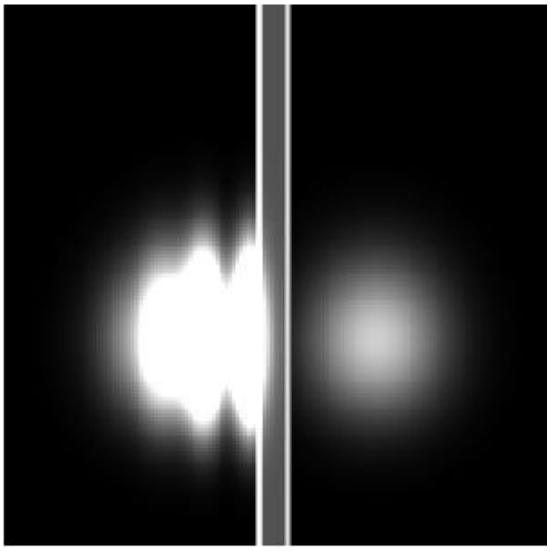


In the ***first case*** we have chosen to measure its velocity and the act of measuring causes the wave packet to smear out - we lose detail of where it is - its position. In the ***second illustration*** we have chosen to measure where it is and as a result we lose information about how fast it is travelling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





This micrograph consists of millions of exposures superimposed. The lighter the area the higher the probability of the electron being present. It clearly shows the barrier (grey vertical line) and the high probability of the electron being inside the trap (left hand side) but also a probability of it being outside the box. Some has pondered whether this is the origin of the hint for landing on earth . . . to 'think outside the box'.

This phenomenon is called ***quantum tunnelling***. However it is important to realise that the electron **doesn't** drill a hole through the trap and it **doesn't** sneak over the top - it simply has a small chance of being outside the trap!

Quantum tunnelling underpins photosynthesis (hydroponics and all plant life (and hence animal life)), electronics, quantum computers, unbreakable quantum cryptography, solar energy harvesters, QVee technology, many practical aspects of nanotechnology (for example how atoms can be positioned and the amazing behaviour of graphene), lasers used in beam weapons (and elsewhere!), ultra-precise clocks (used in our positioning technology so we know where we are!), teleportation (hot area of research), nuclear fission and nuclear fusion, and enzyme function and our sense of smell!

When you think about it, plants get their energy from sunlight via photosynthesis. Animals eat plants to get their energy or they eat animals that eat plants. No QT = no photosynthesis = no plants = no animals. No QT = no nuclear fusion = no stars!

One of the most practically important applications of quantum theory for mercs relates to where we get energy in our ships when we are in the middle of nowhere!

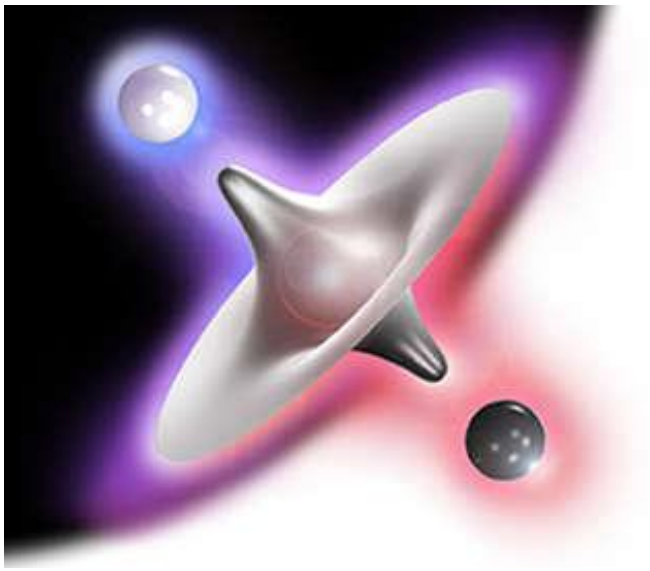
Background - Where the energy and matter come from

A word of warning! To paraphrase an eminent Nobel prize winning physicist in the 20th Century, if you think you understand the following descriptions you probably haven't been concentrating properly!

Quantum foam, (aka space-time foam) arises when Heisenberg's Uncertainty Principle is applied to an absolute vacuum. It is basically subatomic space-time turbulence at extremely small distances and is the building blocks of the foundations of the fabric of the universe. At such small scales of time and space the Uncertainty Principle allows particles and energy to briefly come into existence **out of nothing**, as long as they then annihilate each other in a very short period of time - they don't actually violate energy conservation laws . As the scale of time and space involved shrinks, the energy of these temporary virtual particles increases. According to Einstein's Theory of General Relativity, energy curves space-time. So at sufficiently small scales the energy of the fluctuations are large enough disrupts the smooth space-time seen at larger scales - giving space-time a 'foamy' character. The energy tied up in the transient particles averages out at 10^{107} Mega Joules per cubic metre of the vacuum. Yep that is 10 raised to the power 107 mega joules - a 1 followed by 107 zeroes! - 100 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 000 MJ

This is more energy than the human race will generate over several billion times the lifetime of the universe. And it's available in every cubic metre of space! Feel free to boggle!

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.

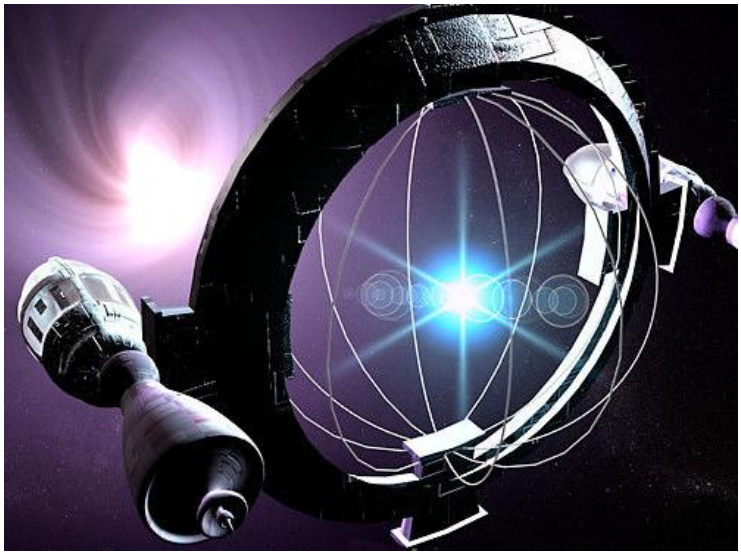


Quantum vacuum fluctuations are always created as particle/antiparticle pairs.

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.

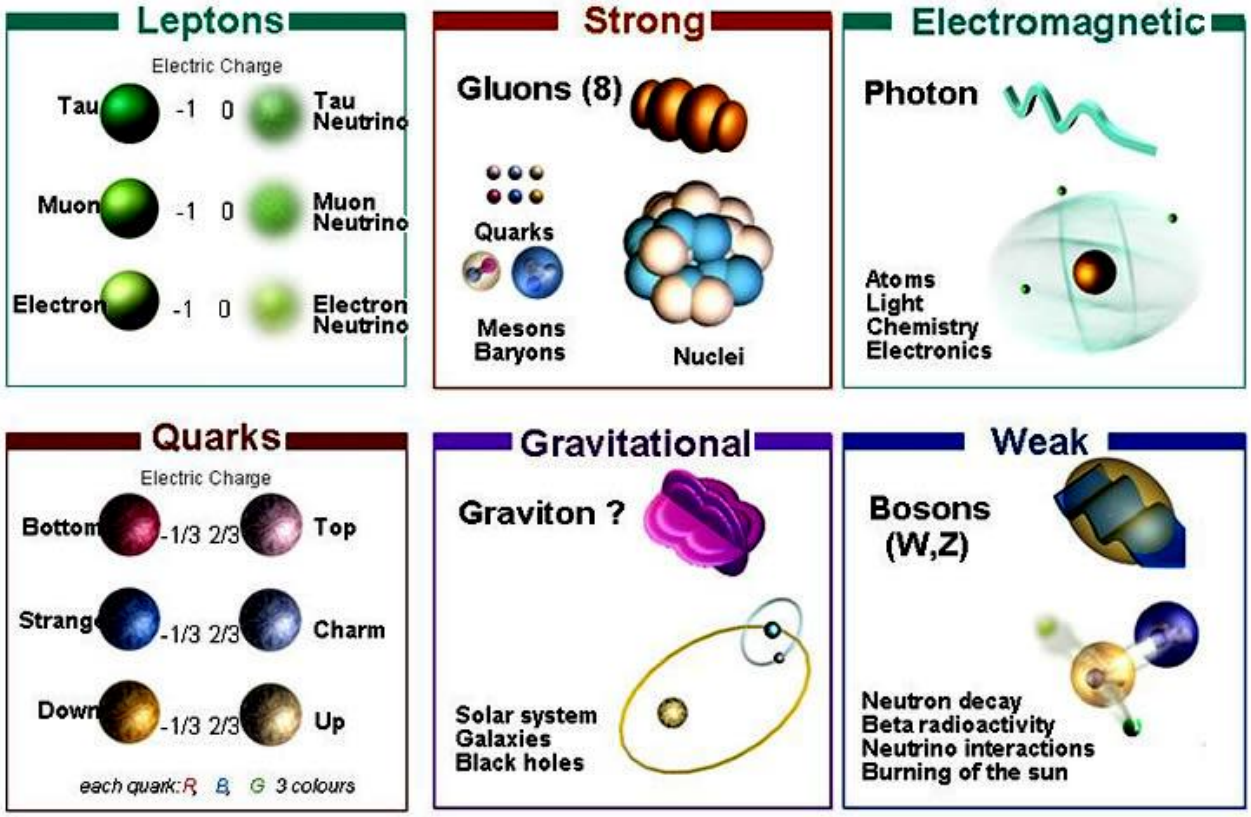
To summarise, the importance of the graviton (as well as keeping planets in orbit and us stuck to our planets, and also being a major component of the defensive shield field matrix and tractor beams) is its role in linking quantum gravity (Quantum Theory) with relativistic gravity (Relativity Theory) 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 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 (that is 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 $10^{1010,000,000}$. 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.

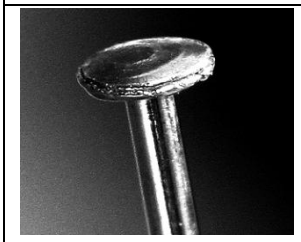
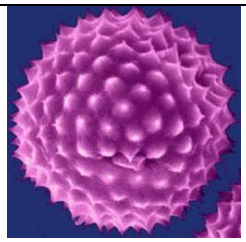
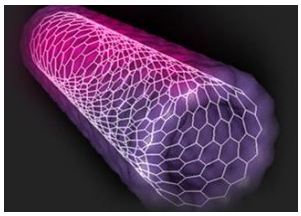
At the boundary between chemistry and physics, research focussed on the creation of ever smaller machine parts, for example gear wheels one ten billionth of a metre across. Engineering technologists were able to develop complex machinery at microscopic and molecular scales.

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 metre, a millimetre is one-thousandth of a metre, and a micrometre is one-millionth of a metre, but all of these are still huge compared to the nanoscale. A **nanometre (nm)** is one-billionth of a metre, 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.

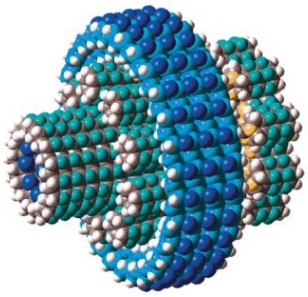
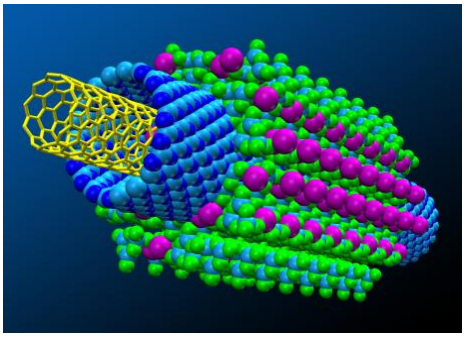
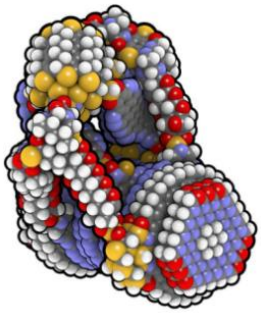
2: Molecular Manufacturing

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

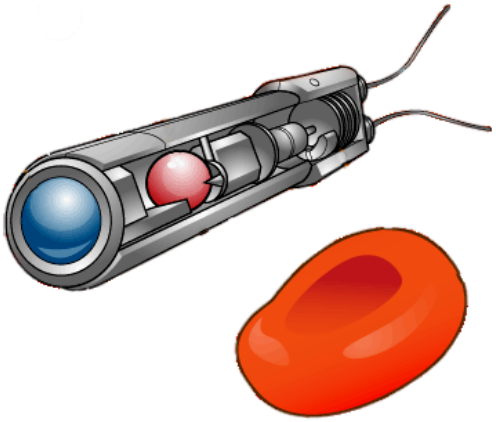




Many conventional designs for basic mechanical parts like gears can be scaled down to the molecular size range (if some care is taken in the design). Other than their small size, it's rather unremarkable. The gears and motor above would be encased in a strained silicon shell with predominantly sulphur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

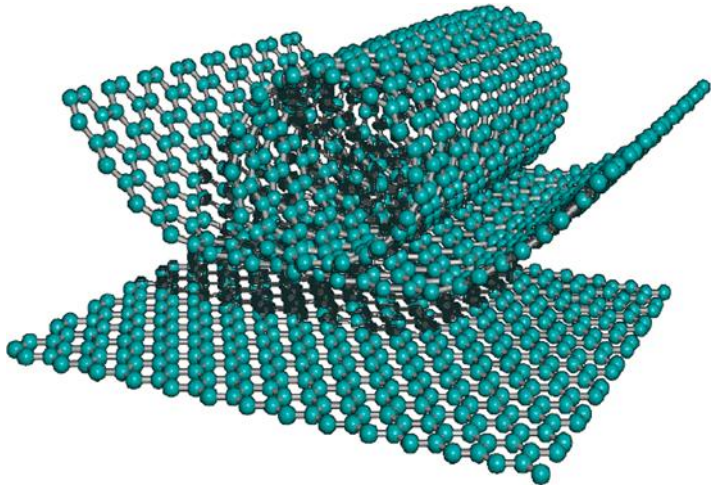
3: Types of nanomaterials commonly used

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.

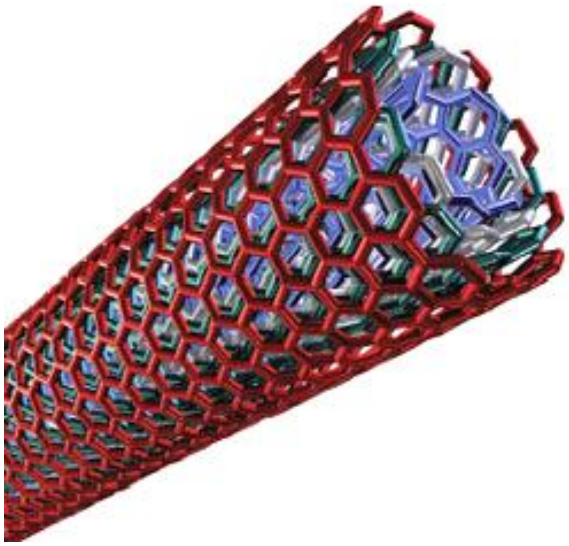
Nanowires and Fullerene (Carbon) Nanotubes

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 nanometre. They are used in the manufacture of tiny transistors for computer chips and other electronic devices. Smaller = faster!

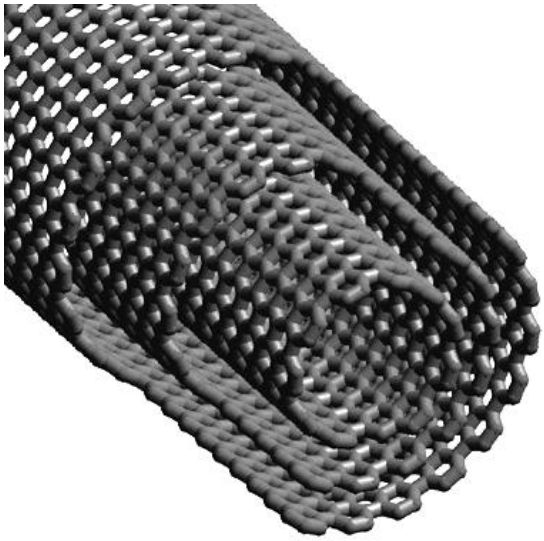
In terms of bulk use, nanotubes have overshadowed nanowires.



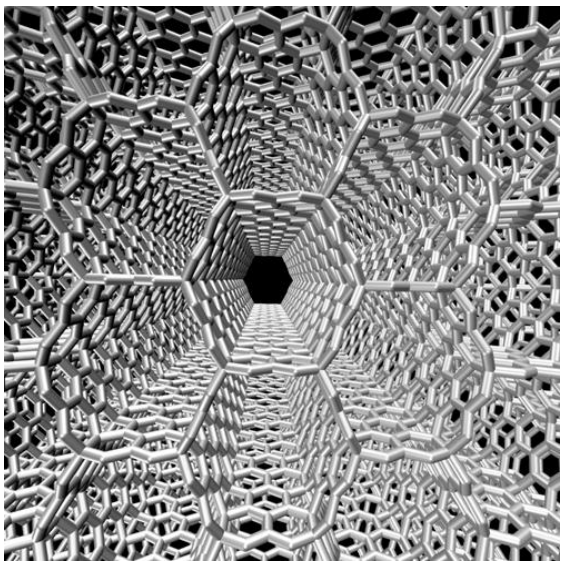
A nanotube is a nano-size cylinder of carbon atoms. Imagine a graphene sheet of carbon atoms, which would look like a sheet of hexagons. If you roll that sheet into a tube, you'd have a nanotube. Fullerene nanotube properties depend on how you roll the sheet. In other words, even though all carbon nanotubes 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'

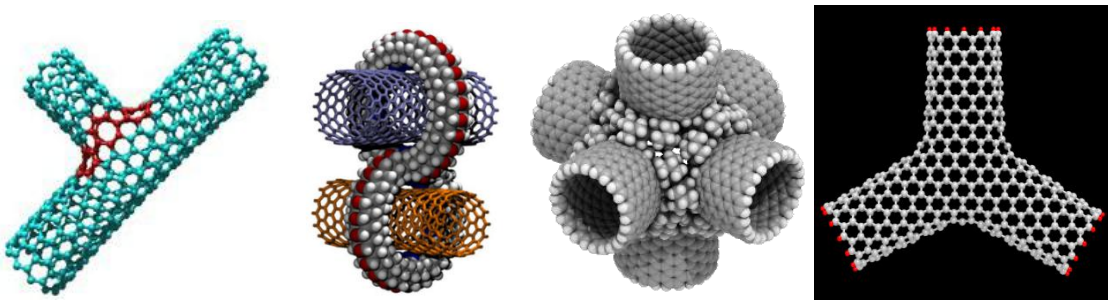


'spirally wrapped from several single sheets'

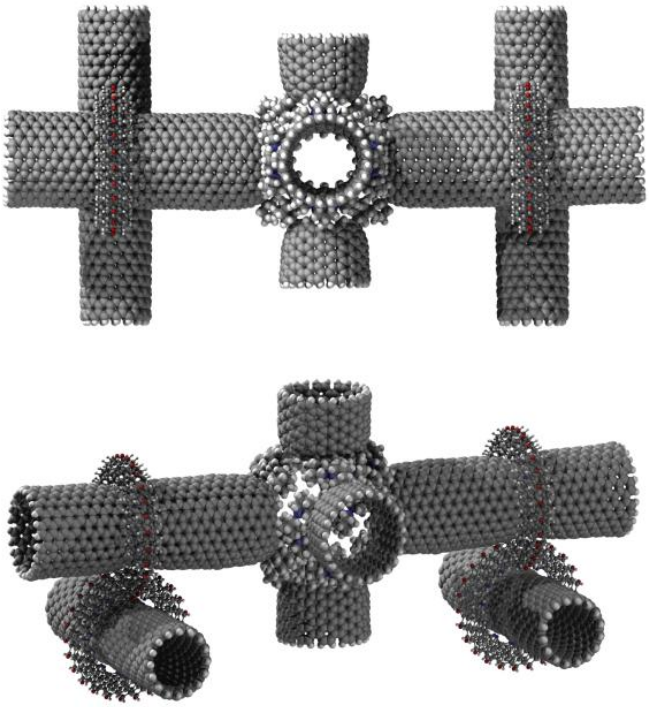


Fullerene tubes can also be manufactured into a 3D structure with tubes joined together along their lengths.

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

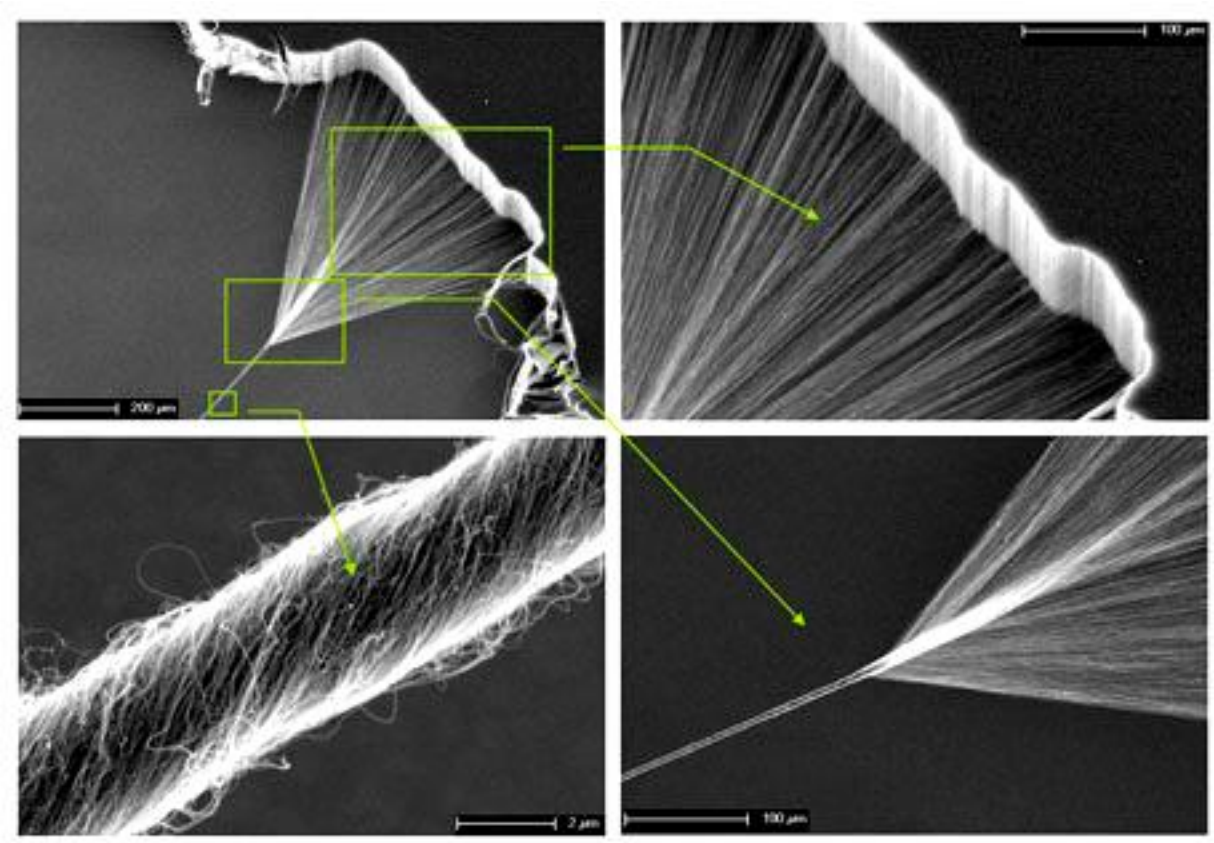


These basic connectors can be used to create very specific complex structures which are especially useful in electronic applications;

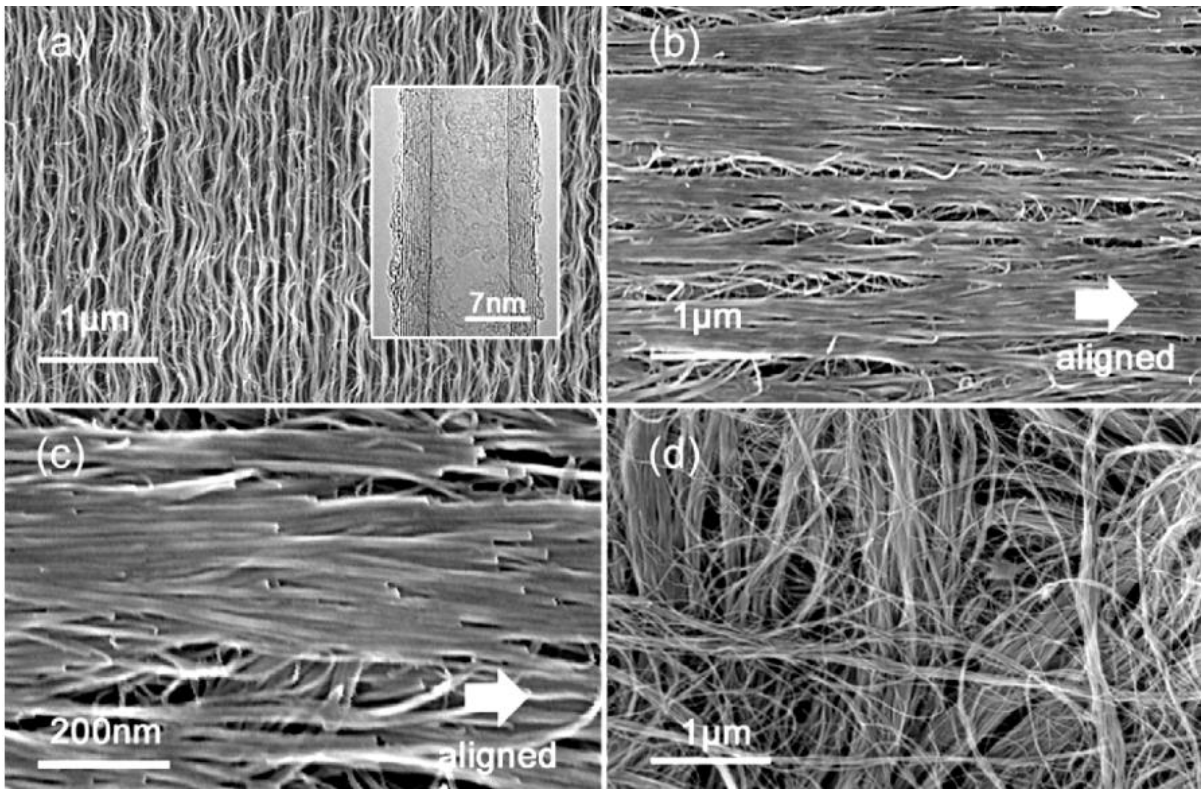


The fine tuning of molecular and macroscopic properties made possible by nanotechnology appears to be unlimited!

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



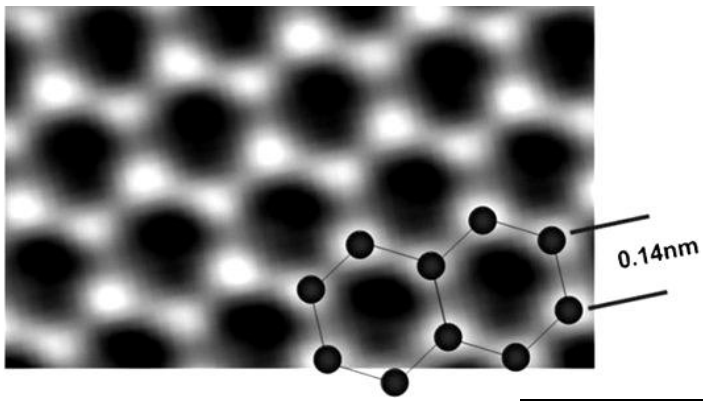
The fibres that can be woven or layered into very strong sheets to more easily create more complex shaped structural units



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.

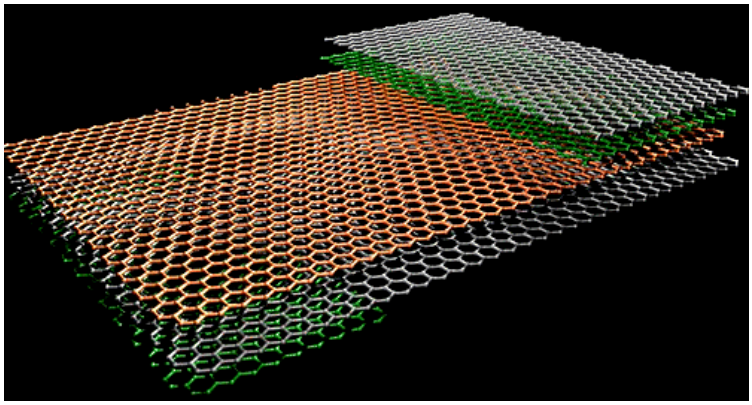
Fullerene nanotubes can also be effective semiconductors with the right arrangement of atoms. This makes nanotubes (partnered with graphene sheets) the preferred option for transistors in microprocessors and other electronics.

Graphene

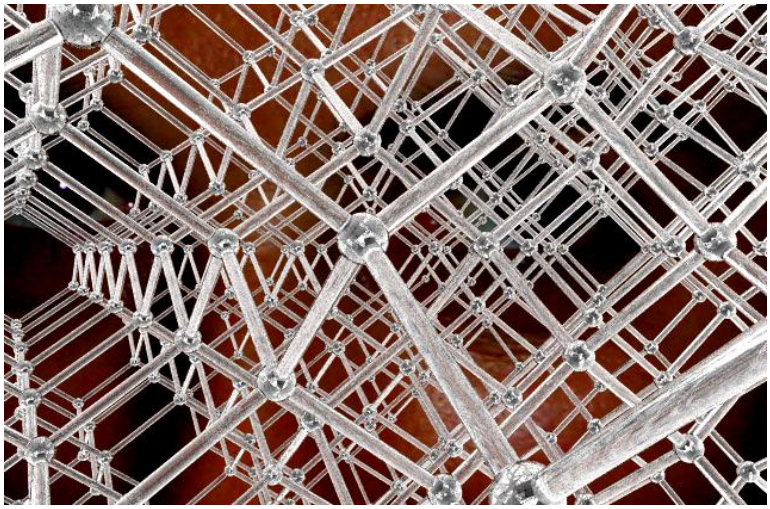


Graphene is a monolayer of hexagonally arranged carbon atoms. It can have a very wide range of electrical properties depending on how the sheets are created and arranged. Room temperature superconducting graphene can be created.

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)

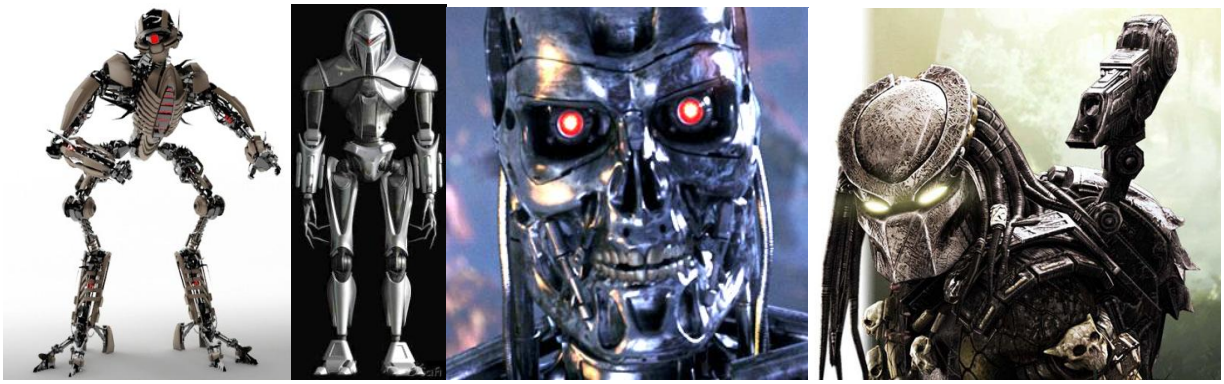
The high expectations for AI research in the late 20th Century and early 21st Century were never fulfilled. Only one AI system has developed an intellectual capacity greater than that possessed by a goldfish. That one system is ***WIKI*** - which became self aware in 2394, though, WIKI is an *idiot savant.* 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.

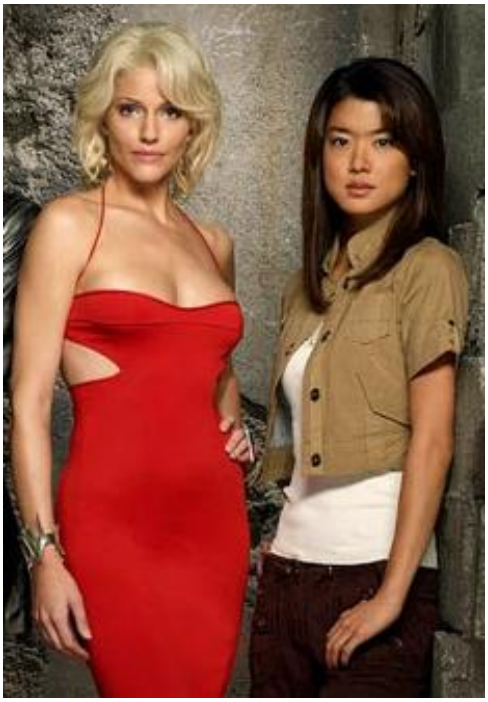
The second generation attempted to make the android chassis more human-like, though practicality was still a high priority.



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 . . . .

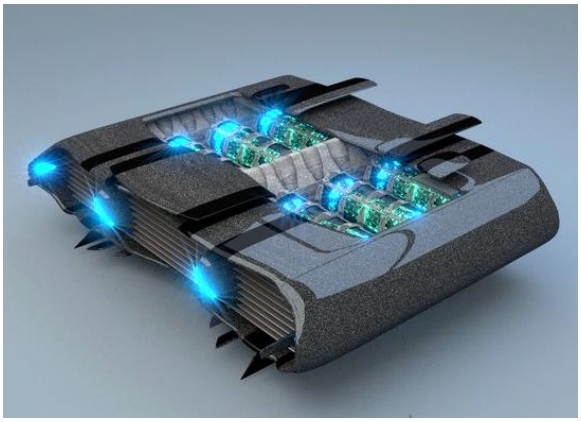


Finally two chassis were released - Model Numbers 6 and 8 - codenamed '*Cap-Six*' and '*Boomer*'. It is probably a comment on the nerdiness of the development team members that only they were surprised when research polls clearly showed that only around 50% of the human population approved of the new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

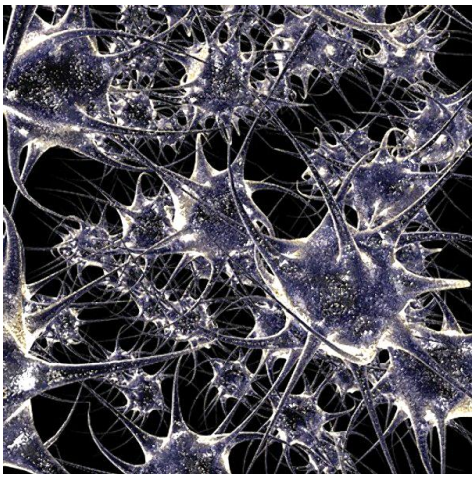
Rumours circulate about the fate of the pre-production chassis of these two models but despite much investigation concrete facts are unavailable.

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



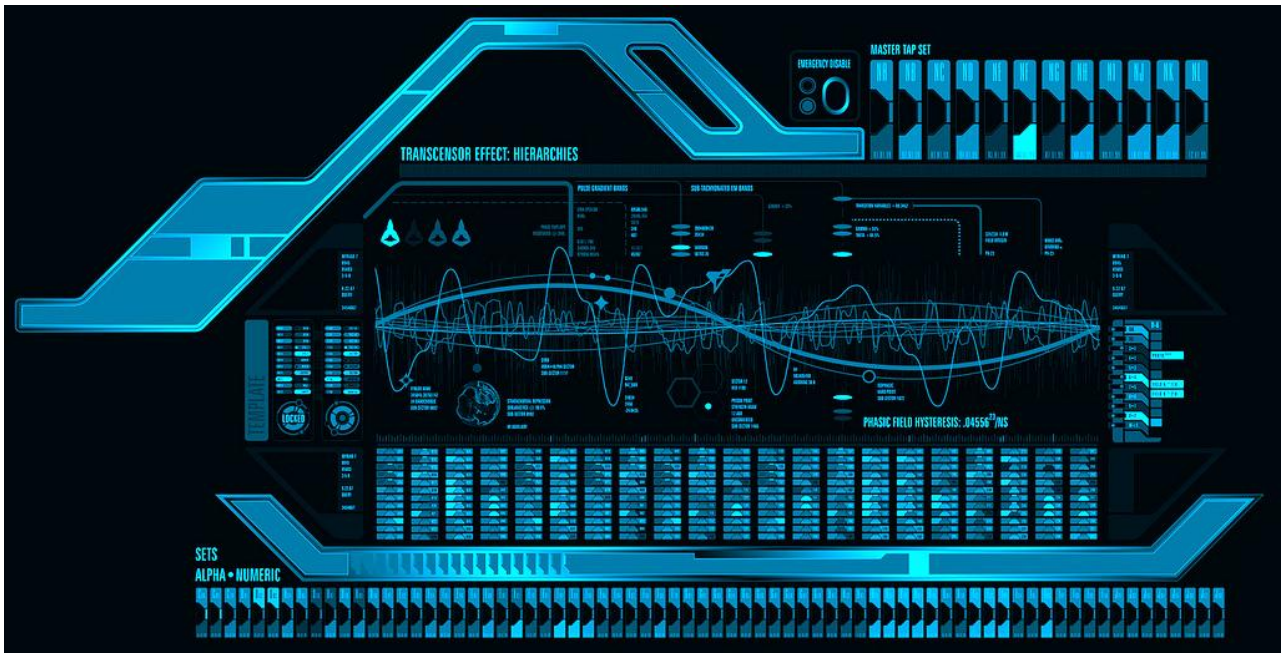
This electronic microphotograph shows a tiny part of the network illustrating the multiple connections between the nodes.

magnification x100 000 000

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 lead 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

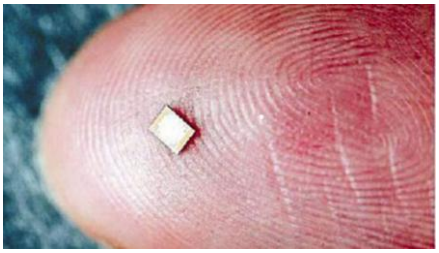
- the optimum proved to be realistic figures of 'average' attractiveness - more perfect faces lead to a feeling of inferiority amongst human users!

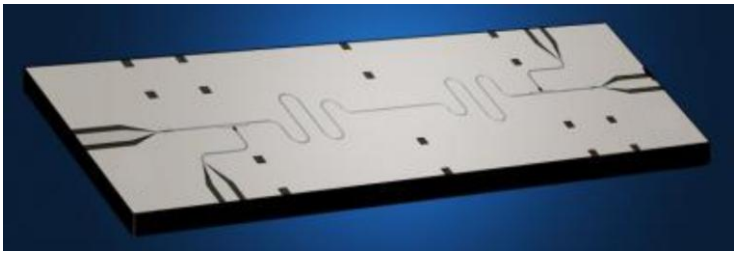
rather than

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 nest 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 : 10x1 = 1x10

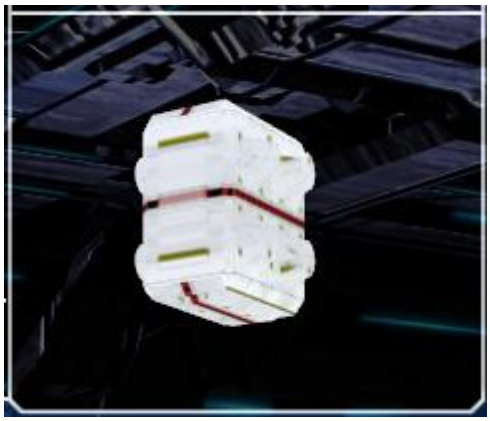
Following Newton's law of equal and opposite action and reaction, the top speed of a ship obviously depends on its mass - the more mass the lower the top speed. Pilots trade off more armour, weapons and equipment slots in return for increased mass and hence a slower ship with poorer agility. See Appendix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

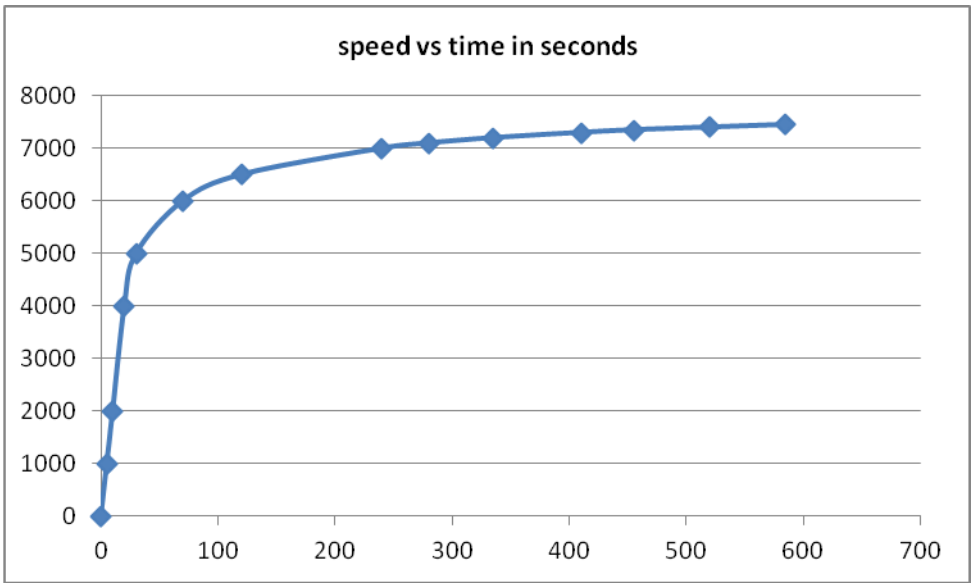
I decided to find out what was happening.

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.

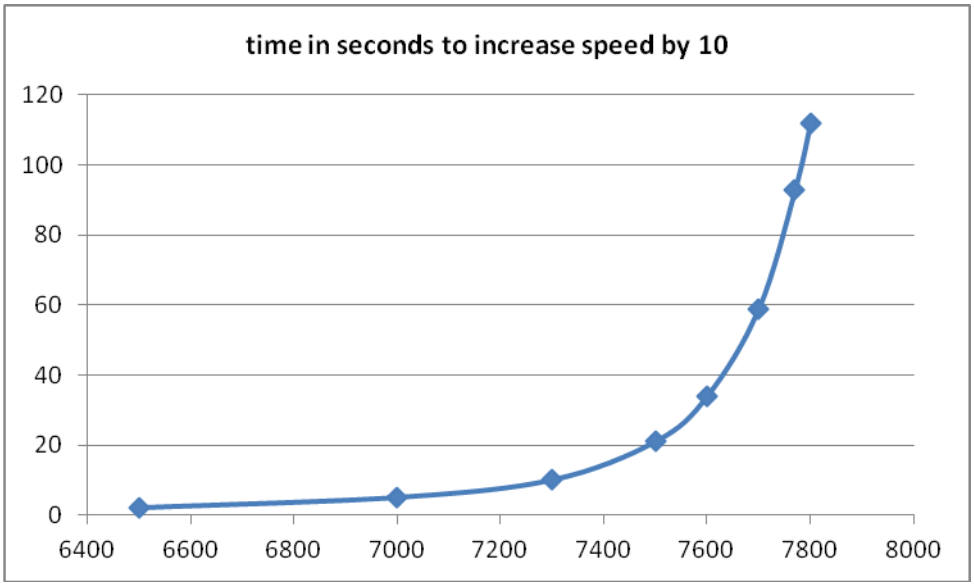
The Graph 1 shows how speed increases with burn time. The steepness of the curve is a measure of the rate of acceleration - the steeper the curve the faster you are acceleration. From a standing start, using afterburner in Inertial Flight Mode, the initial acceleration up to 5000 is very good, but acceleration 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!



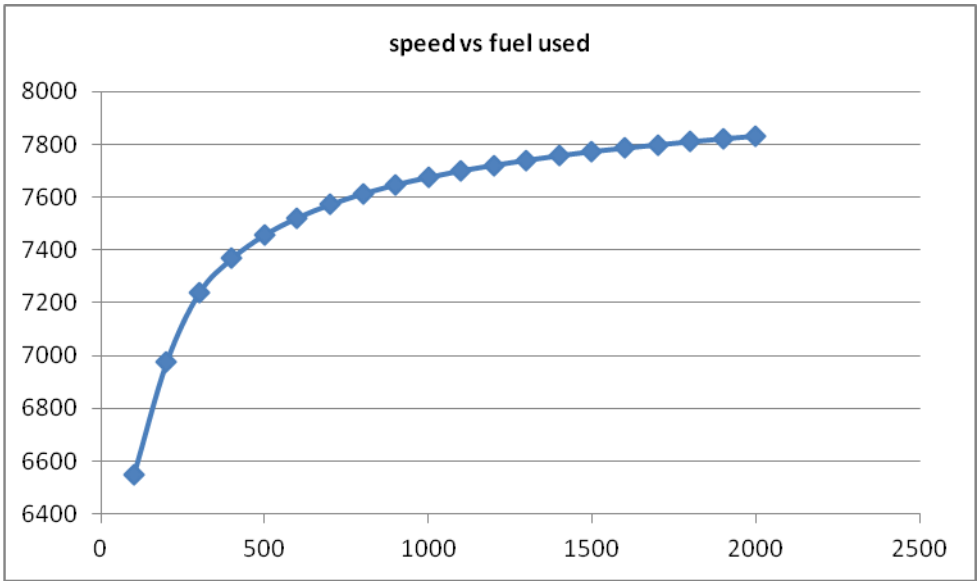
Although the fuel ran out before the top speed was reached I used the trend in change of acceleration to calculate (extrapolate) that the maximum speed achievable would be just under 7900.

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.

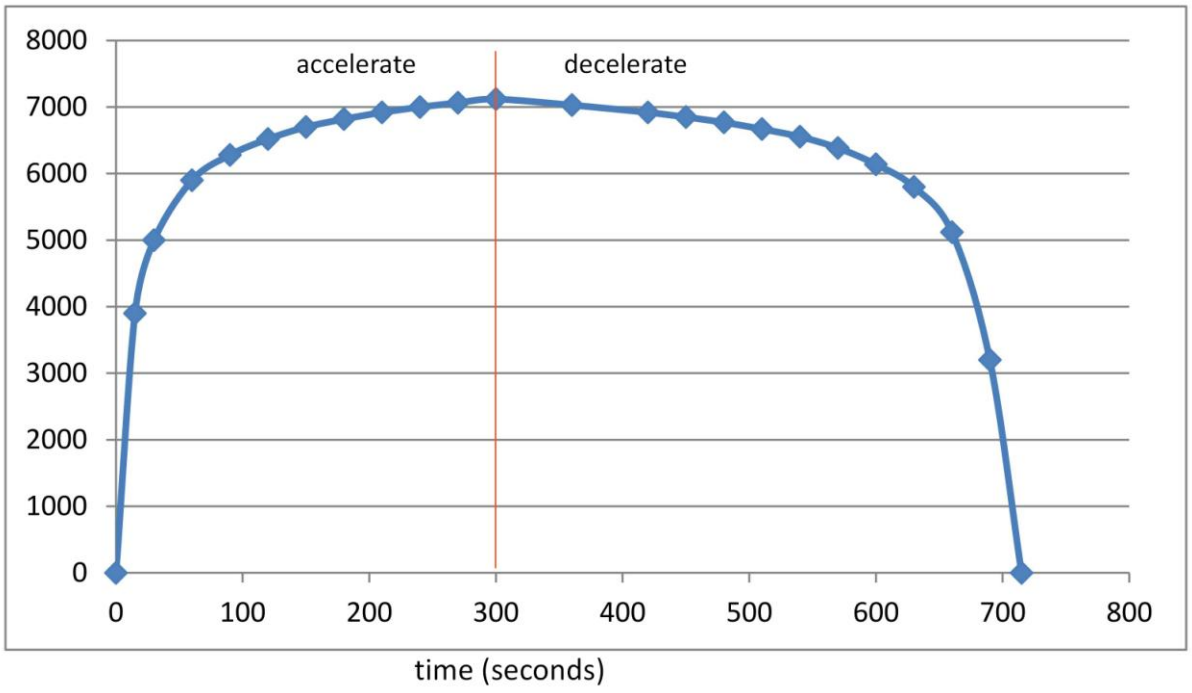
50 units of fuel will also accelerate you from

- 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 mutiplier 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 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 (that is 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 ***splosives*** 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!

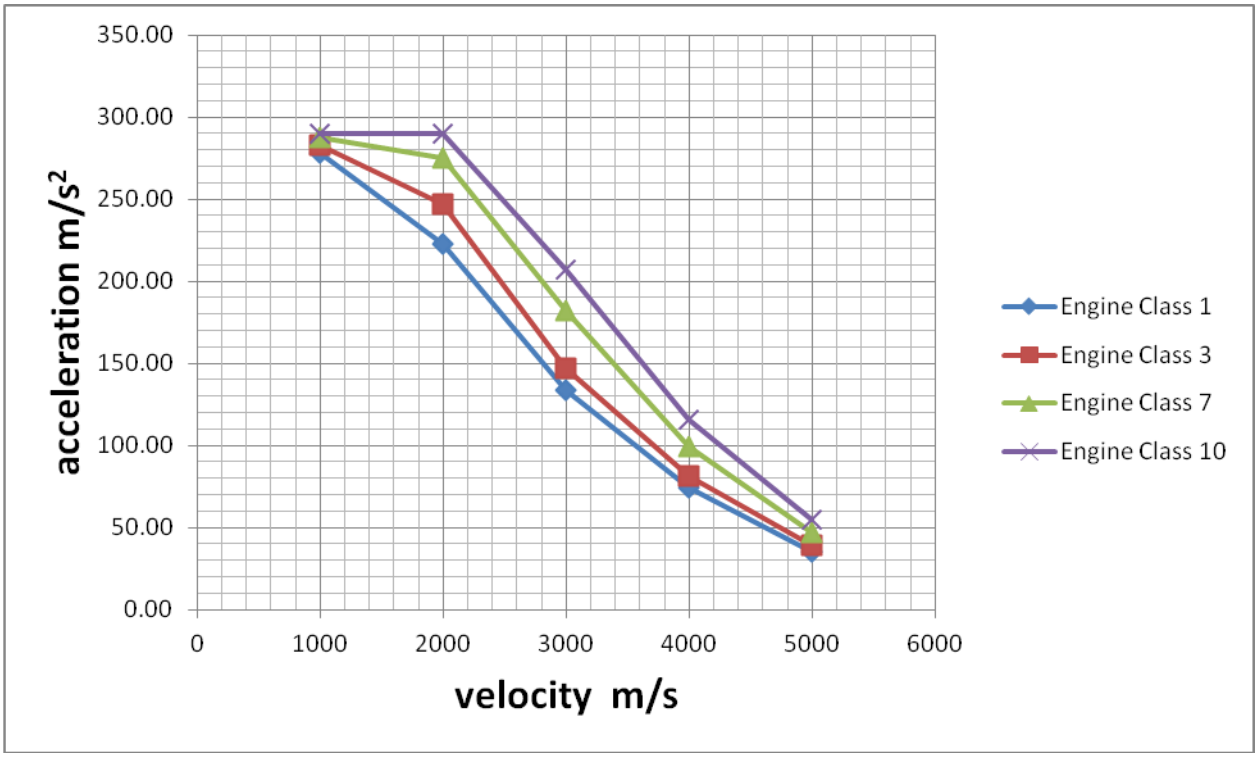
The ships were accelerated from a standing start to 5000m/s using afterburners. The time interval for each 1000m/s of acceleration was measured four or five times and the data averaged. The raw data is available to anyone who would like to play with it - please send me a U2U

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

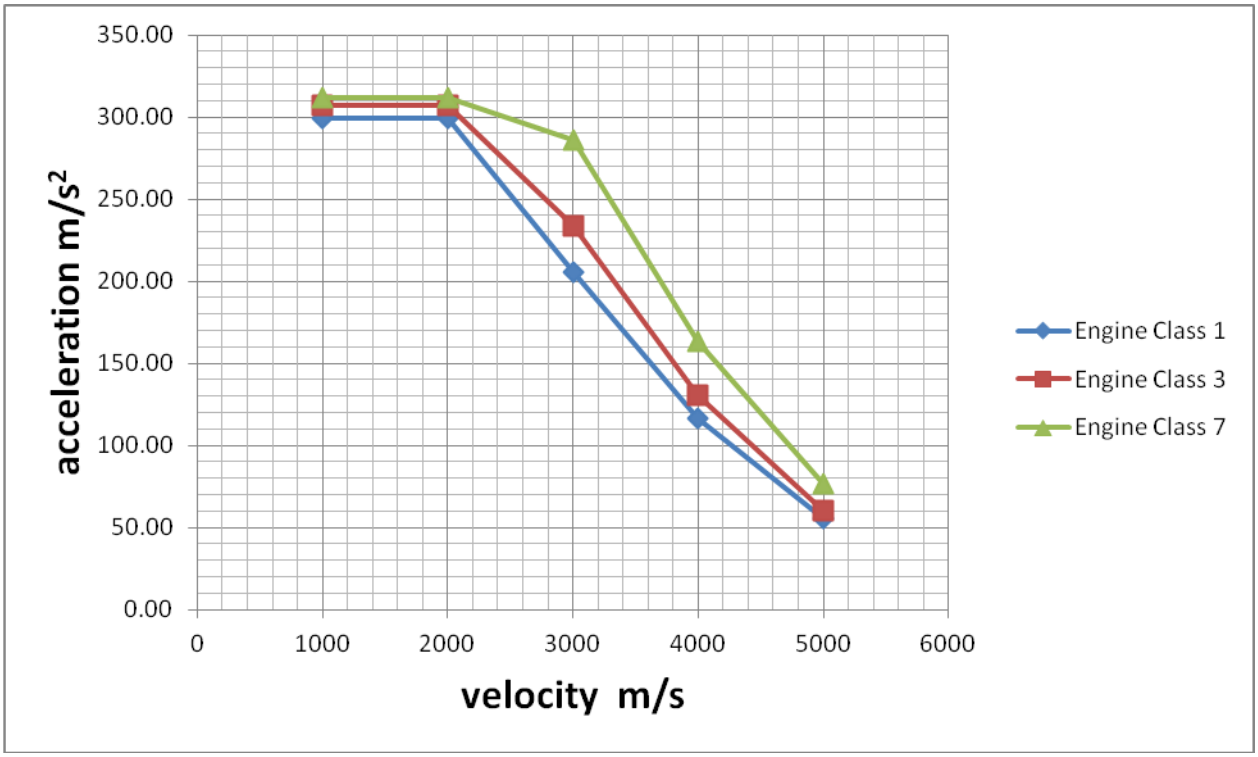
	0-2K acceleration	*Acceleration relative to engine class 1*	*% increase in acceleration compared to engine class 1*
EC1	245.60	1.00	0
EC3	262.93	1.07	7.1
EC7	280.50	1.14	14.2
EC10	300.90	1.23	22.5

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/s^2 compared to around 280 m/s^2 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		
	0-2K accel	**relative**	**%**
E1	245.60	1.00	0
E3	262.93	1.07	7.1
E7	280.5	1.14	14.2
E10	300.9	1.23	22.5

Talon		
0-2K accel	**relative**	**%**
299.40	1.00	0
305.81	1.02	2.1
311.77	1.05	4.1

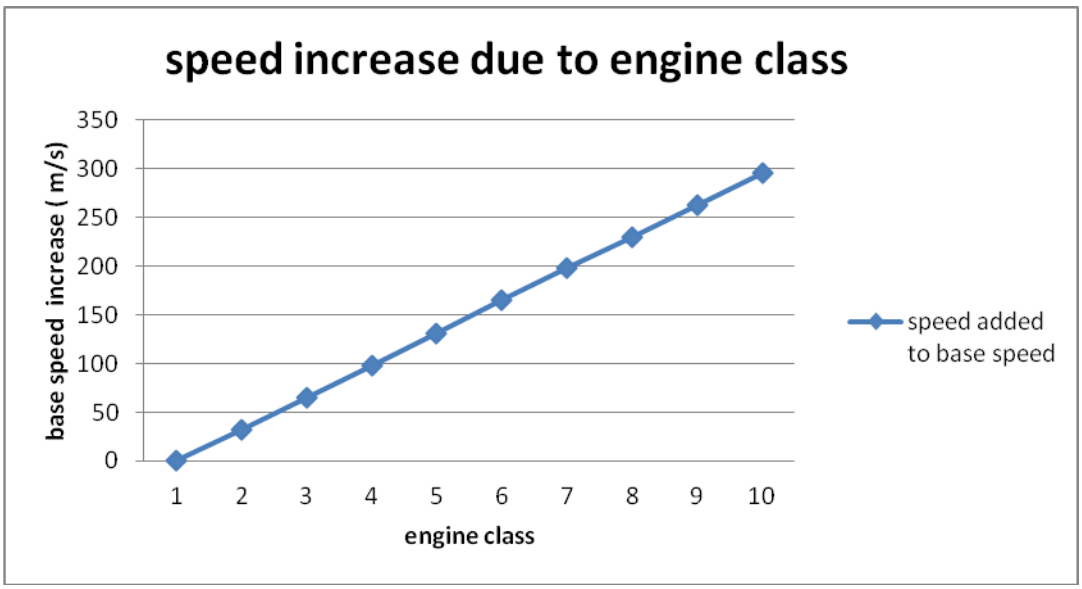
It can be clearly seen that using the same class of engine on two different frames does have an effect on performance. The C1 engine accelerates a Starmaster from 0-2000m/s at 247m/s^2 and a Talon at 300m/s^2.

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 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 (that is 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.

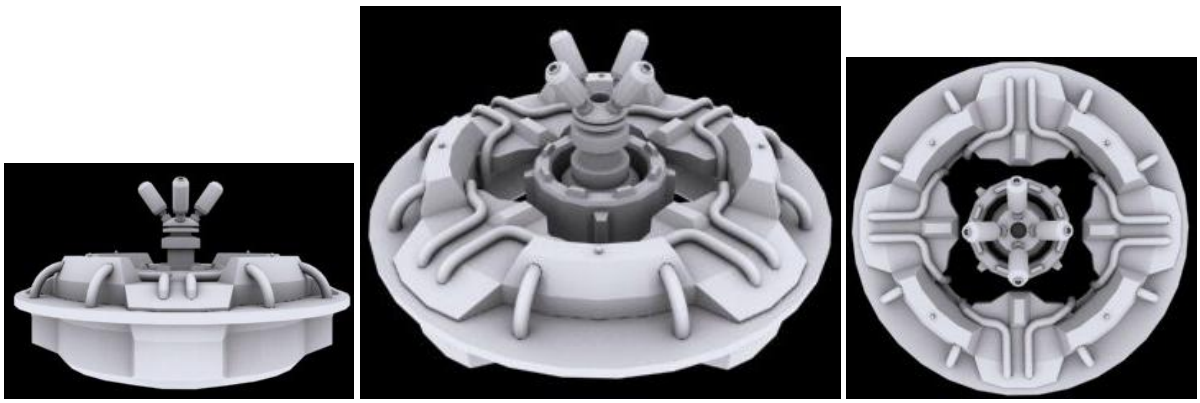
Researchers moved to a different areas of research. Einstein showed that acceleration is indistinguishable from gravity - if you are in an enclosed lift (elevator) and it starts to go up, you cannot tell whether it is the elevator moving up or gravity that has increased (measuring equipment can't tell 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 damping 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;

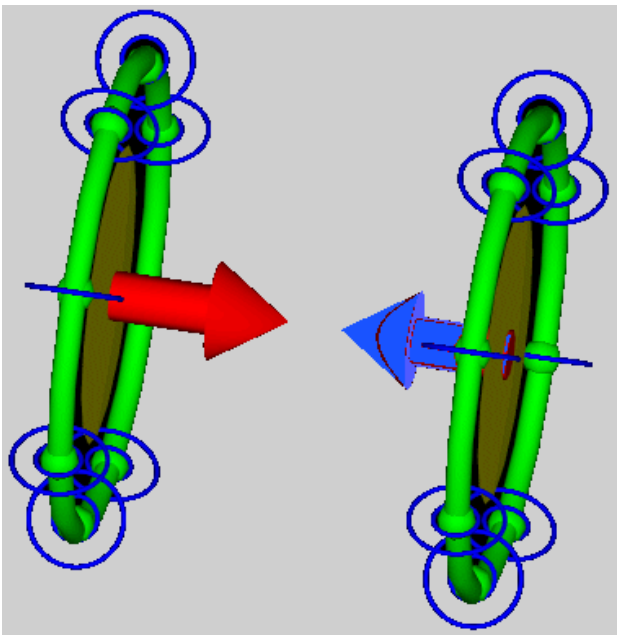


The four antennae at the top are angled so that between then they can generate a graviton field on any required direction. Within each angled generator module is complex set of graviton particle 360 degree emitters:

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 ⅔ 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
0.999999999999	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.

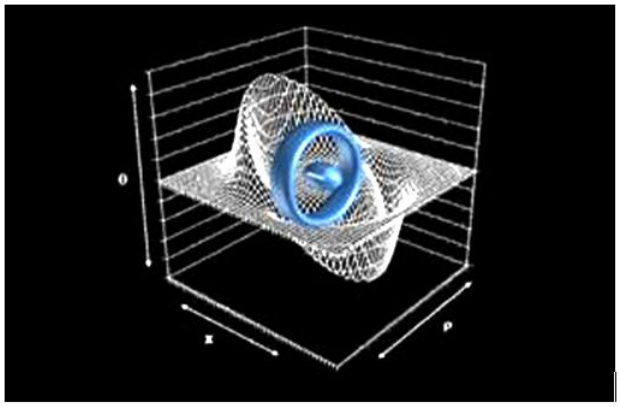
For more explanation look up 'the twin paradox' on ***WIKI*** or ***GOOGLE***.

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.

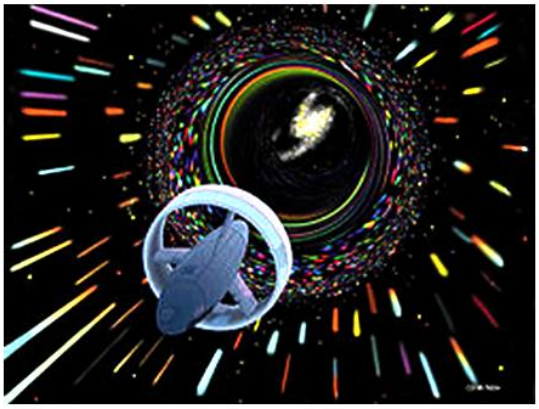
All of which shows why the Fulcrum Drive had to be invented (in 2178) before humanity could reach the stars.

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'!



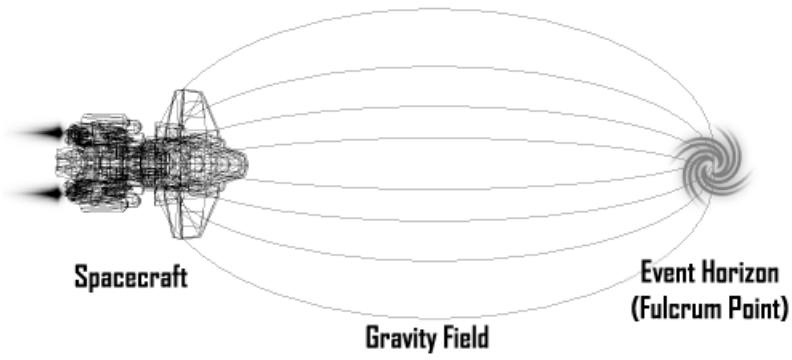
They published various papers but the technological difficulties left it as an 'interesting idea' for the next 150 years. They did however propose an experimental design (right) on which the first successful Fulcrum Drive test probe (below) was based!



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.

Fulcrum Jump Technology Development

Introduction – FJT fundamentals

Fundamentally there are two versions of fulcrum jump technology

i: paired gates that allow the creation of permanent wormholes between two points in space. The advantages are that ships can pass through a gates at any time and arrive safely at the exit gate. The disadvantage is that the entrance and exit points are in fixed positions. Ships are limited to jumping between gates and also limited in size by the diameter of the wormhole event horizons created by the gate technology.

ii: Fulcrum jump drives that are installed in ships and that can create a worm hole event horizon at the distant point in space without the need for a receiving gate. The disadvantages is the relatively short range of the jump drive. In mercenary ships this is five sectors though de-engineered Vonari technology has doubled this to ten sectors in the Mantis Dive. Mantis drives are not commonly available in core systems.

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Timeline I broad outline of Fulcrum Technology Development

early 21st Century; developments in understanding of Quantum theory pointed to the possibility of developing FtL travel. Gradual theoretical progress made over the next five decades lead to the development of the equations describing the creation of stable wormhole event horizon (fulcrum or pivot point. However, the practical developments lagged well behind theoretical advancements, especially the method of creating 'exotic matter' (negative mass/energy matter) required for creating stable Lorenzian wormholes. The sequence of developments is;

i a: development of a mechanism that creates a (microscopic) WH event horizon. These are transient and last for less than a microsecond and are less than a nanometre in diameter.
i b: In parallel, developing a technique for manufacturing 'exotic (negative mass/energy) matter' that is required to enlarge and stabilise the wormhole event horizon
ii: design and development of a mechanism that work in pairs to create, enlarge and stabilise the event horizon at each end of the wormhole allowing a ship to traverse the wormhole in less than the time it would take light to cover the same distance through normal space – effectively bypassing the speed of light as a universal limit. The ship itself never approaches, never mind exceeds the speed of light. These are now known as jump gates.
iii: creation of a mechanism (fulcrum jump drive) that can create an event horizon at a distance (the fulcrum point) and accelerate the ship eventually triggering the folding of space without the need for a second gate
iv: the earliest drives were used to power the exploratory probes sent to other systems. The creation of the fulcrum point was difficult to programme and the therefore the safe jump distance was relatively small. As the drive design was sequentially refined, the position of the fulcrum point could be programmed more accurately, the energy requirements became significantly less and the maximum jump distance increased resulting in . . .

v: the nanotech based constructor units sent to other star systems to construct the second gate required for long distance jumps. These were much more massive than the initial exploratory probes but their maximum jump range was greater.
vi: further improvements lead to the development of drives that could be installed in crewed ships with a performance that could safely send ships to specific destinations over reasonable ranges – even so the first jump enabled ships were capital ships. The jump drives and their energy sources occupied the bulk of their available internal volume for the size of the engines, but mainly the energy generation systems.
vii: these drives were improved to increase their maximum range and reduce their energy drain.

The speed of development of jump technology was one of the most phenomenal in the history of engineering in human history, reflecting the resources and manpower dedicated to it.

Timeline II - Development Timeline Detail

2178: the first practical demonstration of jump equipment utilising the theoretical equations being developed since the middle of the 21st Century. The mass transferred was atomic/molecular in size. A fortuitous development in the created of exotic matter accelerated the speed of development vastly speeded up the size and stability of the wormhole event horizon that could be stably created. Because gates were lined in pairs, stabilising the entry and exit points jumps were possible between planets within the Sol system. As a result . . .

. . . by 2182: Gates are created at strategic places within the system permitting Sol system to be colonised. Normal reaction drives are used within the colonised areas.

Over the next few years, developing and refining the equations that link jump distance, vehicle mass and energy requirements, research focuses of creating more efficient jump technology and in parallel building small, simple, cheap probes that can jump far enough fast enough to reach local stars. Size limitations mean that cargo or crew carrying capacity is impossible. These mini-probes are somewhat Heath Robinson, but they can get to the star systems in a few (rather than a few tens of thousands) of years, utilising a fusion nuclear energy source and simple AI navigation systems that can compensate for the uncertainties in the jump exit points.

2190: probes sent Orion system – map system and relay data back
2195: Orion sector identified as a candidate for colonisation -
2197; nanotech based constructor units with upgraded FJT sent to Orion to construct a gate
2200: Trailblazer Units sent through the gate to prepare for colonists
2205: first colonists arrive in Orion

This is actually a phenomenal achievement – 15 years from starting the exploration to the first colonists arriving!

2212: Recognising that the lack of a jump capable ship is severely limiting colonisation and exploration, a project is started to create FJT that can be fitted into a ship able to carry cargo and crew. The problems prove to be harder than anticipated in the euphoria of colonising Orion, but by . . .
2240: FJT efficiencies and miniaturisation allow the creation of the first jump drives that can be fitted into a ship. The minimum size is military battleships and carriers. Even so, the jump range was still limited (50-100 sectors). A prototype ship is secretly ordered. Build name X1. It is significant that colonisation has become a lower priority compared to the hostile relationships that exist between the Terran Alliance (at home) and the new colonies (flexing their fledgling muscles and yearning for independence)
2245: The X1 is completed and commissioned with the name ABC Lexington. The secret of its existence is maintained from the public while tests were conducted on its new mobile long range Fulcrum Drive and advanced weapon systems for the next nine years!

2248: The Alliance three sister combat carriers named Bismarck, Zenith and Victory, which would be completed by 2259. Rising costs considerations resulted in the second being mothballed, only part complete and three third being cancelled

2254: The public becomes aware of the existence of the Lexington

2259: ABC Bismark commissioned.

2262: The FBC Becker is commissioned.

Over the next decades research priorities turned towards making FJ drives even smaller and even more efficient. The aim was to give fighters a jump capability. They would be transported to their mission area by their carriers but the lack of jump capability limited their usefulness. With sufficient reduction in size came a reduction in jump range. But steadily the range was increased from one tenth of a sector up to a little under two sectors / jump. Once the stability and robustness was proved, FTJ drives were retrofitted to Alliance F144A StarWraith fighters in ***2279***, just a year after their introduction. The Federation quickly followed suite with their UFA-80 fighters

It proved to be very fortunate that some much time and energy and money was focussed on military development. Consider what the outcome of the First Vonari Invasion would have been without two honed military organisations to face them!

By the mid 2280's the technology was mature enough and cheap enough to be fitted to mercenary ships. The role of the present mercenary dates from that time. The next major development created a step change in ship jump drives, ironically starting as a radical development in jump gate technology

2288: Dr. Adam Shefeld developed a radically new design for a vastly more efficient warp-gate device that could open a temporary stable fulcrum field pathway to a specific programmable point without the need for a receiving gate. The efficiency was much higher and range was significantly further than the drives installed in capital ships and could be used by to send many ships quickly to the same point in space. This was revolutionary – until this time gates had to be created in pairs and capital ships could only transport themselves plus their fighter squadrons and their jump range was limited. Coordinating fleet battles was virtually impossible due the unpredictability of a battle fleets arrival time.

Despite being pivotal in saving the Earth from invasion during the First Vonari Attack in 2288, only a very few Shefeld gate were built. A cost benefit analysis balanced its cost and difficulty in maintenance and the complex procedure of targeting a safe exit point against the simplicity and utility and lower (though still substantial) cost of maintaining a network of paired gates. The study concluded that creating a network of Shefeld gates was uneconomical except for a couple of rare situations. A 'wild' WH was discovered in the Olympus/a core system that linked to a major system well outside the core - Wolfzone. Natural WH's provide a one way journey leaving ships travelling to Wolfzone stranded. It was decided that building a Shefeld gate in Wolfzone, with a single destination hard coded back to Olympus Prime was the most economical solution!

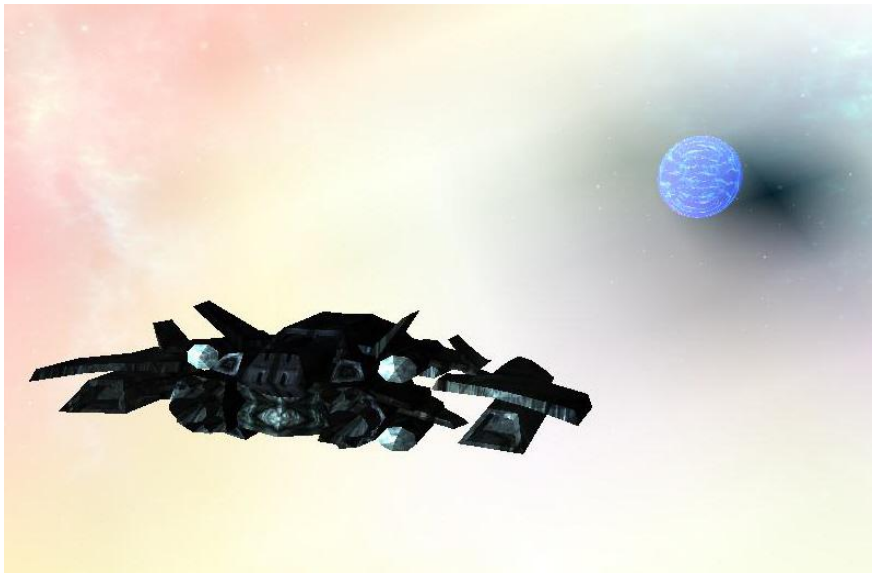
However Shefeld and his team continued their research and steadily reduced the size and increased the energy efficiency of their technology and succeeded in turning it into a successful ship borne jump drive. Capital ships were retrofitted with modified Shefeld drives that had a vastly greater jump range (around 3 000 sectors) coupled with higher energy efficiencies. The much smaller drives, though having much shorter ranges (1-5 sectors) became cheap enough to fit into solo mercenary frames in place of the Mk I jump drives developed from the military fighter jump drives introduced in 2279.

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

Background : Relativity

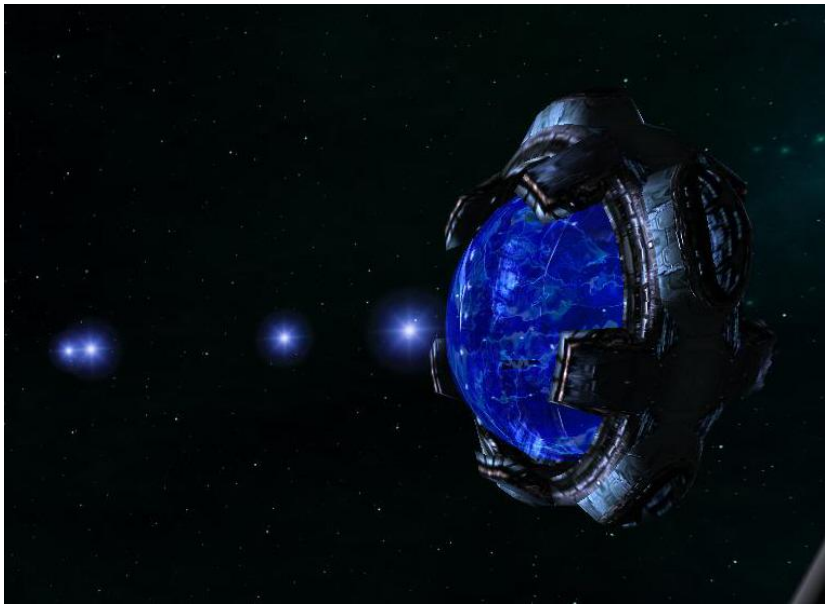
This depends on wormholes. The basic theory is the same as the small event horizons generated by the Fulcrum jump drive, but utilises 'permanent' WHs. All appear as blue spheres with a rippled fluid surface. There are three types:

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.

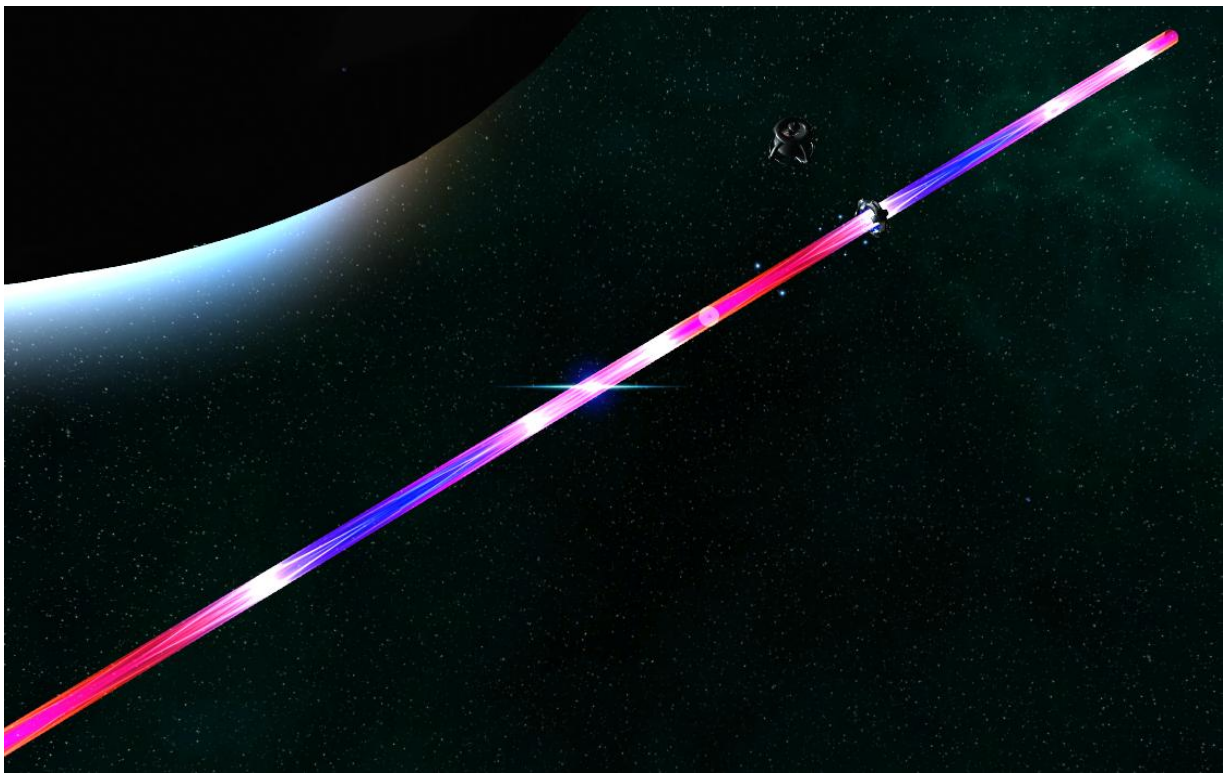


Type II worm holes were formed inside BH's and were stable enough to survive the eventual evaporation of the BH by its emission of Hawking radiation (see earlier). The negative mass/energy 'exotic material' created in the intense BH gravity field interacting with CDM became incorporated into the WH 'mouth'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



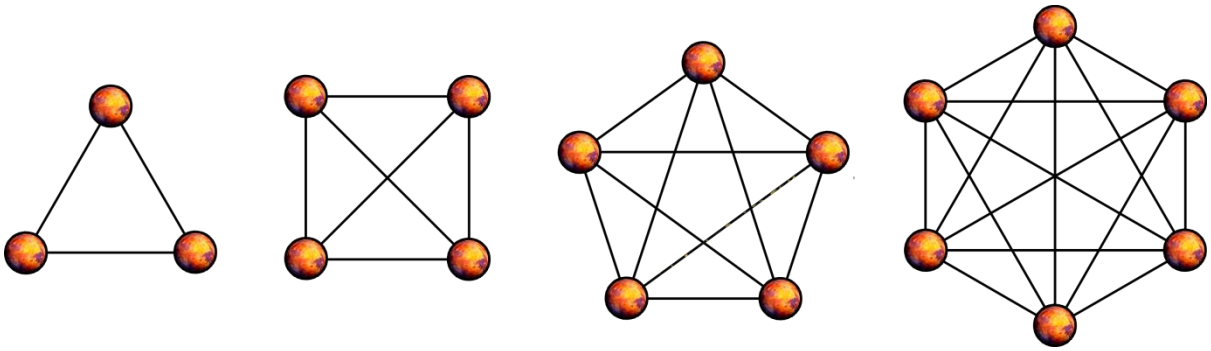
The WH mouth is extended into a visible tube for a brief period as the ship enters it and the ship can be seen starting it's jump - a truly beautiful and awesome sight!

Why don't we have more gates? Gates, WH, BH and Ancients' technology - distances and economics compared

	System 01	System 02	distance / sectors
Central	Sapphire	Olympus Prime	1360
	Sapphire	Fauston	940
	Sapphire	**Thuban**	**480 : min**
	Sapphire	Lambda	1300
NE Quadrant	Olympus Prime	Onyx	2300
	Onyx	Cerulean	1580
	Cerulean	Atlas	1520
	Cerulean	Talison	2080
NW Quadrant	Talison	Fauston	1340
	Talison	**Sierra**	**2760 : max**
	Sierra	Aries	1960
	Aries	Merak	1560
	Aries	Cygnus	1960
	Cygnus	Fauston	1260
SW Quadrant	Lambda	Emerald	1960
	Emerald	Rigel	1950
	Rigel	Iota	1200
	Rigel	Sirius	1280
	Sirius	Orion	1840
	Orion	Thuban	2140
SE Quadrant	Thuban	Pices	1820
	Pices	Pearl	2040
	Pearl	Rucker	1700
	Rucker	Aquila	800
	Aquila	Alpha Centauri	960
	Alpha Centauri	Deneb	2200
	Rucker	Capella	1000
	Rucker	Virgo	1260
	Virgo	Vega	860
	Virgo	Thuban	1100
Natural 'Wild' WH (These are one way transits)	Riftspace	Sol	16630
Ancients' Tech	Andromeda	Rigel	30940
Blackhole	Andromeda	unknown near Pearl	30000

It may seem from the table that jump gate (using artificial stabilised WH's) are relatively short range – min/mean/median/mode/max = **480**/1550/1540/1960/**2760** sectors – whilst the longest known 'wild' WH jump is almost 17 000 sectors and the Ancients' device covers a staggering 31 000 sectors.

However the apparent limited range of gates is due to economics rather than the limit of the technology. There is a link between the mass of the ship, distance travelled and the energy required to create the jump tube between the pair of gates. See below for details. As Evochron was explored and each planet suitable for colonisation discovered, a gate was built from the nearest colonised planet in that quadrant. Once the number of planets colonised reached a critical level some thought was given to creating an efficient network, dividing Evochron into four quadrants around Sapphire at the centre. Repeatedly someone raises the question of creating a 'more efficient' network where every system is linked to every other system.



However the number of gate pairs required to link '***n***' planets **= (n x (n-1)) / 2**

Plotting increasing values of ***n*** into this equation leads to an exponential increase in the number of gate pairs required. The first 10 sequential numbers are 0 – 1 – 3 – 6 – 10 – 15 – 21 – 28 – 36 – 45

These numbers are the gate pairs that would need to be built and maintained if every system was linked to every other system; 45 gate pairs = 90 gates to link just 10 planets. To link the 27 core systems to each other (ignoring warzones, the Agate twins and the specials like Wolfzone) would require 351 gate ***pairs*** which is 702 gates. The economic cost of maintenance almost 12 times as many gates is exorbitant, especially given how quickly a ship can cross the core using the present 30 gate pairs.

No-one knows the maximum distance a gate can cover; theoretically 0t is in excess of 5k sectors, but military capital ships are reputed to be able to jump around 9k sectors from one side of the core to the other (Sierra – Deneb) in a single jump. Eat your heart out Mantis drive owners!

The longest jump through a wild worm hole is over 16.6k sectors. The record for the longest single jump is via the Ancients' technology in Andromeda to Rigel which covers over 31k sectors

There is speculation that when a WH is in the heart of a BH it has a longer range. The Ancients' Teleporter is thought to recreate this effect without the conditions found in the centre of a BH. However, statistically these conjectures can't be supported – there simply is insufficient numbers of wild WH's and WH's in BH to provide data to model performance

The energy required to creating a pivot point in space between two locations increases by the power of $^{5}/_{4}$ as the distance of the jump increases for a given mass. Having a gate at either end doesn't decrease the energy – it simply stabilises the wormhole event horizon

distance (sectors)	energy requirement increase
1	1
2	3
3	6
4	9
5	11
10	27
50	180
75	300
90	375
95	390
100	420
500	2 900
1 000	6 600
1 500	10 800
2 000	15 500
5 000	47 000
10 000	110 000
30 000	425 000
50 000	800 000

Thus, the maximum jumps distances seen (none of which are created gates) require 75 times as much energy as the average gate jump of 1500 sectors. This puts a practical, rather than theoretical limit on gate ranges. The longest jump (Talison<>Sierra – 2760 sectors) requires 8 times the energy of the shortest (Sapphire<>Thuban – 480 sectors).

The energy requirement increases with mass by unity power (so doubling the mass of a ship doubles the power requirement). It has major implications for capital ships – theoretically they can jump the 9 000 sectors but they rarely do so because of the enormous energy requirements of jumping such a large mass. . . .

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 ($c1 = SQR (x^2 + z^2)$).
2. Measure or calculate combined component ($c2 = SQR (y^2 + c1^2)$).
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 two armament fabrication and supply monopolies; 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 lead to a significant reduction is 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 for their fighters 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 location 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.

	Input Parameters	*Output Parameters*
Type: Particle Cannon		
classes: • plasma • metal projectile • rail cannon • fusion	• emitter output • actuator speed • capacitor reserve • heatsinks	• yield • heat • energy • range • rate of fire
Type: Beam (Laser) Cannon		
classes: • refractor • metal vapour • coil • neodymium • fusion	• emitter output • capacitor reserve • heatsinks	• yield • heat • energy
Type: Missiles		
classes: • impact • reactive • fragmentation • shaped charge • compound core	• detonator capacity • thruster power • guidance system • casing armour	• yield • agility/speed • range • CM resistance

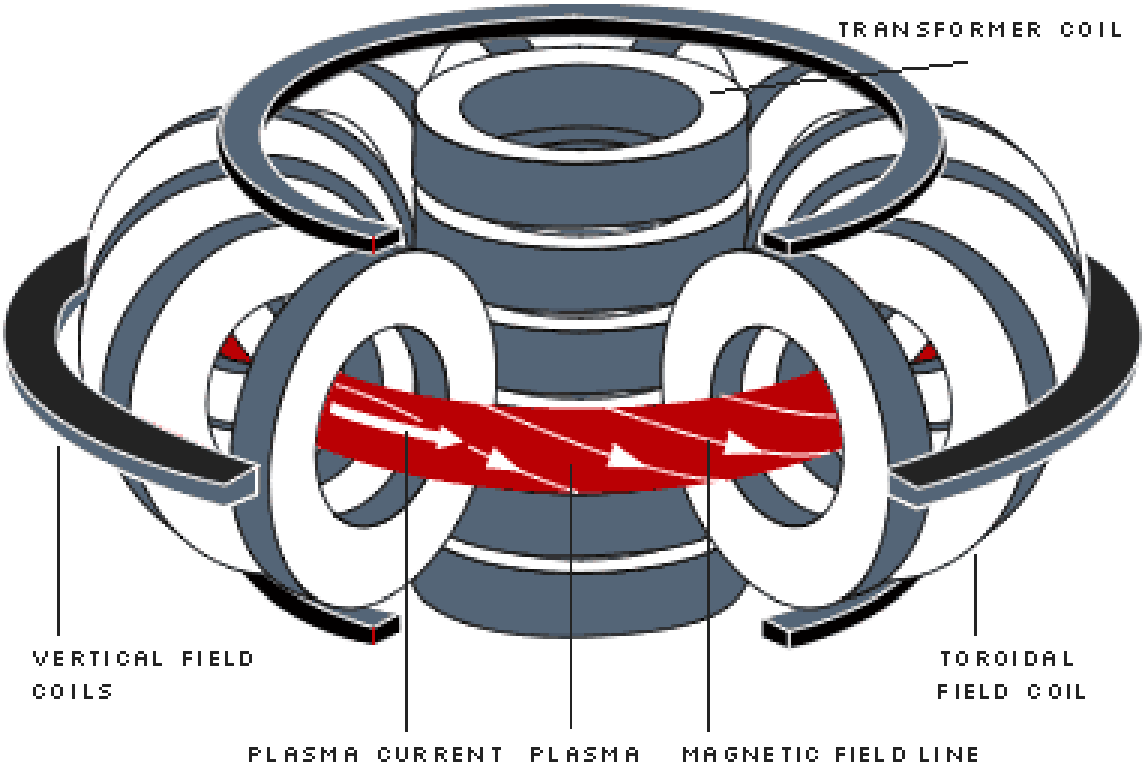
The following sections begin by describing the standard weapons in each class that have been available for many years and then follows with details relevant to the additions available via the Weapon Lab. This in turn is followed by information on how to use the Weapon Lab.

Particle Cannon Classes

Plasma Particle Cannon

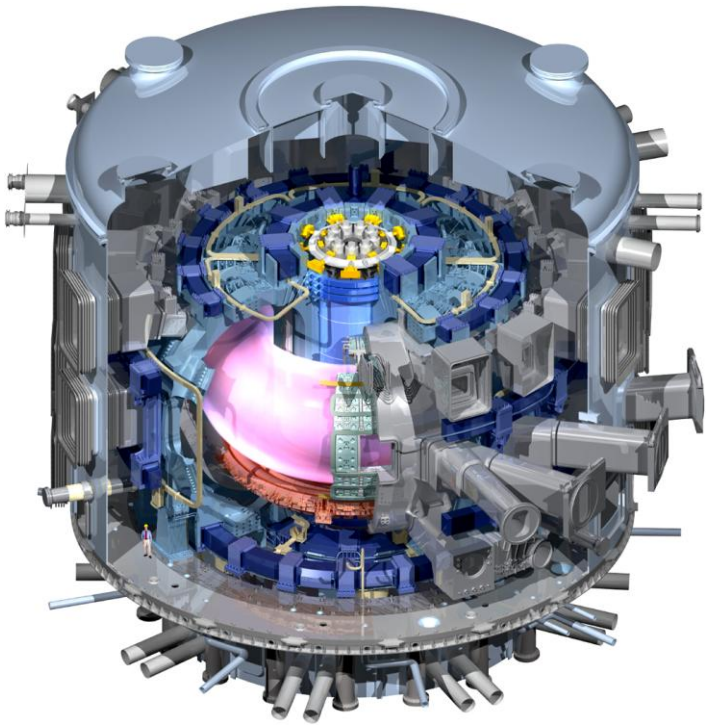
Plasma particle cannon have been available for many years.

CDM is 'harvested' and then converted into normal atomic matter. Packets of matter are heated to 6000K 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;

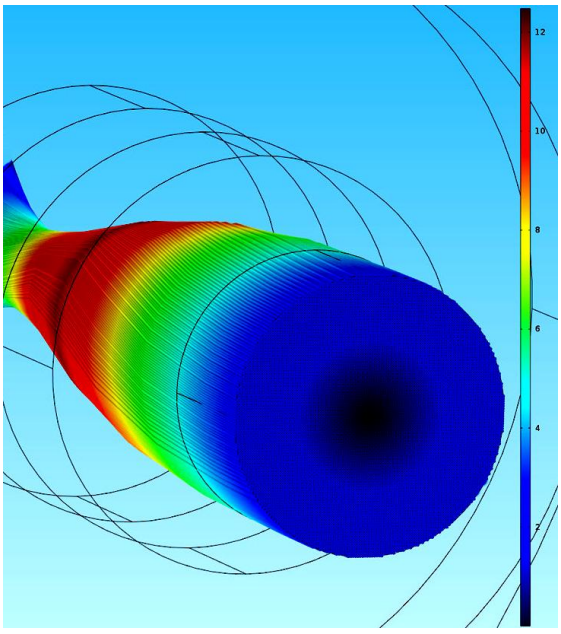


- Firstly the time delay between a packet being 'fired' and the next packet of plasma being delivered to the electromagnetic lens / acceleration system allows the cooling system in the barrel of the cannon to work with an reasonable degree of efficiency - without the cooling cycle, the cannon would overheat (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'.

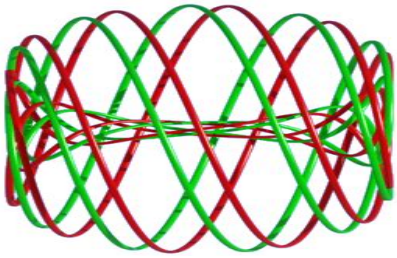
Finally the packet is subject to electrostatic acceleration to a very high speed; the plasma is confined within an magnetic field during the acceleration phase both to protect the barrel and to increase the cannon's range.



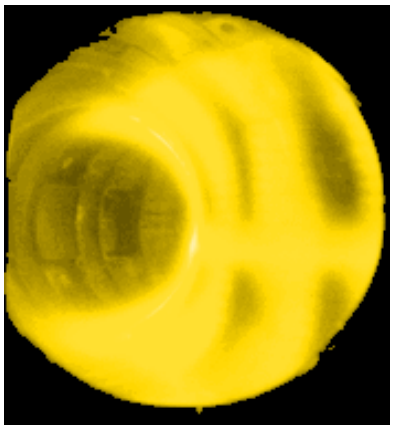
The lens focuses the relatively diffuse plasma packet by concurrent lateral compression (into a narrow cylinder) and longitudinal compression to shorten the cylinders to create a high density cylindrical plasma packet. The packets are called ***plasmoids***. The name *plasmoid* was coined in the 20th 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.

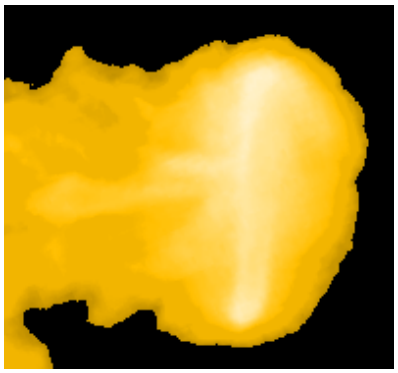


Since a plasmoid is a coherent structure of plasma an induced magnetic field is created within the packet due to its spin. This diagram shows a simulation of the induced field. The plasmoid is travelling left to right and rotates around its flight path.

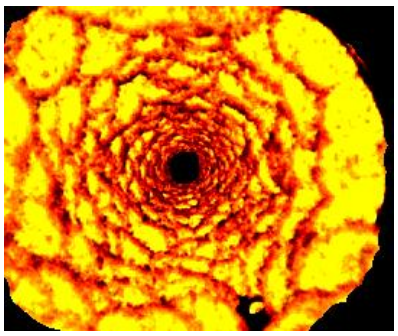


The plasma is therefore emitted not as an amorphous blob, but in the form of a short tube - an elongated torus.

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.

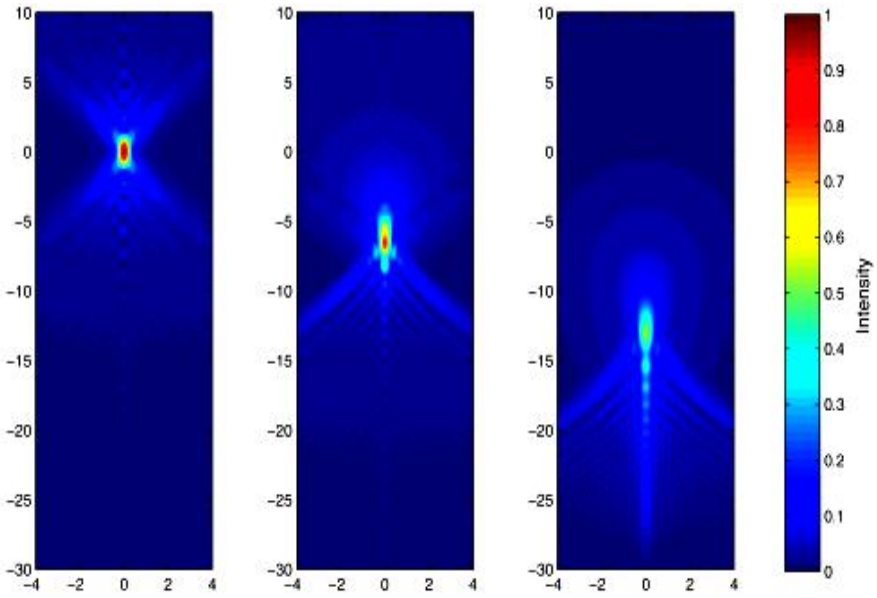


However the packet does dissipate quite quickly reducing the effective range of plasma cannon to below 800 metres



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

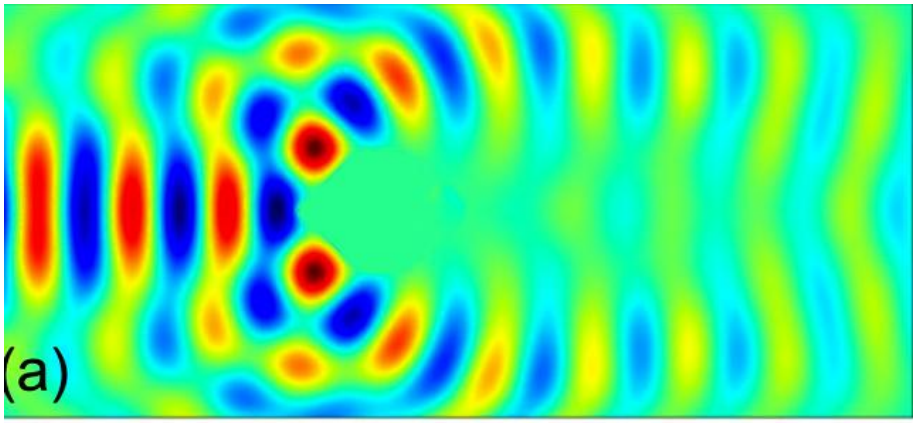


diagram (a) shows the plasma packet dissipating rapidly within the acceleration tube in the absence of the em lens's focussing;

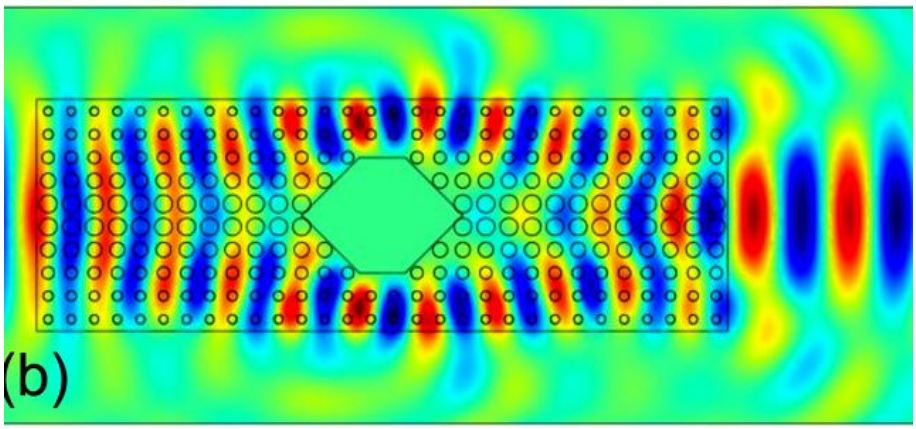
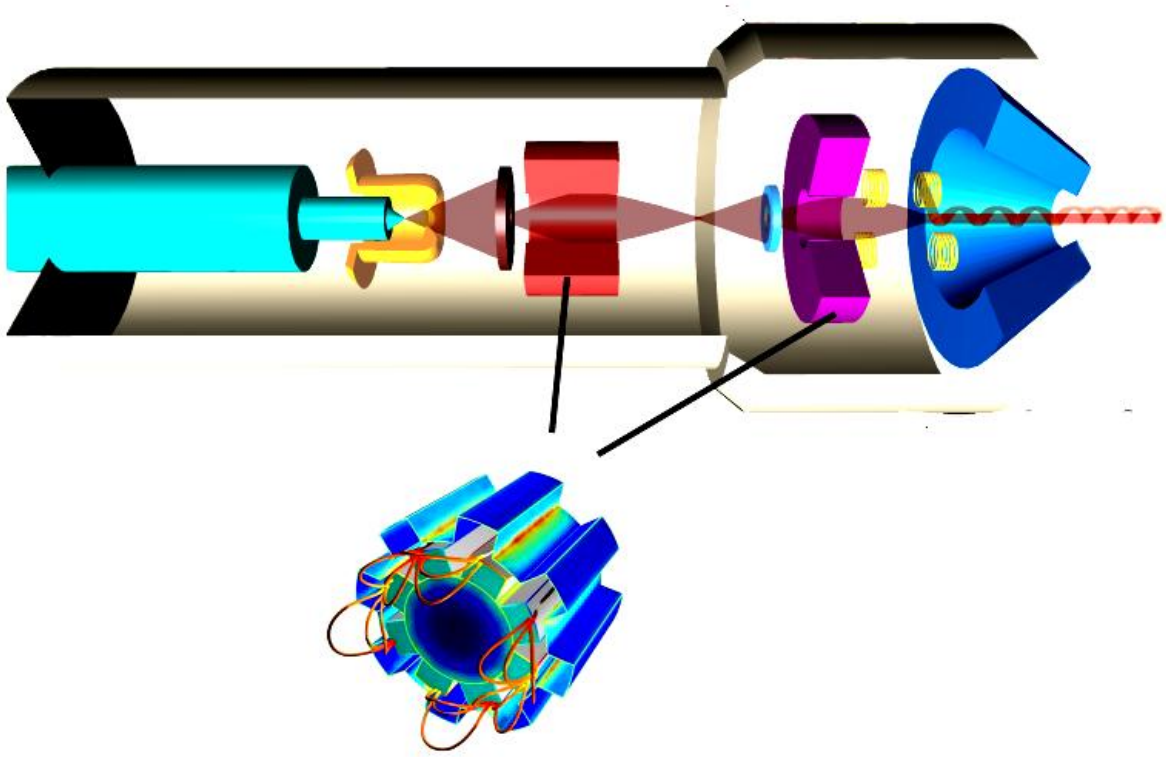


diagram (b) shows the collimating effect of the em lens concentrating the plasma packet;

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 velocity ^{2}) 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 breeched 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 breeched. 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.

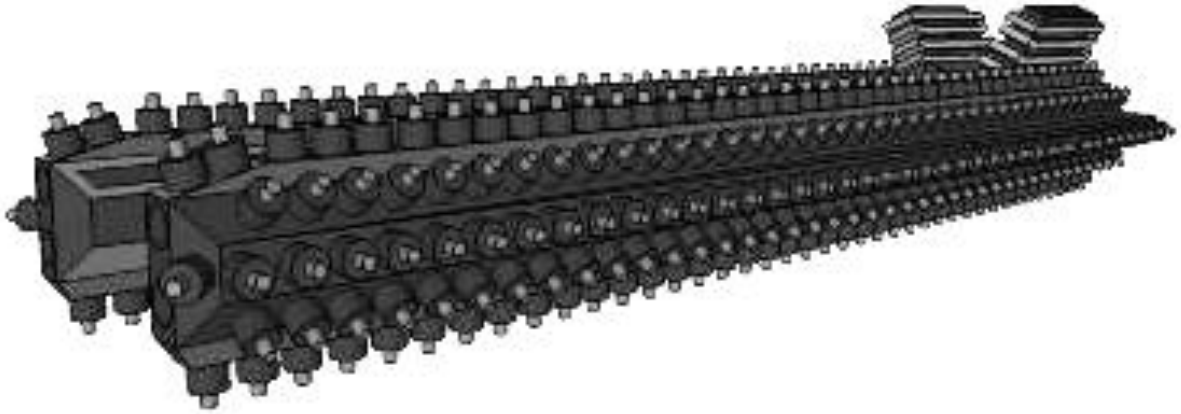
Secondly, this simple analysis assumes that every shot hits. In a combat encounter, using MTDS it is rare that all shots hits. Mercenaries experiment until they find a combination of yield and fire rate that suits their combat style.

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!!

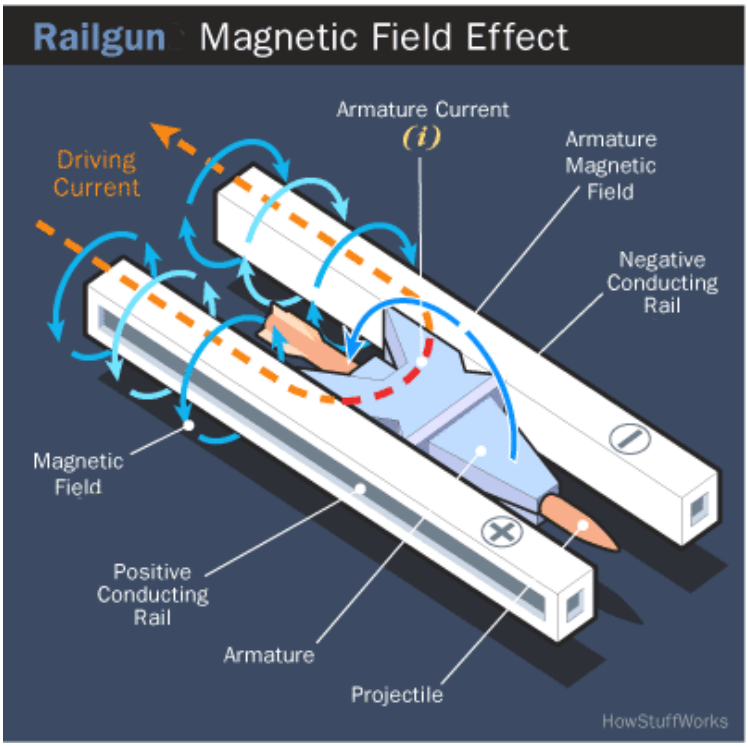
The plasma focussing device is similar to but stronger than that of the *plasma particle cannon*. The DPF ejects plasma in the form of a plasmoid, without 'squeezing' it but because of the more extreme conditions inside requires a more complex generating and acceleration electromagnetic field system.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



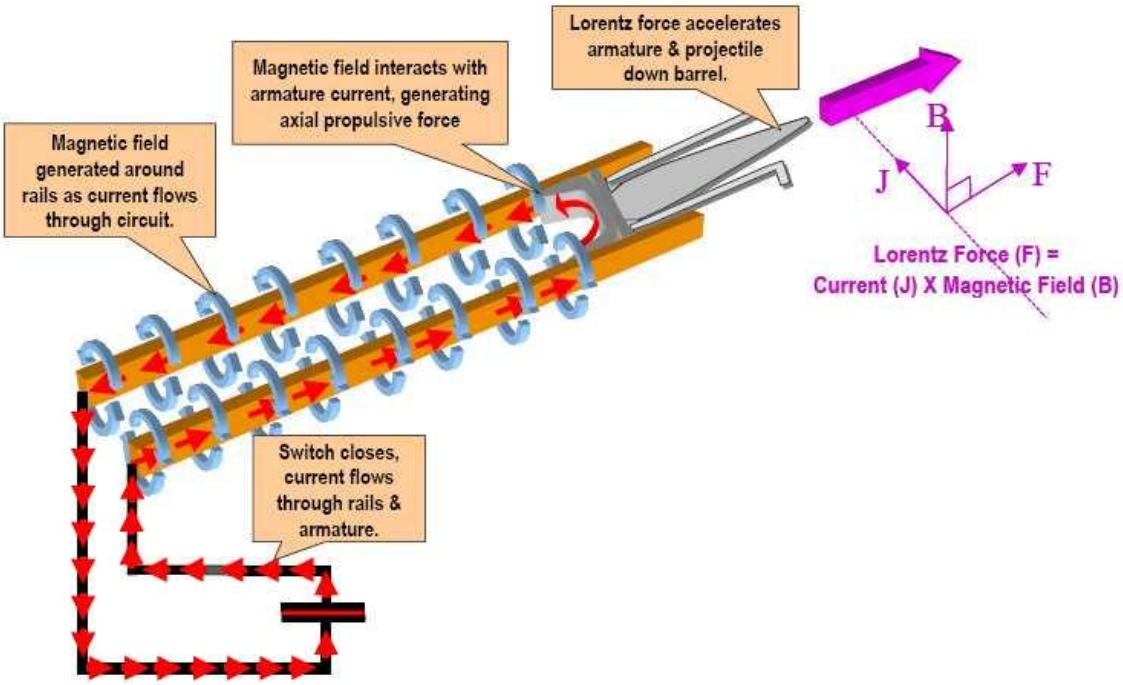
The barrel and the rest of the systems are wrapped in a case to create an easy install package. The grey plate just in front of the plasma chamber is part of the cooling system.

Railguns

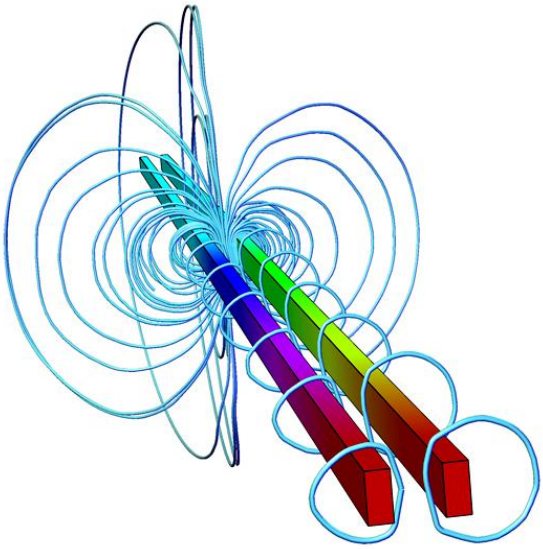
Railguns (aka 'slug throwers') are potent weapons, a masterpiece of the Earth Alliance technology. Conceptually simple, it is just a linear electric motor that accelerates a conductive projectile, though it requires very good material technology to reach the extreme velocities needed to became a really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



Schematically the system is quite simple



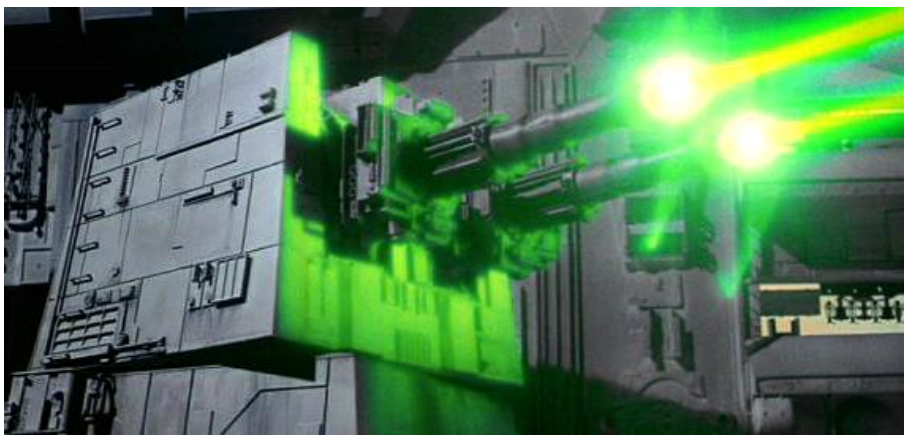
The magnetic field is complex in shape, though not difficult to generate:



The rounds fired are sold, 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.



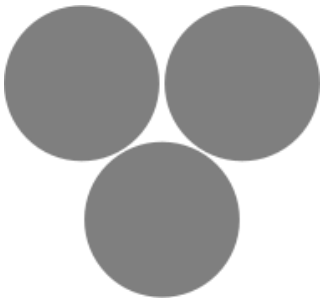
A big advantage of pulse cannon though was the ability to build them into turret batteries. The first Vonari -Human War was an hard teacher, but in those desperate days, the Navy 'Rail Frigates' were among the few warships able to inflict heavy damage to the Vonari units, in the occasions when they were 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, developed from capital ship close-in defence cannon, has begun the renaissance of this weapon system for mercenary ships! Mercenary ships are small and hence don't have the enormous (fusion) energy generation 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 titanium 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 25 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 munitions 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' perspective and less so the target's.

The glow can 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 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: $E=mc^2$. 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.

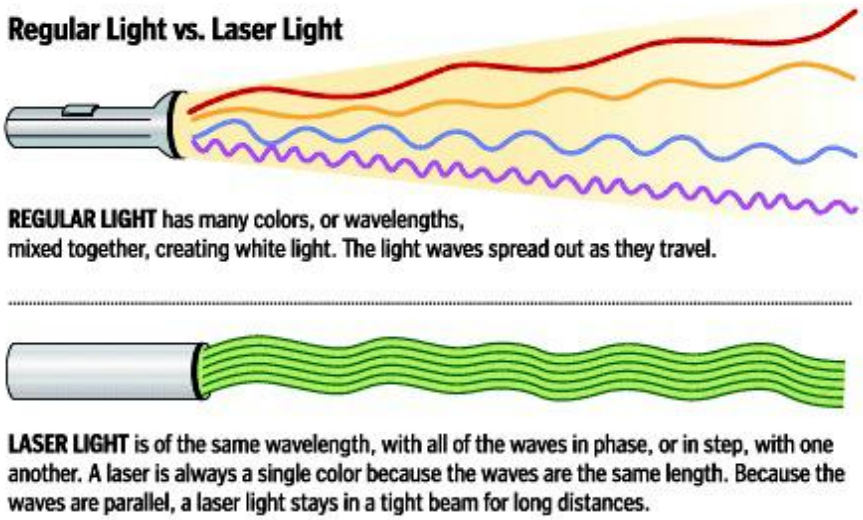
The main damage is done to the shields. Experienced combat pilots recommend using beam cannon to take down a ship's shields, since beam weapons use energy at a lower rate than particle cannon. The emr disrupts the shield field matrix, which requires more energy to reform it. The 'damage' eventually drains 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.

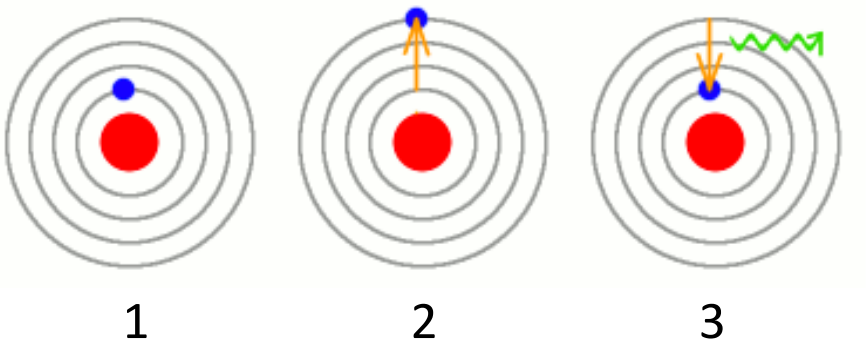
Lasers are more than just powerful flashlights. The difference between ordinary light and laser light is like the difference between ripples in your bathtub and huge waves on the sea. You've probably noticed that if you move your hands back and forth in the bathtub you can make quite strong waves. If 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.



Laser is an acronym for **Light Amplification by Stimulated Emission of Radiation**.

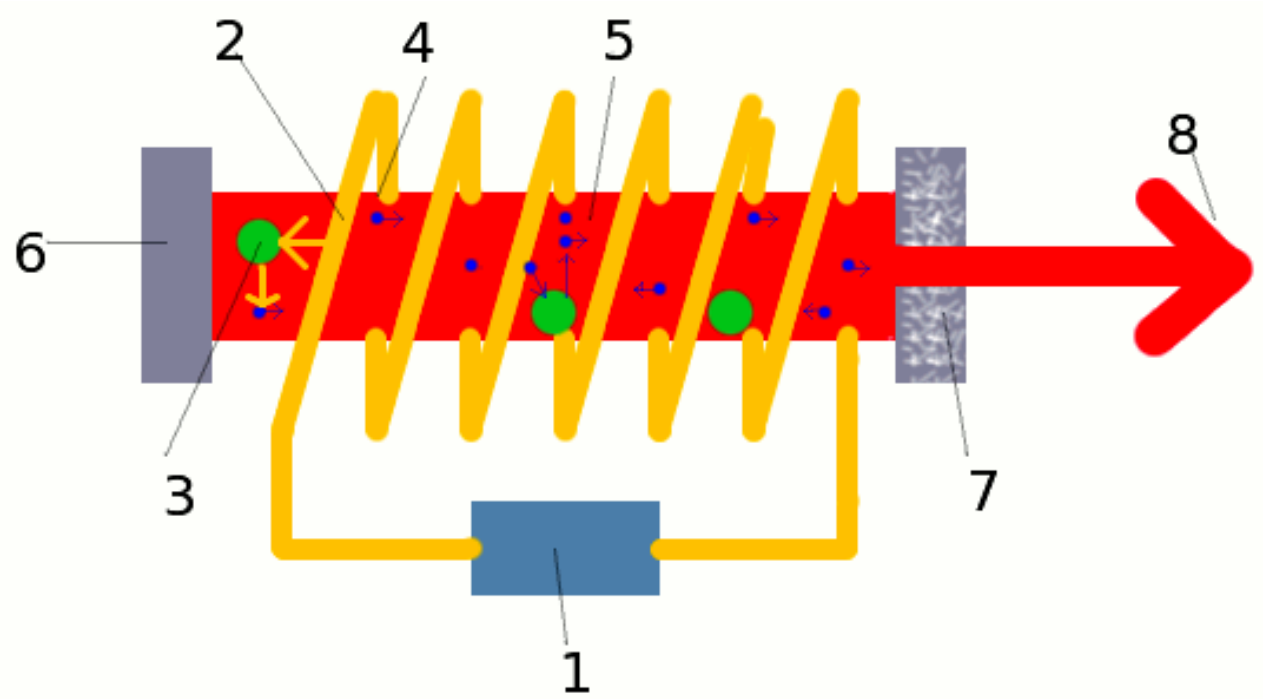
Lasers are possible because of the way light interacts with electrons. Atoms make light in a three-step process:



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.

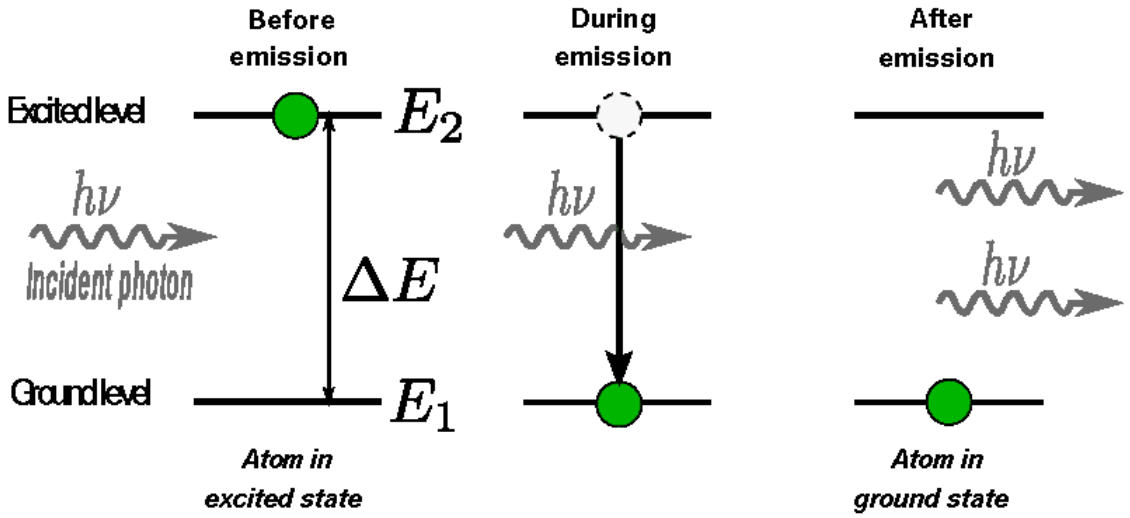
A laser is effectively a machine that makes billions of atoms pump out trillions of photons (light particles) all at once so they line up to form a really concentrated light beam.

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?

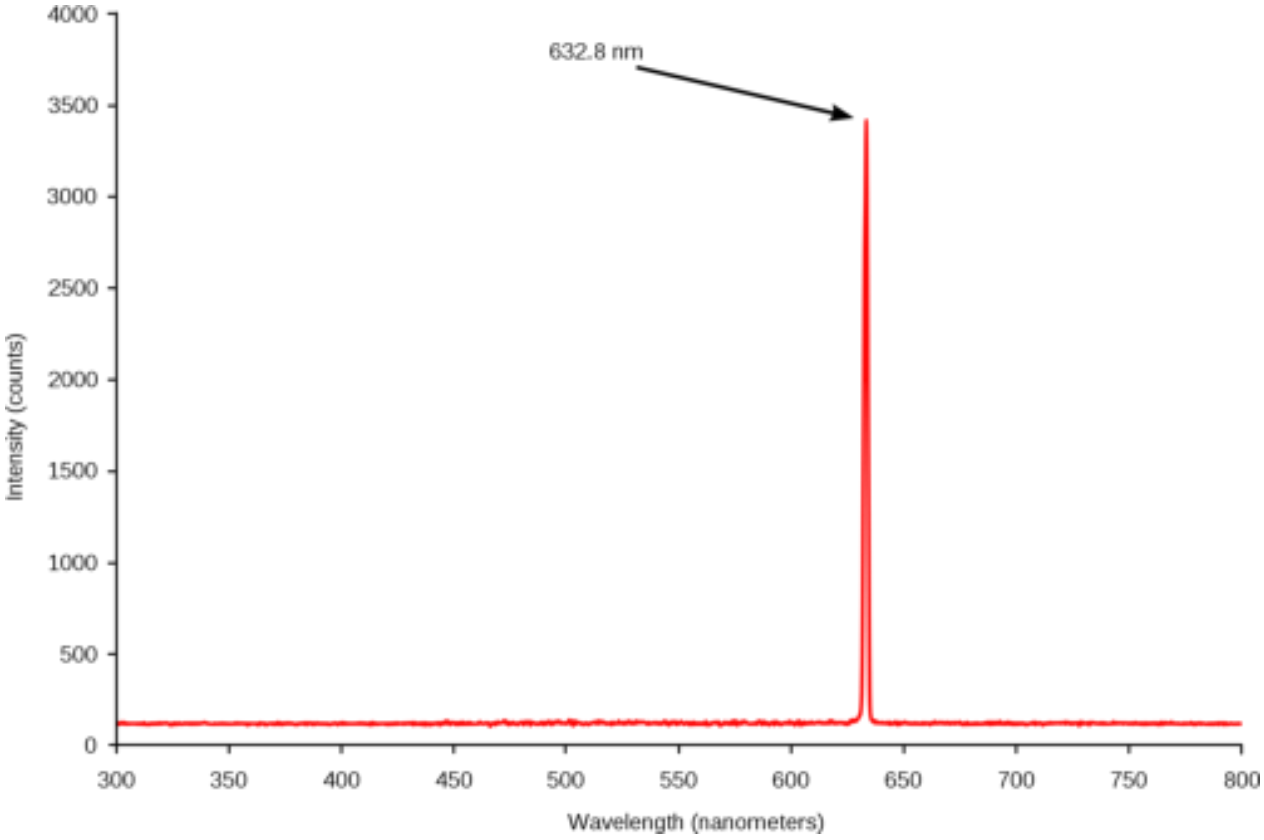
1. A high-voltage electric supply makes the tube flash on and off.
2. Every time the tube flashes, it 'pumps' energy into the ruby crystal. The flashes it makes inject energy into the crystal in the form of photons.
3. Atoms in the ruby crystal (large green blobs) soak up this energy in a process called 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, travelling 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 allows some to escape.
8. The escaping photons form a very concentrated beam of powerful laser light.



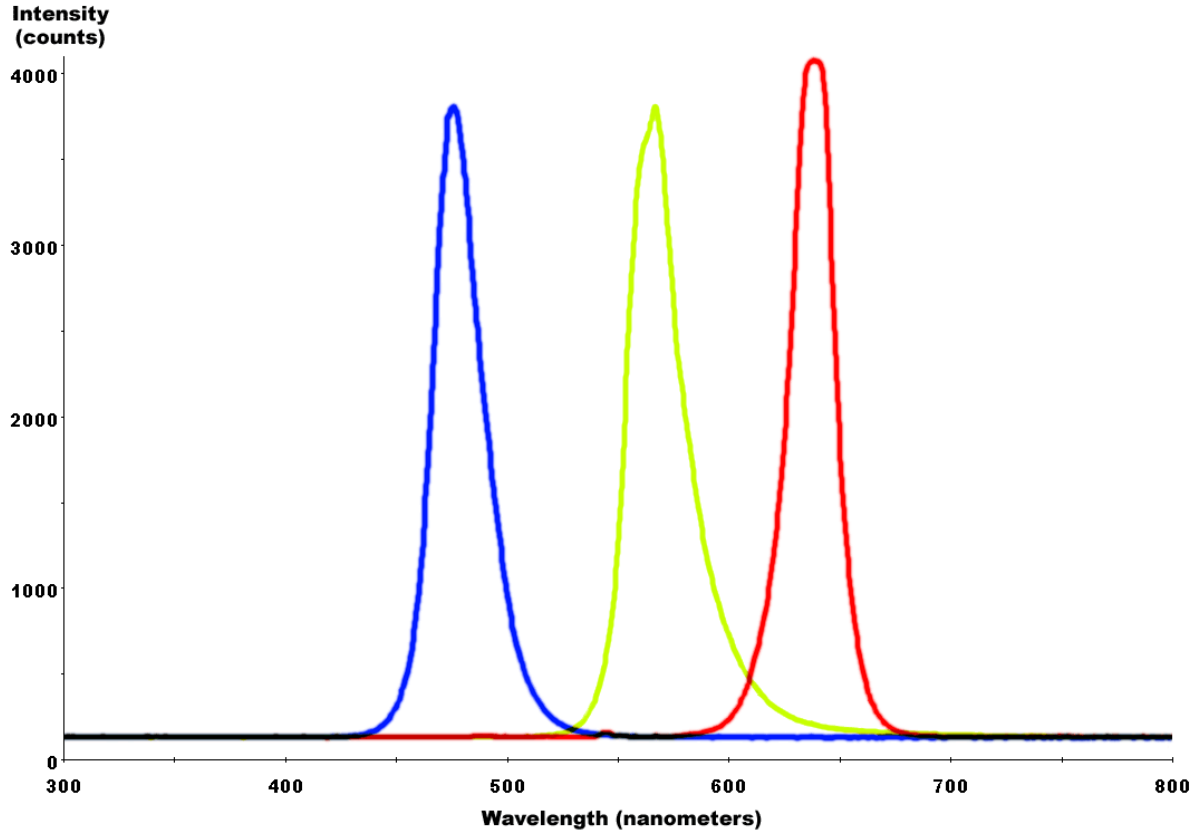
$$E_2 - E_1 = \Delta E = h\nu$$

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)

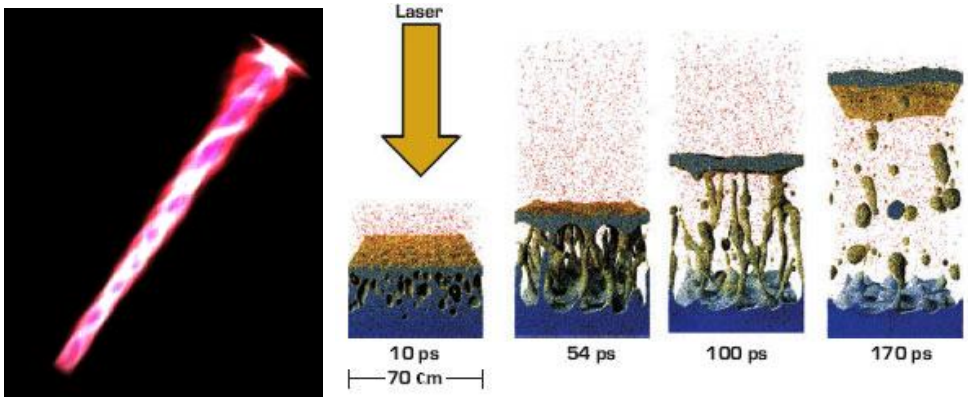
To summarise the important part as far as pilots are concerned - the beam - the light generated by stimulated emission is very similar to the input energy in terms of wavelength, phase, and polarization. This gives laser light its characteristic coherence, and allows it to maintain the uniform polarization 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.

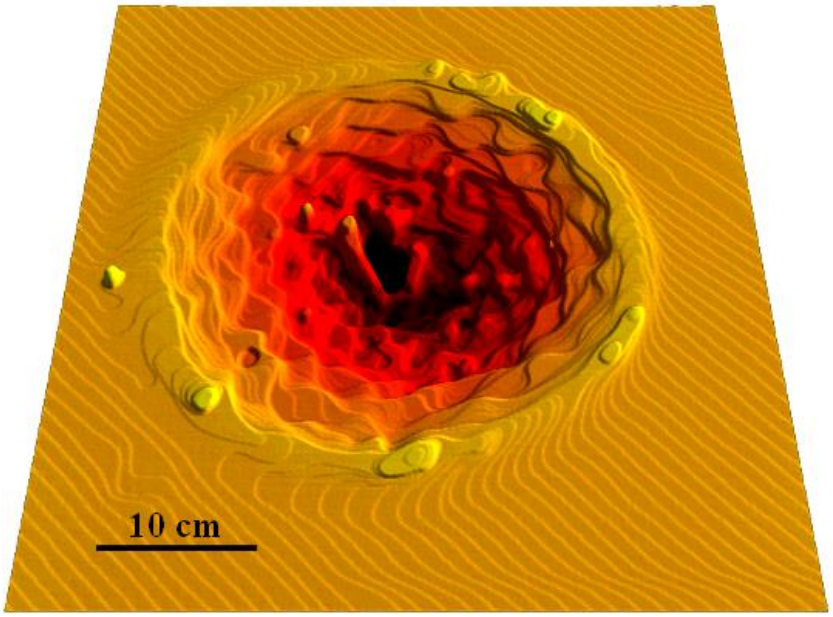
Beam Weapon Characteristics.

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 Mega joule 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 it's 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 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 90^0. The second missile is launched as the first tube begins its reload sequence; the tube mount rotates again , the third missile launches, the second tube starts its reload process and the first tube completes its reload sequence and this cycle continues until all eight missiles are fired. At that point the 180 second missile regeneration sequence starts as new missiles are created and the tubes loaded.

Sequence step →	1	2	3	4	5	6	7	8
Tube 1	launch first missile	reload phase 1	reload phase 2	prime & position for fire	launch second missile			
Tube 2		launch first missile	reload phase 1	reload phase 2	prime & position for fire	launch second missile		
Tube 3			launch first missile	reload phase 1	reload phase 2	prime & position for fire	launch second missile	
Tube 4				launch first missile	reload phase 1	reload phase 2	prime & position for fire	launch second missile

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 minutes 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

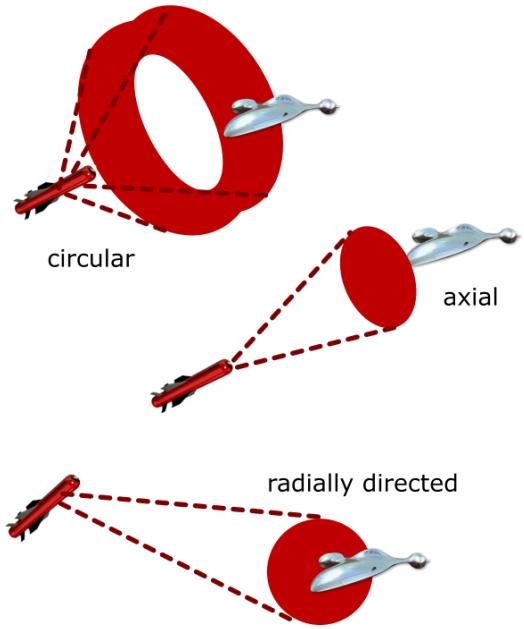
Missile Warheads Classes - summary

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 Tera Joule (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. Fragmentation 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

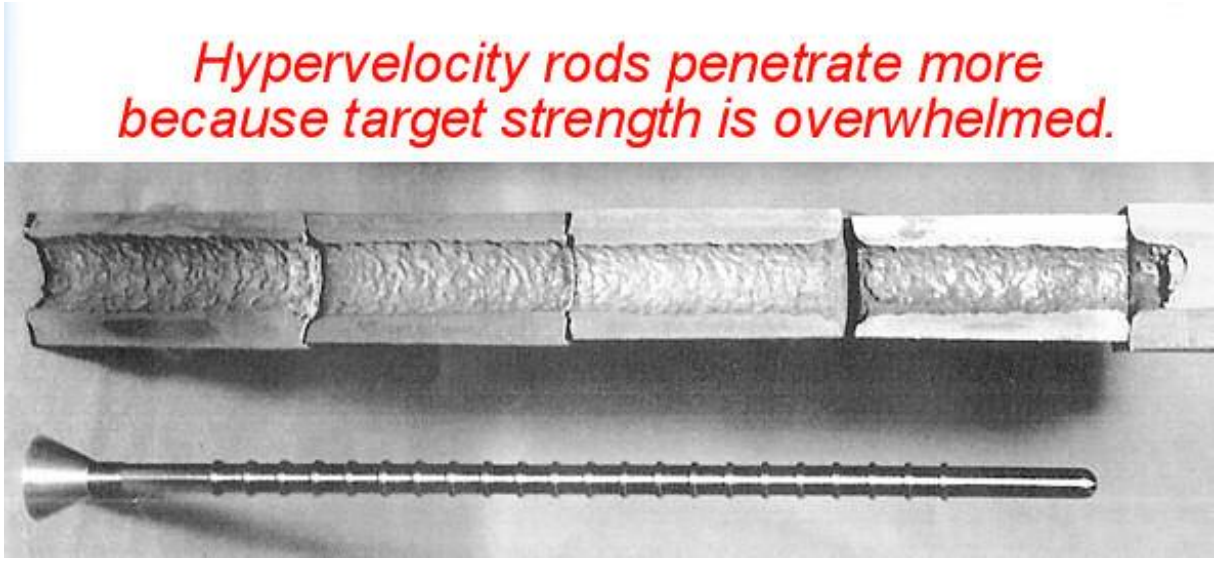
Missile Warhead Technology - details

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 (that is 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.

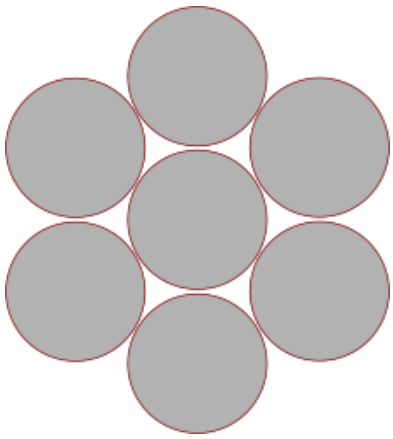
The downside is the need for very high accuracy - nearby isn't good enough! Their exceptionally high accuracy is ensured by the missile's main secret, the so-called ***transverse control engine***, developed by *General Thrusters Industries* on Talison, which effectively rules out misses during the final 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.

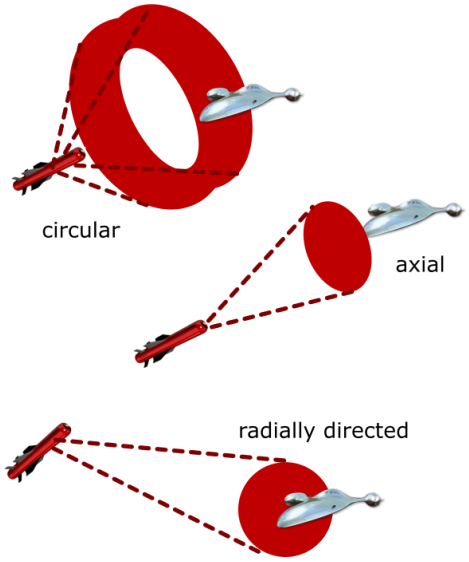
The fragments are propelled at high velocity. Whereas the effects of an idealized blast payload are attenuated by a factor roughly equal to $1/R^3$ (R is distance measured from the origin) since the blast is omnidirectional, the attenuation of idealized fragmentation effects will vary as $1/R^2$ because 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.

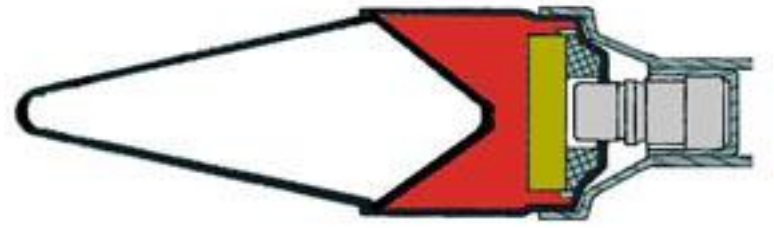
Under research are materials with high mechanical strength, high density, high energy density, and which can rapidly convert from a consolidated structural material to fine powder with large surface area, be dispersed and then ignited to produce a large energy blast that can swamp shields. These will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

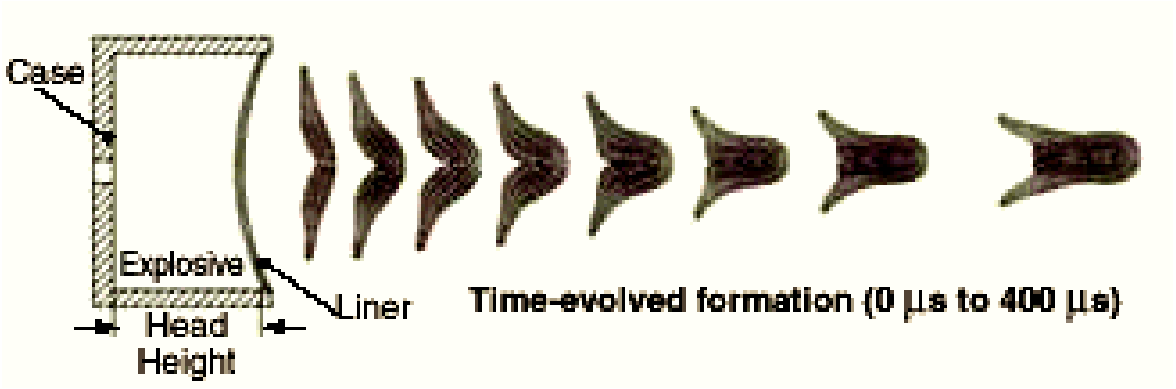
A **shaped charge (shaped core)** is an explosive charge shaped to focus the effect of the explosive's energy to penetrate armour. A typical modern lined shaped charge can penetrate armour alloy to a depth of 7 or more times the diameter of the charge (charge diameters, CD), though greater depths up 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.

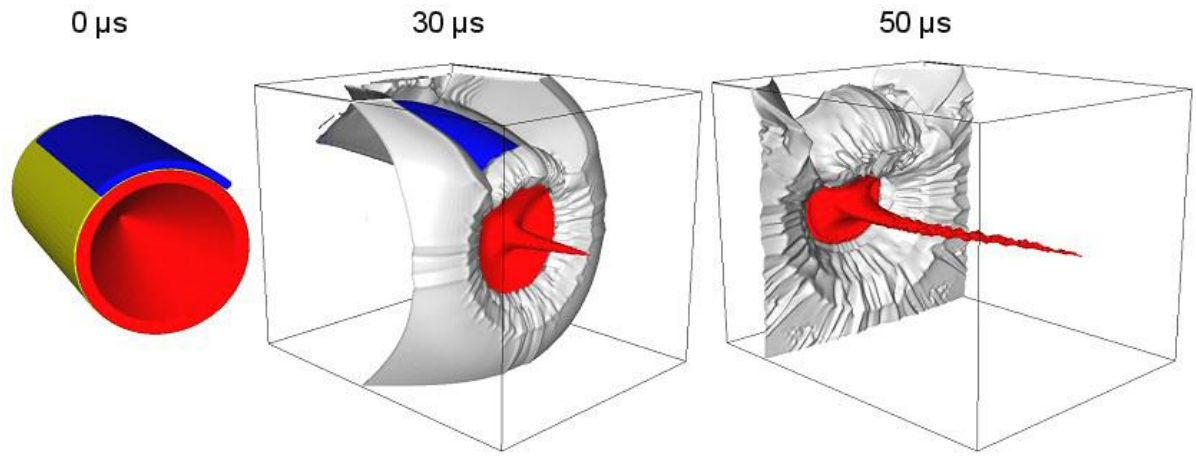
A shaped charge warhead consists basically of a hollow liner of metal material, usually copper or aluminium of conical, hemispherical, or other shape, backed on the convex side by explosive. A container, fuse, and detonating device are included.



When this warhead strikes a target, the fuse detonates the charge from the rear. Explosive energy is released directly away (that is 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 metres. 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 tera pascal. 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!!!**

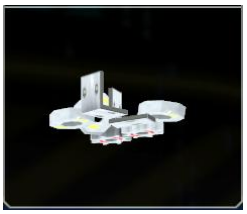
Using the Weapon Lab I - Raw Materials needed

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

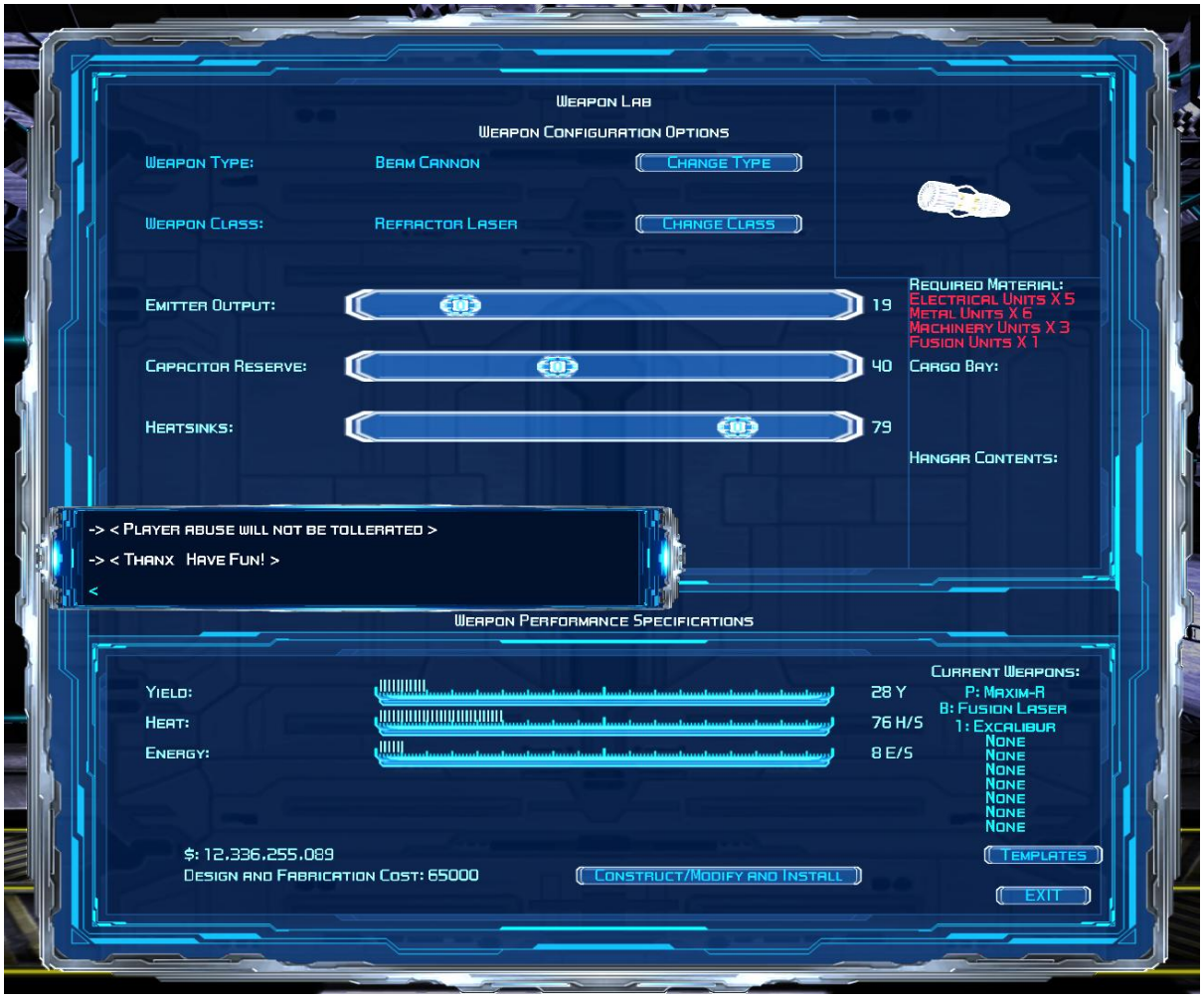
Using the Weapon Lab II - Interface

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

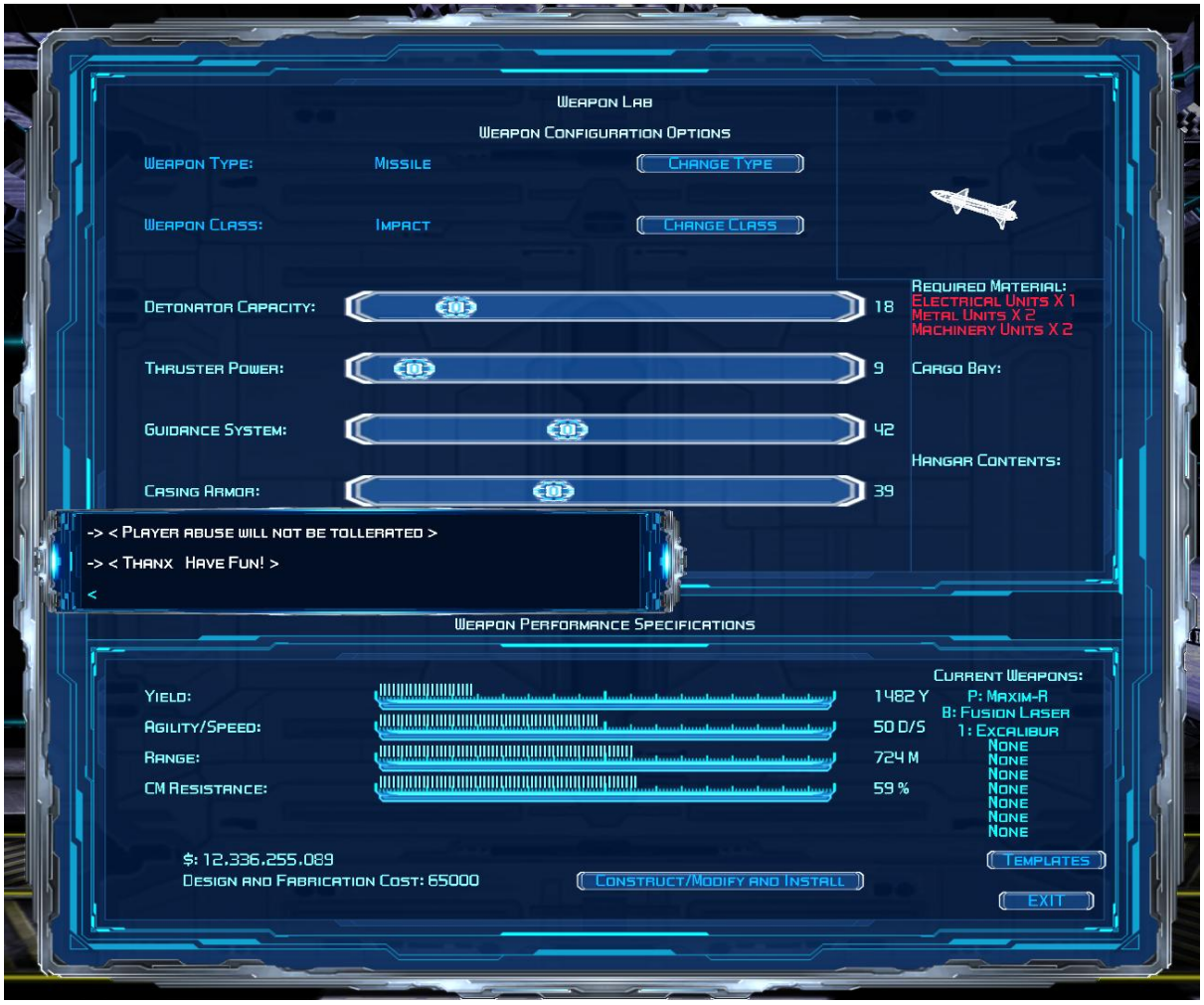


The characteristics of the cannon you create are pretty much self evident;

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 Armou***r 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+

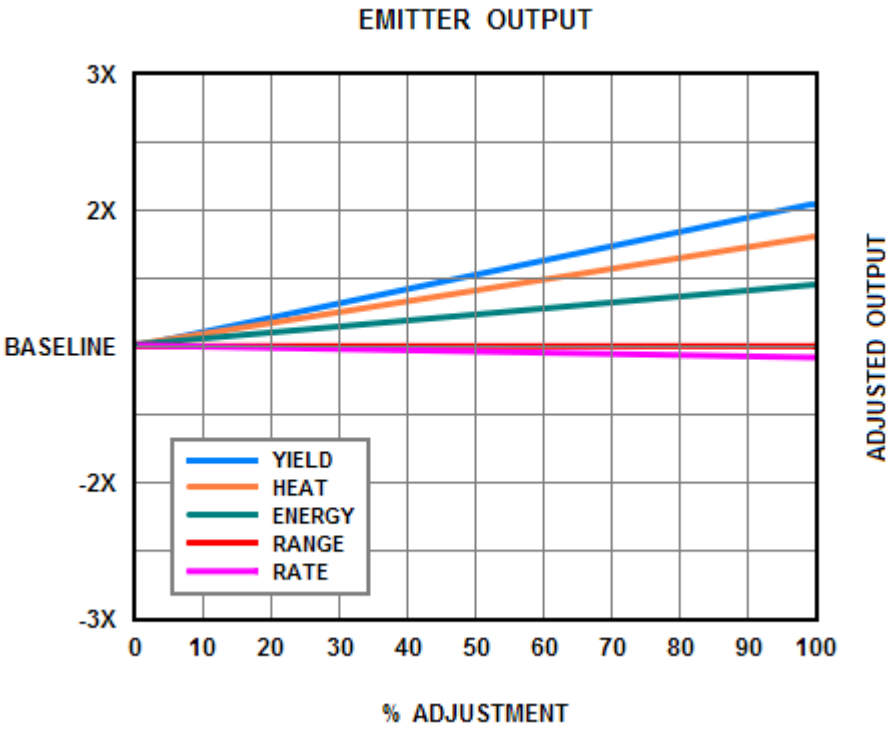
Beam Cannon	Emitter Output	Capacitor Reserve	Heatsinks
Yield	max	max	N/A
Energy	max	max	N/A

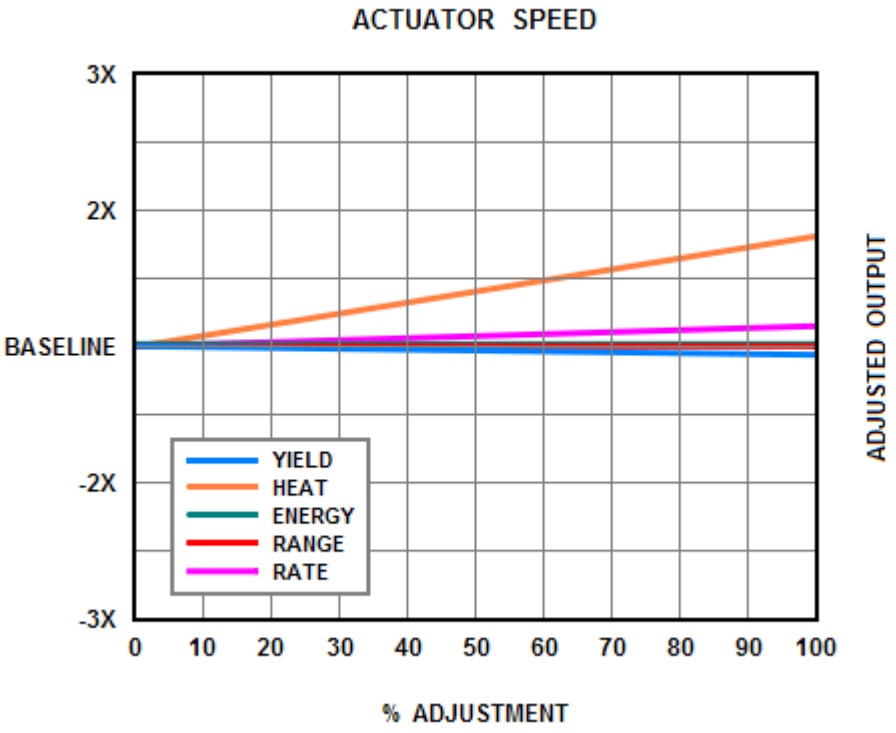
Missiles	Detonator Capacity	Thruster Power	Guidance System	Casing Armour
Yield	max+	min	max+	min+
Agility / Speed	min+	max+	max+	N/A
Range	N/A	N/A	max+	N/A
CM Resistance	max	min+	max	max

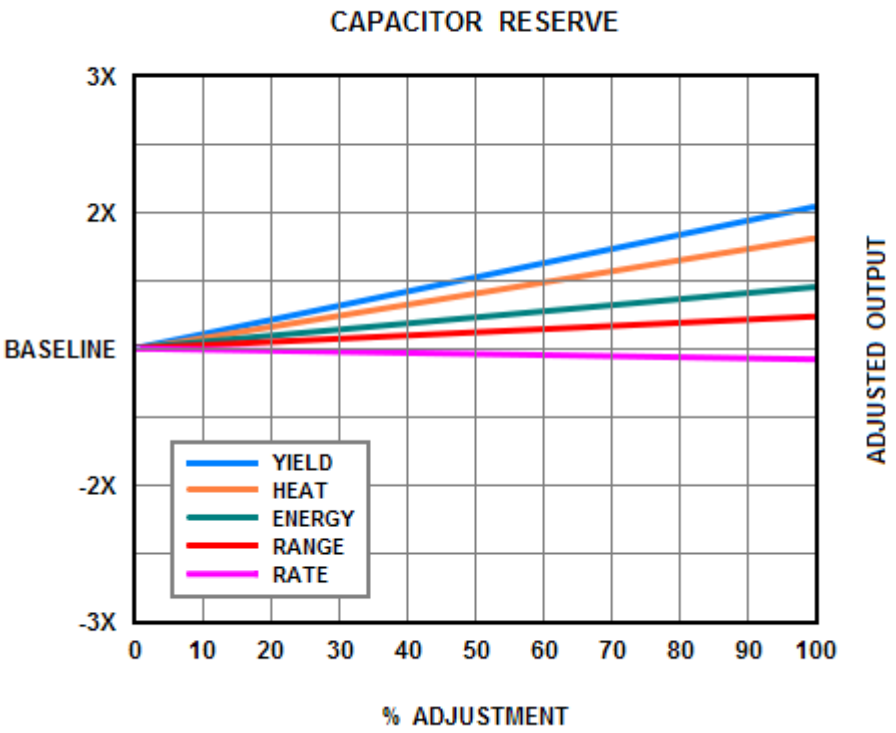
'N/A' means the parameter has no effect
'+' means the parameter has a big effect

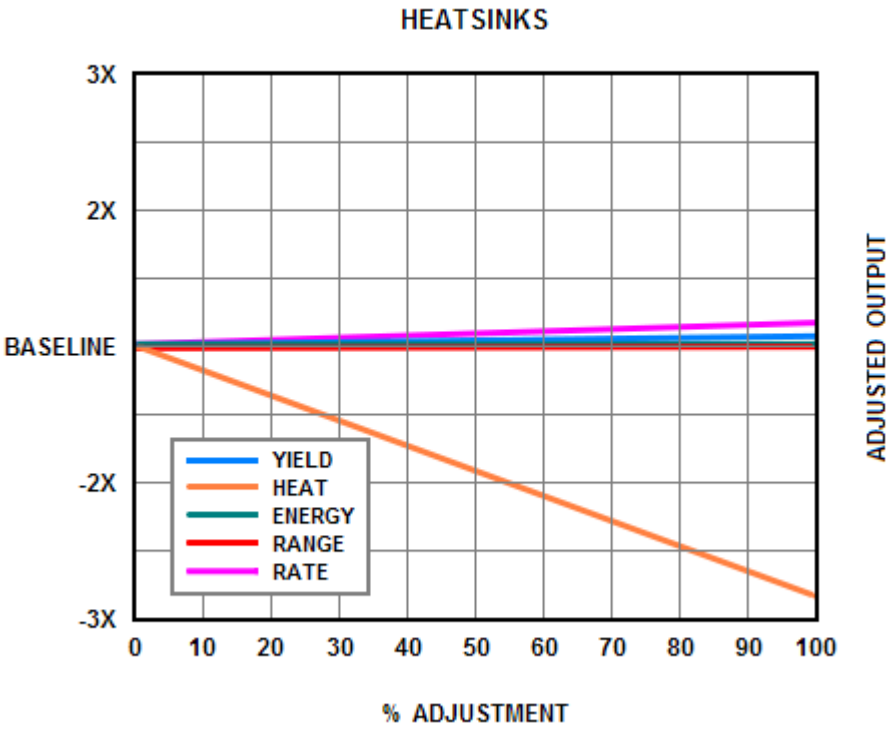
Maarschalk has created a comprehensive spreadsheet of the data for the effect of each slider on each type and class of weapon! The raw data is given in Tables below. It can be processed as you wish in a spreadsheet and it is easy to generate graphs in a variety of formats to analyse the data in ways 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
3X
2X
BASELINE
-2X
-3X
YIELD
HEAT
ENERGY
RANGE
RATE
0
10
20
30
40
50
60
70
80
90
100
% ADJUSTMENT
ADJUSTED OUTPUT


ACTUATOR SPEED
3X
2X
BASELINE
-2X
-3X
YIELD
HEAT
ENERGY
RANGE
RATE
0
10
20
30
40
50
60
70
80
90
100
% ADJUSTMENT
ADJUSTED OUTPUT





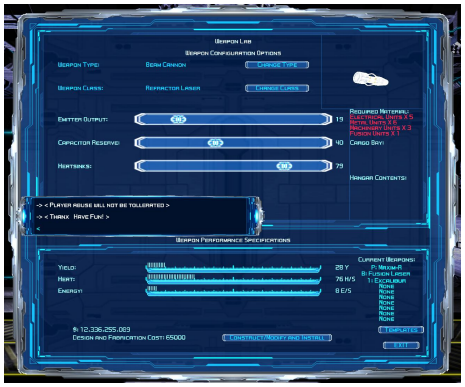
In reality there isn't a simple recipe to produce the 'best' cannon or the 'best' missile. It will inevitably depend on your view, your combat technique and your particular missions. The only way to create your 'perfect' weapon is to experiment!

Using the Weapon Lab III - Slider Data

The following data has been provided by Maarschalk. Data is provided for each class of each type of weapon. Each type of weapon (particle cannon, beam (laser) cannon and missiles) has several data tables covering each class of weapon in that type (e.g. Plasma, Metal Projectile, Railgun & Fusion Plasma for the particle cannon type)

The format is the same for each. Table 1 shows the slider settings ranging from all sliders at 100% through to all sliders at 0%. Table 2 (which are large and hence split over several pages for each weapon type show the weapon outputs for each of the combination of sliders in Table 1.

Instructions and examples are given in each part. It's easier to use than describe!!



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

continued

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)

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%

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

Other Weapons Technology

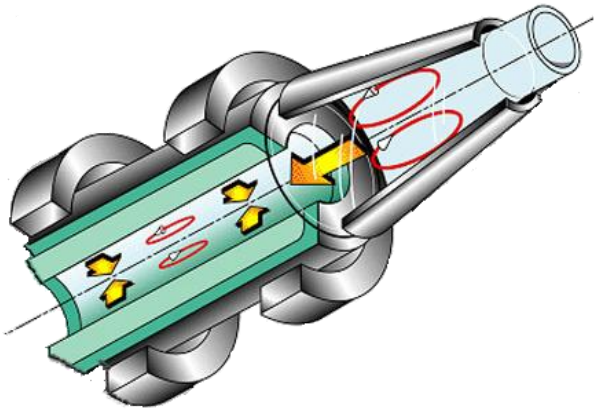
Background: nanotechnology + Engineering

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."

Xxxxx'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 SpecOps 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-high-speed 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?"

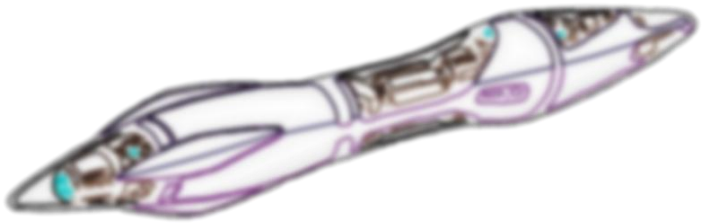
The video was replayed on the large monitor in the control room. The playback was at slowed speed from the time immediately before the railgun slug impacted the shield.

A hole opened it 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!

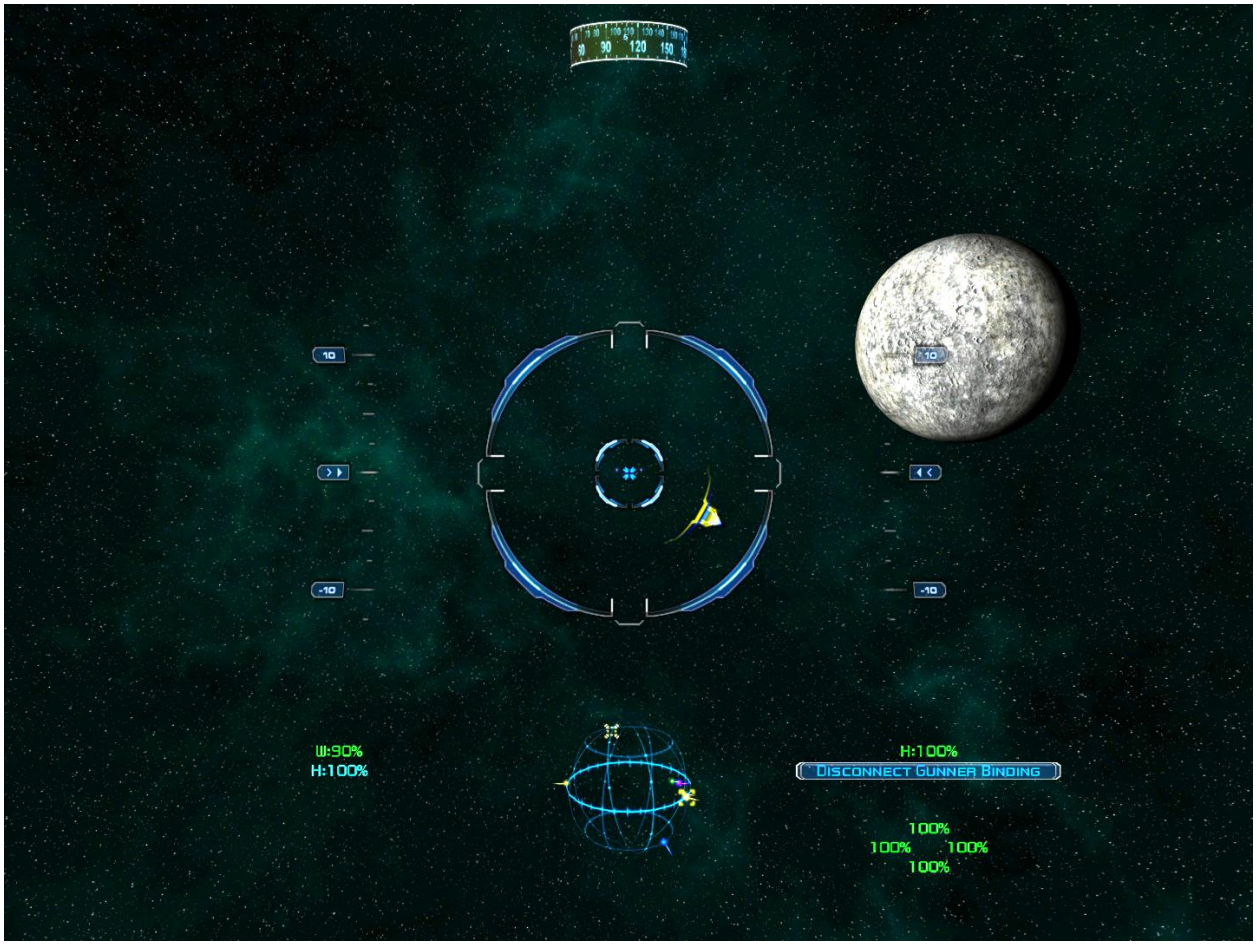
The result is that there is an awesomely rapid acceleration of the target ship towards the wormhole mouth, which virtually overwhelms both the Inertial Damping System and the Structural Integrity Field Generators of the ship. The outcome is catastrophic damage to the ship's hull and innards. The completion 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

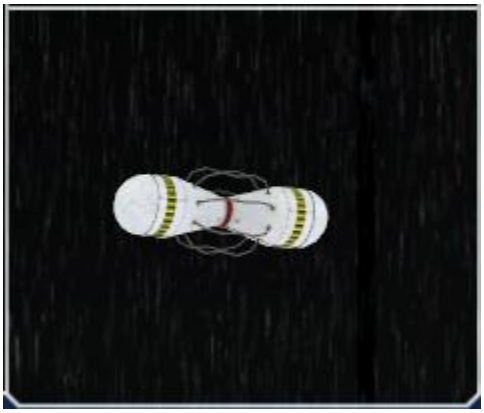


The turret operator controls offer a limited HUD and data readout. The teaming up of a defensive gunner who can watch your back and increase your attack fire power has proved to be a popular and powerful addition to ships in combat. It also provides a good learning environment for new pilots to get practical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

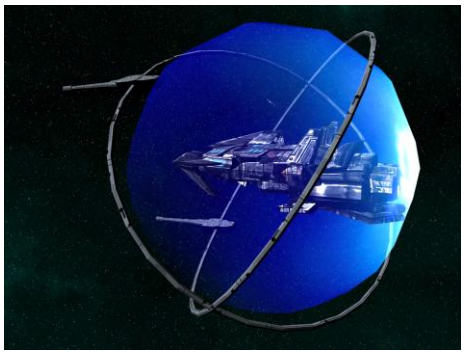
The quoted yield is actually the equivalent explosive yield it would require to physically blow up the massive station. ('massive' is used in the sense of containing megatonnes of matter). It is obvious why the mechanism is both secret and extremely will protected.

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)



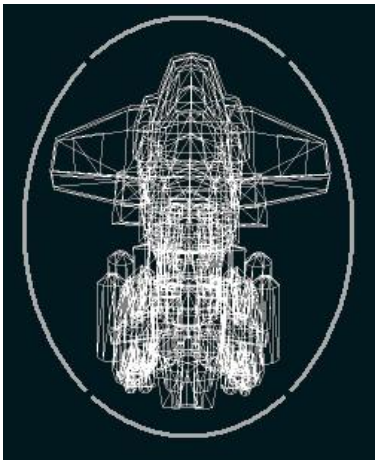
Impacts on the shield field matrix causes Cerenkov radiation (see above) to be released, often perceived as a flash of blue which 'lights up' the shield, rendering it briefly visible.

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. In smaller ships like the ones used by mercenaries the shield energy fields are emitted from four shield generators which wrap around the ship; fore & aft and starboard & port. 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.

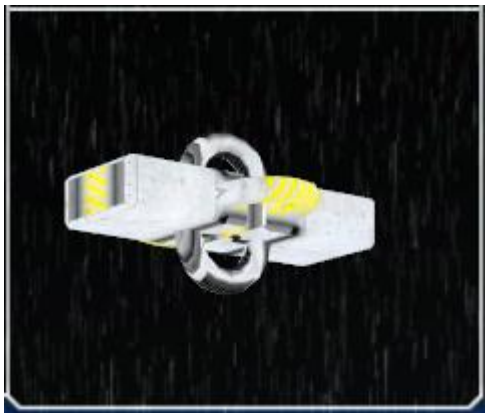
The central HUD shield strength display can also flash to indicate the direction of incoming fire - useful extra information in a combat situation.

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.

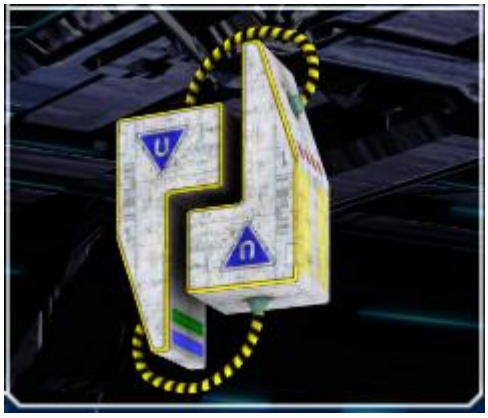
It can be wasteful with CM's, so pilots should train to use this system most effectively to minimize CM loss. A relatively unsophisticated (and hence affordable) AI core module tracks incoming missiles and makes pessimistic decisions about the timing and number of CM units to release. The design criteria 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!)

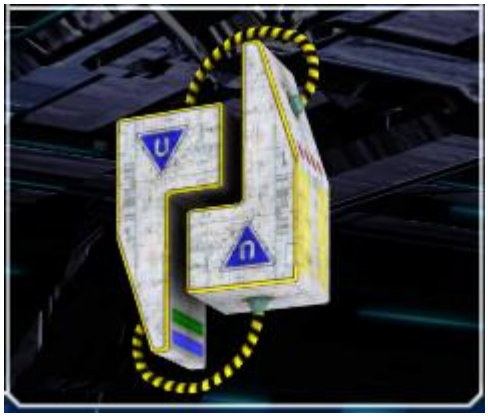
Each CM unit is 'fire and forget' (FaF), non-tracking and passive. It releases a spherical wave of microwave frequency energy that heats the missiles and eventually causes their detonation. Several CM's are usually required, though competent combat pilots tend to develop an excellent sense of timing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

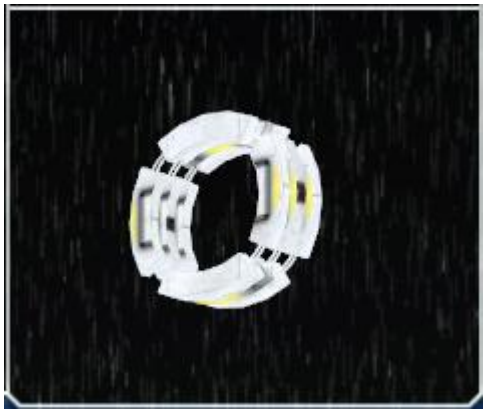
One Shot Stealth Device & Sensor Probe



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.

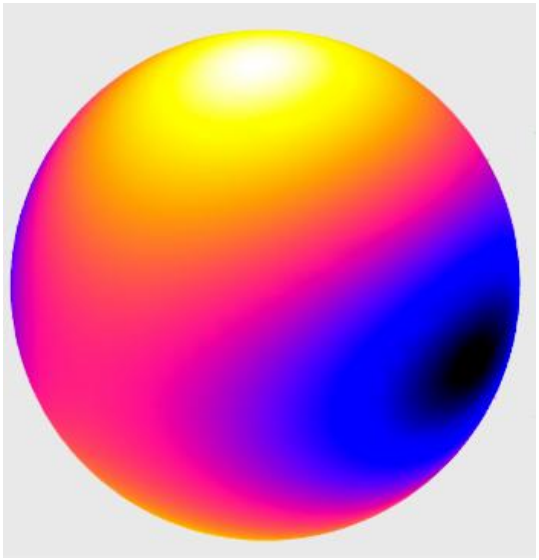


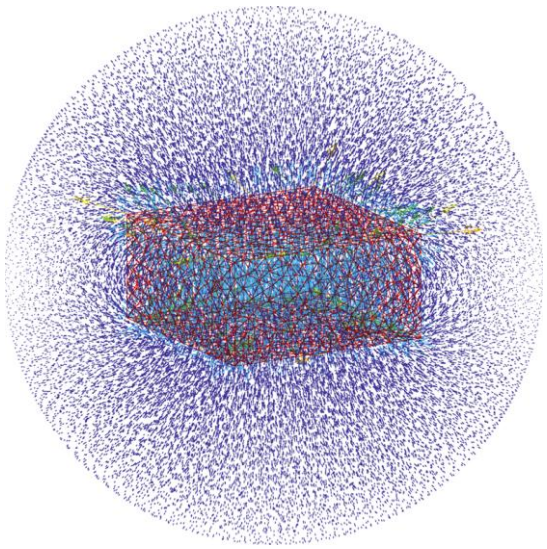


one shot stealth unit permanent stealth field generator

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 is 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 'recloaking' 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

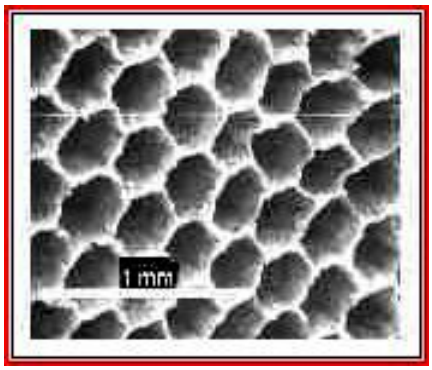
Armour is a somewhat valuable commodity constructed from metal ore. It can be built at constructor stations from mined metal for higher trade values. Nickel/Iron asteroids often contain traces of rare metals such as vanadium, chromium and titanium along with platinum. Mixtures of these metals creates 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.

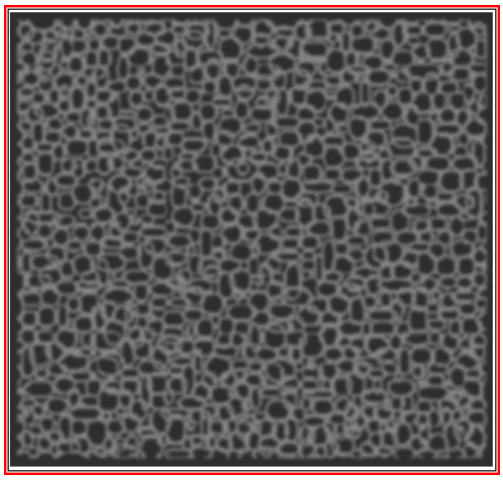
The external layer, being modular, allows easier repair and, in case of a close thermonuclear explosions, reduces the thermal stress on the structure, due to the dilatation room in the joints of the modules. The Boron based ceramics are highly refractory, and the beryllium is very likely the best heath 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. *nanofoam*
3. *carbon nanotube sheet*
4. *nanofoam*
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.

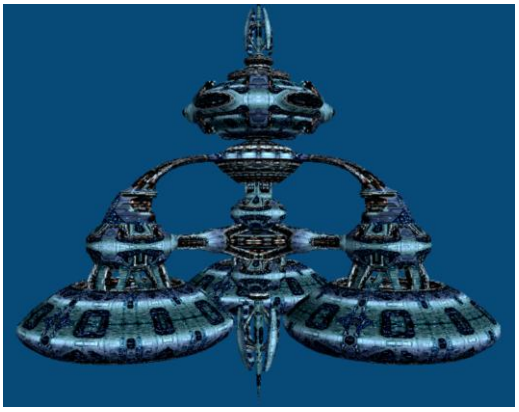
You will also see stations that carry adverts and that you cannot dock unless you have the appropriate clearance and identification beacon. These stations belong to major industrial players requiring zero gravity research and development and/or fabrication facilities. They are also more easily protected 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.

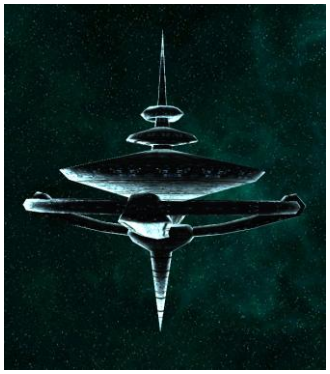
In uncharted systems, and only very occasionally you might stumble across an anonymous station that will warn you away when you get too close. These are the private residences of those very rich and powerful people who value their privacy greatly - you would be well advised to stay clear!

Constructed Stations

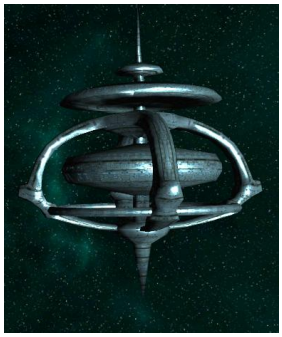
A build constructor unit actually doesn't build the station. The shipboard installed constructor unit sends coordinates to a central control facility in Sapphire. The plan for the particular construct required is used to create a shell plus the fabrication equipment for the items stocked by the station. 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



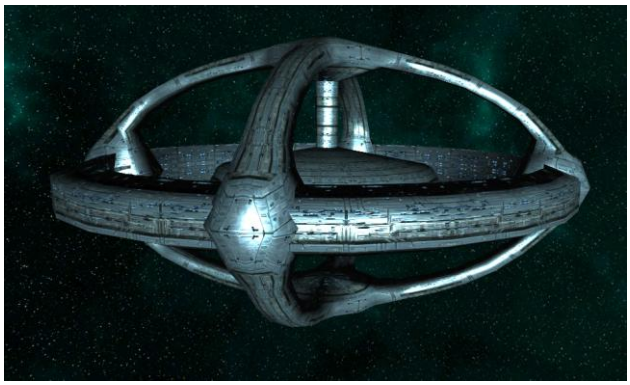


Research Stations utilise AI cores and quantum computers to provide a rapid and sophisticated data analysis capacity within the system. This is a streamlined version of the distributed computing networks first seen in the late twentieth century. The result is an increase in the star system's technical 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

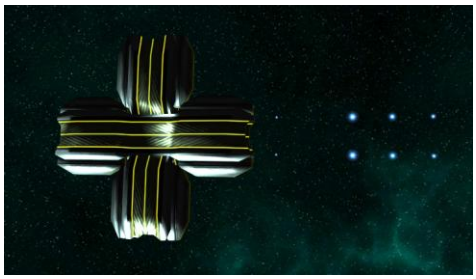
Ore Processors

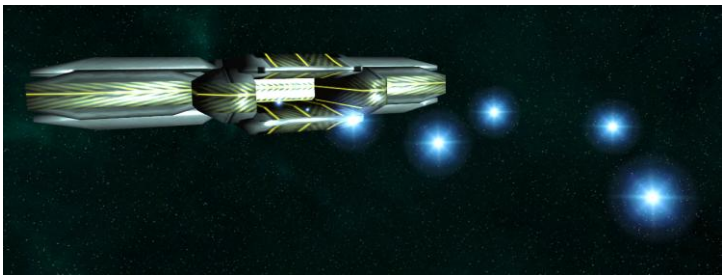


These perform basically the same functions. Constructor stations are more specialised and limited but they are accessible to pilots. Ore processors are automated and meet the needs and demand from trade and other stations and cities that require 'parts' for their construction industries

and

Constructor Stations



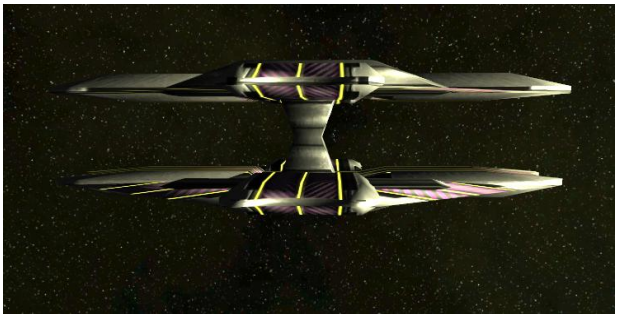


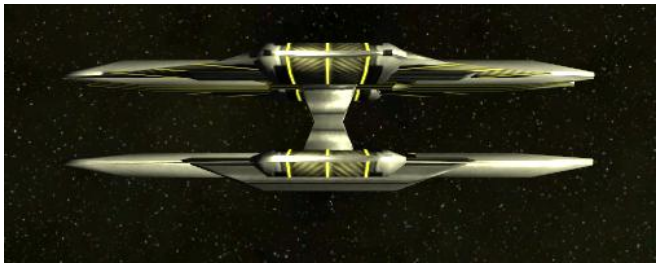
where mercenaries can have a variety of raw materials converted into technological artefacts, worth more then the raw materials would fetch on the market.

Deployed Stations

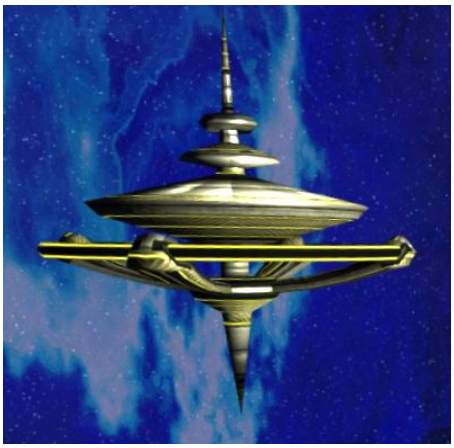
These are smaller and have a limited functionality - each has a single function and will all types self destruct (scuttle) when you leave the sector.

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.

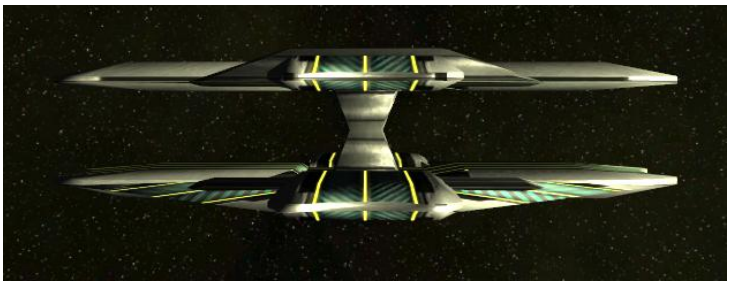


The ***Shield Array*** is a bigger and much more powerful version of the unit in your ship (or a scaled down version of the unit in a real trade station!). It uses IFF technology to allow friendlies in and to keep hostiles out. To ensure safety if hostiles do manage to bypass the IFF identification protocols, 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

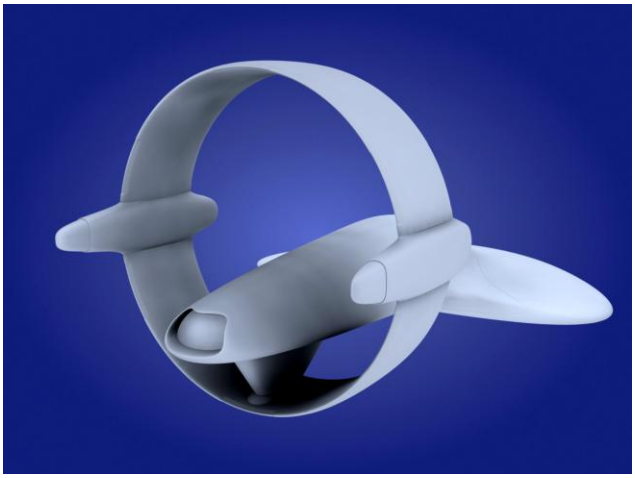
The manufacturing facilities are not located in Evochron! They are in fact not located in our universe!! They are located a nearby parallel membrane universe of the multiverse. Hints to the solution of several problems were provided by implications of the mathematical equations describing String Theory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

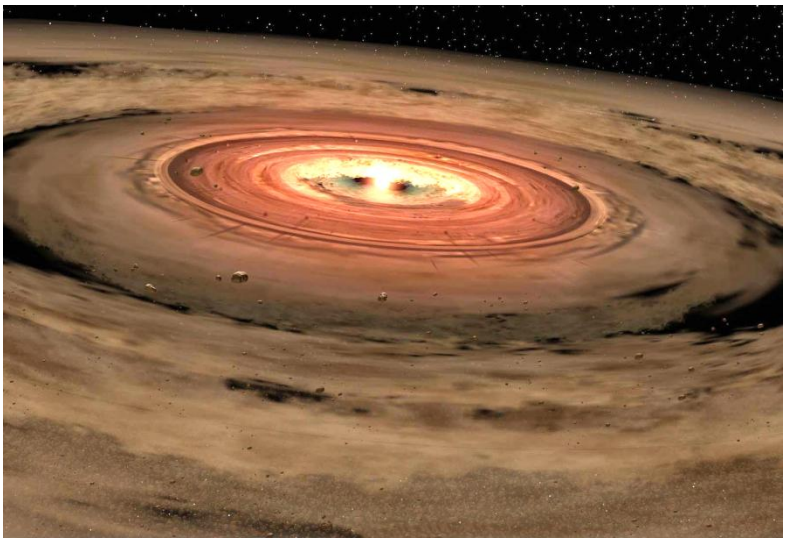
One probe's data stream confirmed that even the way time flows in a parallel universe may be very different from ours; one probe returned after a microsecond with its internal data store full and its internal clock suggesting that it had been gathering data for several months. The time had passed very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

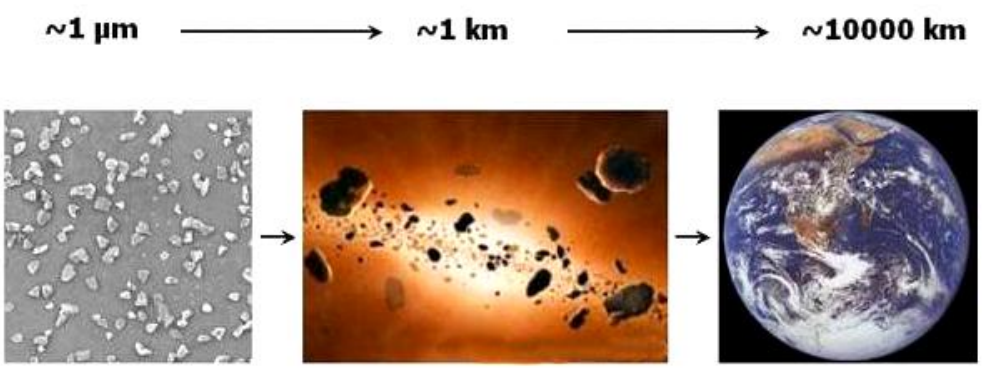
Importantly the most valuable element for our manufacturing needs - carbon - is available and in large quantities. The metals required (mainly gold, platinum and iron) are rarer there than here, making mining somewhat more difficult but not impossible since only relatively small quantities are required.

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).

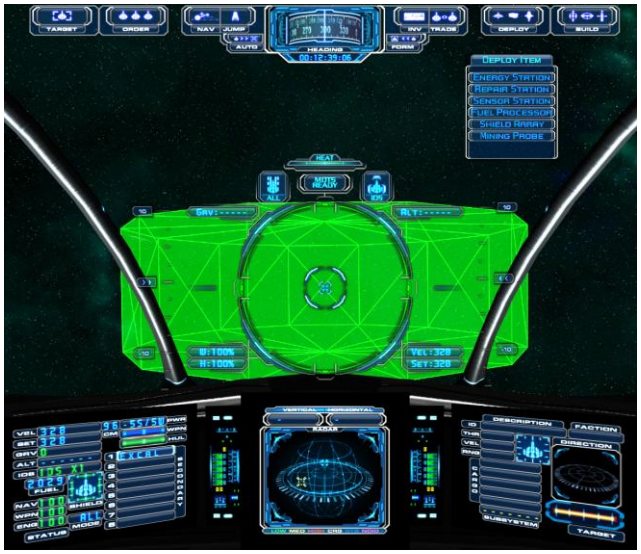
The whole facility is shielded to protect it from the constant bombardment by the 'rubble' orbiting the proto sun. Although such large shields are prohibitively expensive in energy use to be of practical use in Evochron, the vast energy resources available in U-42X and the fact that relatively few shields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

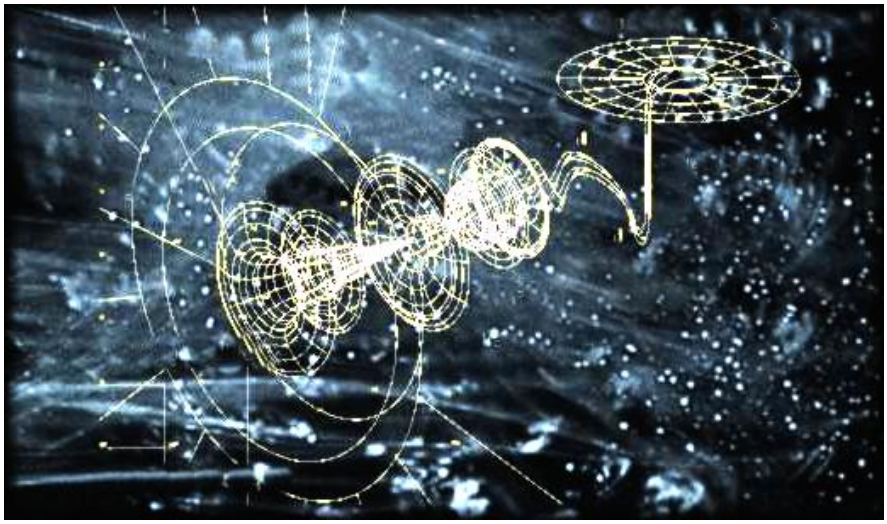
By design, Deploy stations are physically smaller and less massive because they are single function units and are not required to have the long lifespan a build station will have - they self destruct when the Deploy Constructor moves out of range which in practice means leaving the sector. Because of 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!

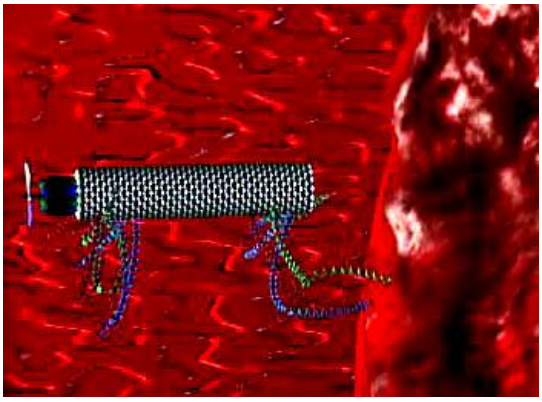
Deploy stations, being smaller and simpler and due to the time differential between our universe and U–42X appear virtually instantly. The larger and more complex Build stations tend to be assembled on demand and hence require a few minutes to appear!!

How are the stations fabricated?

background: nanotechnology

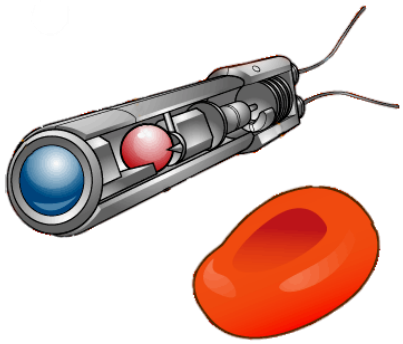
Mining raw materials

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



Nanobot Type 1 - fluidiser

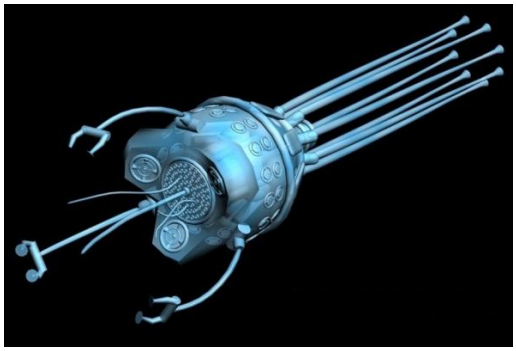
The function of these bots is to dismantle the material of the asteroid down to an atomic level working from the surface inwards. They are the most numerous of the three types of nanobots. The resulting atomic 'sludge' can be traversed by the other two type of mining nanobot and the microbots that form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

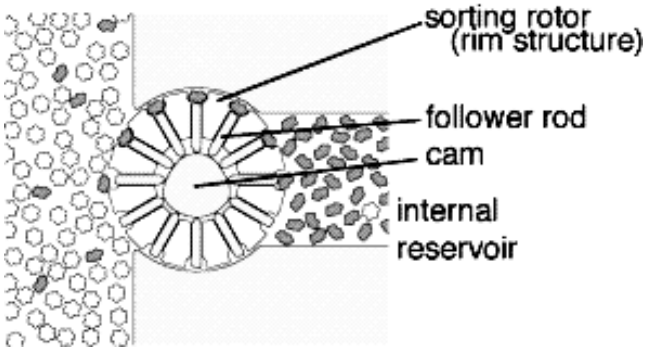


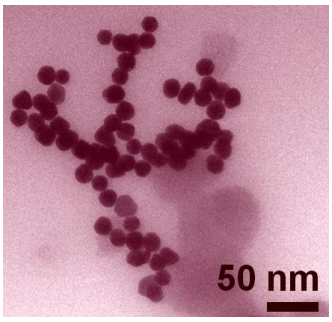
Nanobot Type 2 - element identification

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

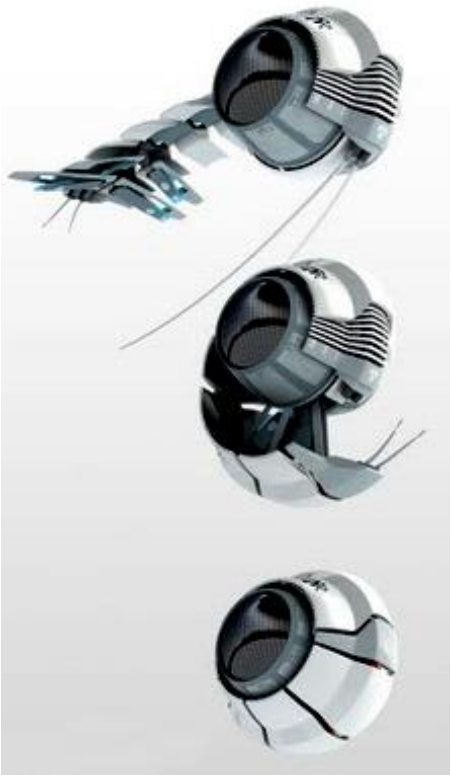




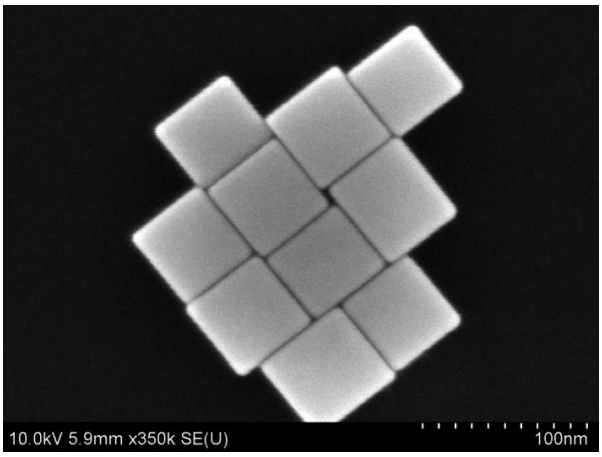


These pick up the individual atoms using a precisely positionable grip, and stores them in a reservoir. When full the nanobot excretes the metal as a spherical nugget

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 make 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.

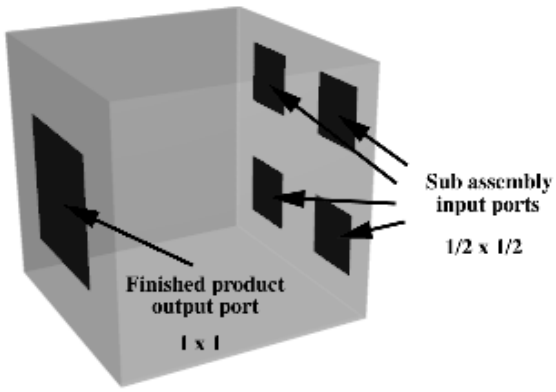
Nanotech can make very big things as well as very small things. An attractive approach is to use *convergent assembly*, which can rapidly make products whose size is measured at the metre scale starting from building blocks whose size is measured in nanometres. It is based on the idea that smaller parts 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!

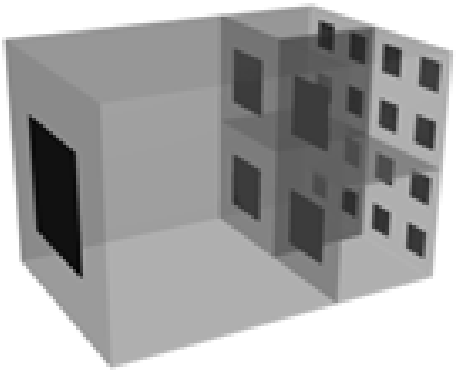
It's common to make bigger things by assembling them from smaller things. To make a cubic assembly one metre per side, we'd need to assemble eight smaller cubes, each of 0.5 metre in size. This relationship holds approximately for many products. A one metre sheet would require four half metre sheets.



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.

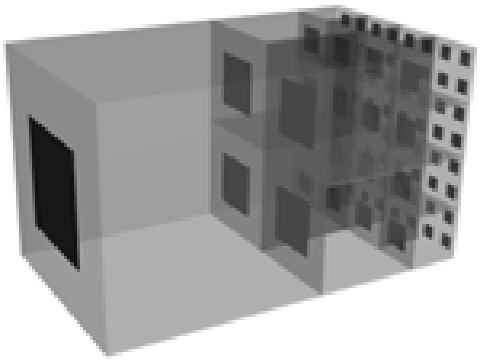
If the output port has a size of one metre by one metre, each input port would have a size of 0.5 metres by 0.5 metres. We could assemble our eight subassemblies into a finished assembly by using one or more robotic arms (or other positional devices).

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.*

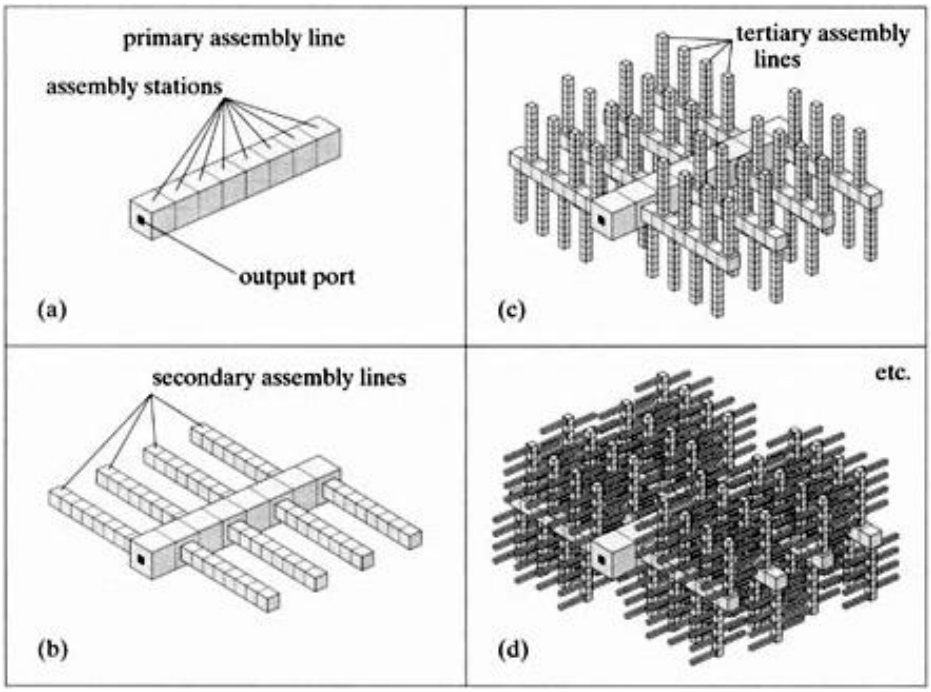
Say that the final stage of the assembler (which assembles the final product) takes about 10 seconds. Therefore the 0.5 metre assembler needs to complete one sub-assembly in 5 seconds, i.e. twice as quickly. (*An object which is half the size can finish a movement of half the length in half the time: 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.

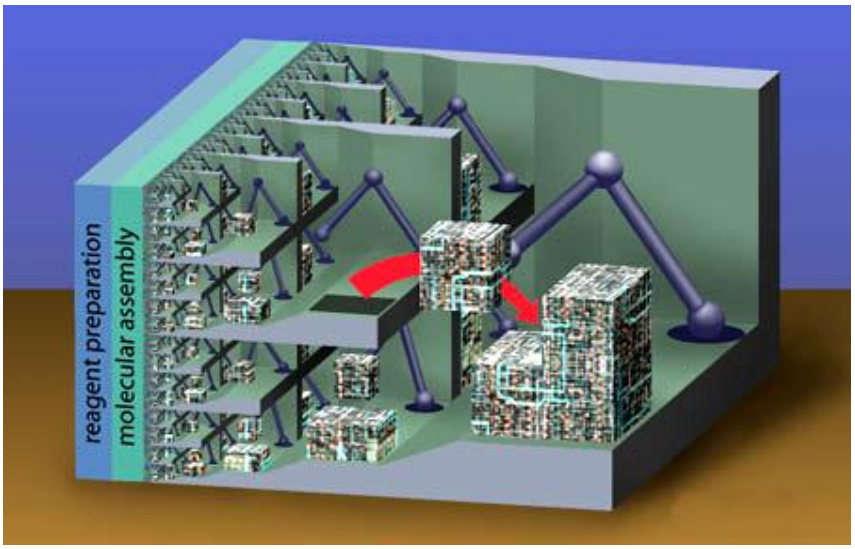
Where we require larger components we can of course extend the assembler system in the other direct with four 1 metre assemblers feeding a 4 metre assembler and so on.

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: Mercenary scale mining, nanotechnology & colony 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.

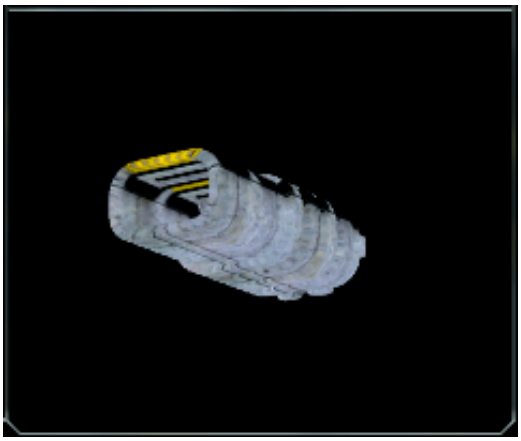
Silver is generally less valuable than gold, although it has many uses that make it valuable in most economies. Certain digital and solar technologies also keep it in high demand. Although a good electrical conductor it is less resistant to corrosion than gold and platinum, unless alloyed with either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

The third method of mining is biomining, used by colonies to extract metals deep in the ground without the need to dig down or bring the ore to the surface.

Technology of large scale mining on Evoverse Planets

Biomining

Summary: microbes are used to extract metals from low/very low concentration ores. The microbes get energy by oxidising sulphide minerals or iron compounds that make up many ores. This is a relatively slow process but economic and technologically easy to do. Fracking allows the microbial solution to be pumped deep into the earth and the dissolved metals returned to the surface.

Because of the lack of plate tectonics and mantle convection currents, metals ores haven’t been stratified and hence concentrated in pockets near planetary surfaces. Hence all ores are extremely low grade. Even ‘high’ local concentrations, formed by serendipity during the original formation and gravity stratification and cooling of the planet are low compared to planets that have or have had plate tectonic activity.

Mining beam technology can extract some materials – those in higher concentrations like 'metals' (=iron) platinum, gold and silver but it can only work to a shallow depth. Consequently other materials that are absolutely vital to modern technology and engineering (for example rare earths, copper, cobalt, vanadium, nickel, zinc, tungsten, uranium) have to be mined in a more traditional way.

The historical methods employed for high grade ores was pyrometallurgy [smelting]. This is a quick method of extracting metals from their ores. It is limited to high concentration (=high grade) ores. In the early 21st Century, as high grade ores became depleted on Earth, the use of microbes was developed as a method of extraction from lower grade ores. The main disadvantage was the length of time the available methods took. smelting takes hours, and biomining of spoil takes weeks, months or even years!

Background

Bioleaching, which works with rocks that contain metal sulphides; and bio-oxidation, which works with metals that are occluded in sulphur- and iron-containing minerals. Bioleaching takes advantage of the fact that metals released from metal sulphides naturally dissolve in sulphuric acid, producing a metal-rich leachate that can be collected.

The initial methods used was by crushing the extracted rocks into small fragments and piling them into heaps up to 10m high. Sulphuric acid is then continually poured over the top of these heaps to encourage the growth of the rock-munching microbes, which are also often added to the acid. The heaps are placed onto a polyethylene lining to collect the metal-rich leachate, while air lines are inserted into the heap to supply oxygen and carbon dioxide.

The released metals are usually extracted from the leachate using a combination of solvent extraction and electrowinning, in which an electric current passing through the leachate causes the metal to come out of solution and plate an electrode. The metal-free leachate is then recirculated back to the heap, having reverted to a microbe-containing acidic solution.

The next development, bio-oxidation was made using bioreactors but the time was still between three and five days. Although using the same microbes and oxidation process as bioleaching, bio-oxidation takes place in huge bioreactors, often placed in series, rather than heaps. Indeed, bio-oxidation uses bioreactors with volumes of more than 1300m^3, which are the largest reactors used for any bioprocess in the world.

The problems

- like conventional mining, it still requires digging up rocks and blasting them to bits
- the rock crushing is energy intensive – in the first decade of the 21st Century breaking up rocks takes about 5% of all the energy human beings consumed
- bringing ores from deep mines is expensive

The solutions

We now use biomining to extract metals directly from deposits that are economically unreachable deep underground. This uses a mix of fracking technology and biomining microbiology.

Rather than dig up the rocks from deep underground and extract the metal at the surface, microbes could be sent underground to extract the metal and the resultant leachate pumped up to the surface for metal recovery. This is much less costly and energy-intensive, and there is minimal environmental disruption at the surface. We don't send the microbes down, just ferric or ferrous iron ions that carry out the extraction chemistry. Which is used depends on whether the metals are sulphides or oxides. The relevant microbes produce these in tanks at the surface in a tank at the surface.

The development of fracking technology for extracting oil from rocks deep underground helped make this option feasible

The Chemistry

Biomining takes advantage of microbes that eat rocks, or lithotrophs. The first example of such a rock-munching microbe, now known as *Acidithiobacillus ferrooxidans*, was discovered in the 1940s, but many more microbes, specifically species of bacteria and archaea, have been discovered since then. Whereas normal microbes obtain energy from sunlight or by breaking down organic compounds, rock-eating microbes get theirs by breaking down the minerals in rocks.

In most cases, the microbes break down these minerals by oxidising the sulphur and iron within them. Because metals such as copper, nickel and zinc naturally form sulphides, while other metals such as gold are trapped, or occluded, within sulphide- and iron-containing minerals, this oxidation process ends up releasing the metals.

While most of the metals in these rocks are released via the oxidation of sulphides, it is actually the iron-oxidising microbes that perform that most important role. This is because the iron found in common minerals, such as pyrite (FeS_2), is in the form Fe^{2+}, known as ferrous iron, which the microbes oxidise to ferric iron (Fe^{3+}), and this form is very effective at oxidising sulphides.

This means that the main contribution of the sulphur-oxidising microbes isn't oxidising the metal sulphides directly but oxidising sulphur-containing compounds released from the breakdown of the minerals. This is a central part of the process, however, because it generates sulphuric acid, which solubilises the ferric iron so that it can oxidise the sulphides effectively.

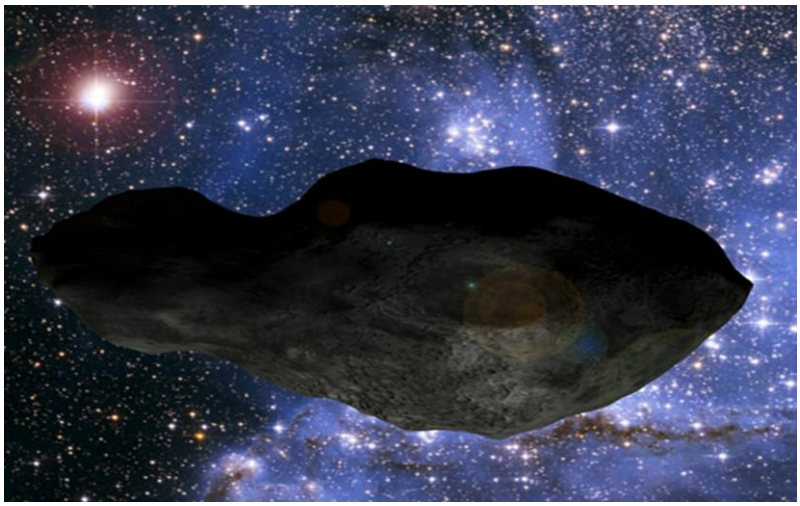
Both iron- and sulphur-oxidising microbes were naturally found in rocks, along with microbes that degrade the organic molecules produced as waste products by the lithotrophic microbes, with many microbes possessing multiple abilities. Biomining simply encouraged the growth of microbes that are already in the rocks and collects the released metals (see box below for details).

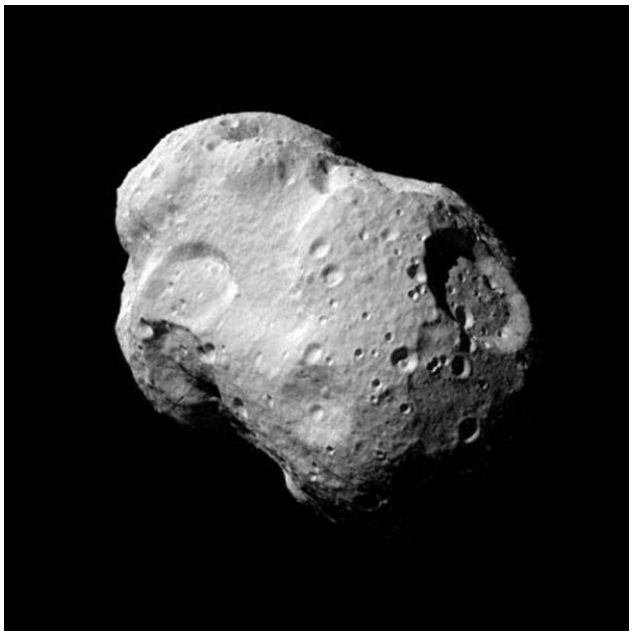
Nowadays we utilise genetically engineered bacteria that are far more efficient than natural lithotrophs. The microbes are tailored for their temperature tolerance and metabolic rate. On 'hot' planets (hot in the sense that deep rocks are at a high temperature either due to radioactive decay or that the planet is still relatively young) extremophile thermophilic bacteria are used. On 'cold' planets we use extremophile cryophilic microbes.

Asteroids

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

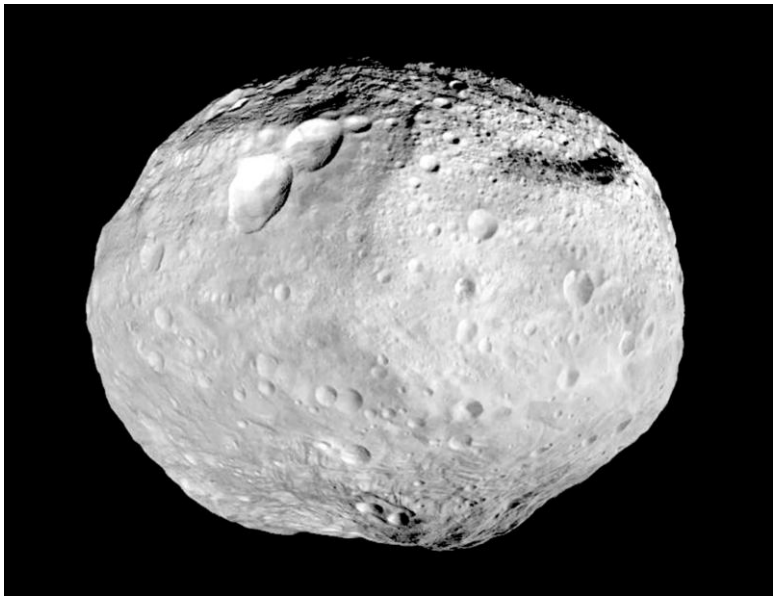
(C-type) Carbonaceous asteroids (stony and darker than coal) are the commonest and contain many complex organic molecules and form raw materials for much of Evochron's chemical industry, creating medicines, plastics and resins and fibres and elastomers, solvents, detergents, dyes and pigments, paints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





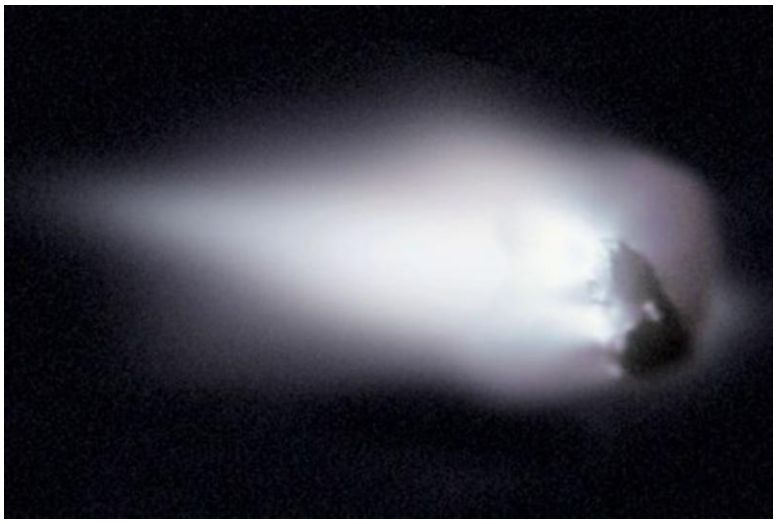
(S-type) Silicaceous asteroids (bright, stony bodies which contain metal) are the next most common. Composition is metallic iron mixed with iron- and magnesium-silicates. They are rich sources of 'metal alloys' with traces of platinum and diamond

(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.

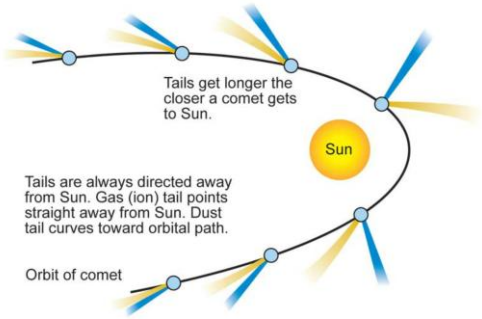
While the ice asteroids are in the outer system the cliché description is actually very accurate for the vast majority - they are 'dirty snowball'.



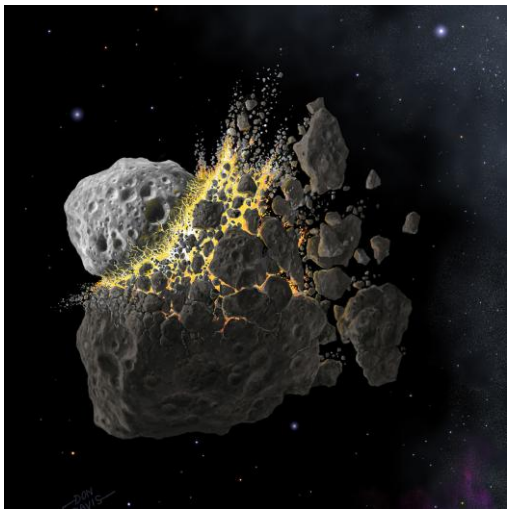
Periodically comet's orbit is gravitationally perturbed and it begins a long fall 'in system' towards the star. Some are evaporated before they reach the inner parts of the system, some don't survive their swing around the star and some pick up gravitational energy from the star and are flung out into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

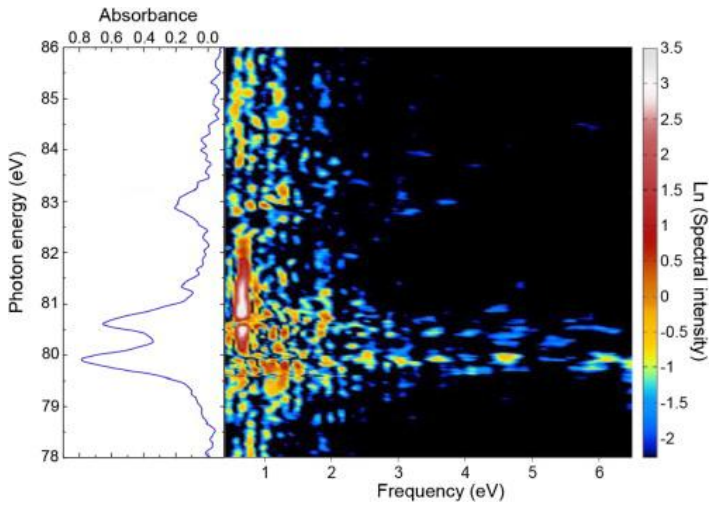
During the closest approach to the star, comets develop their characteristic twin tails.

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	*Earth Mission Control*	***Mars Habitat***
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.

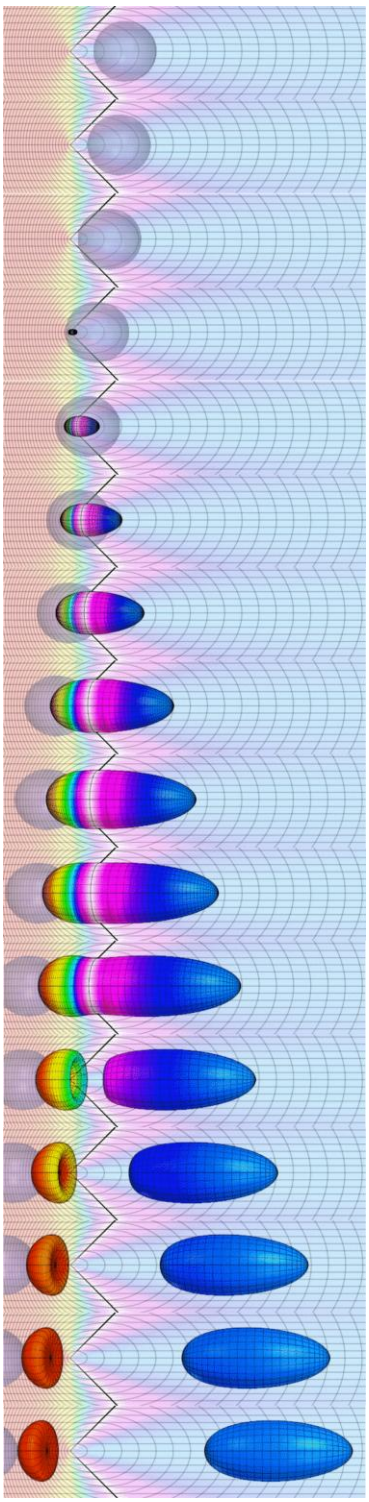
Since jump technology was already being developed, and because of problems with the technology involved with Quantum entanglement and the fragility of the entanglement of the photon pairs, WH communication is the technology used in human controlled space in Evochron. Prototypes of the transmitter created 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.

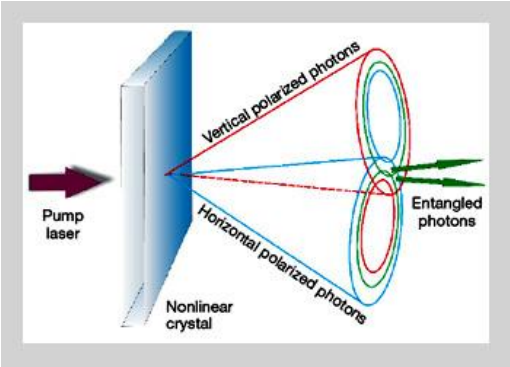
There is a good animation of these still images at

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

http://www.messagetoeagle.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.

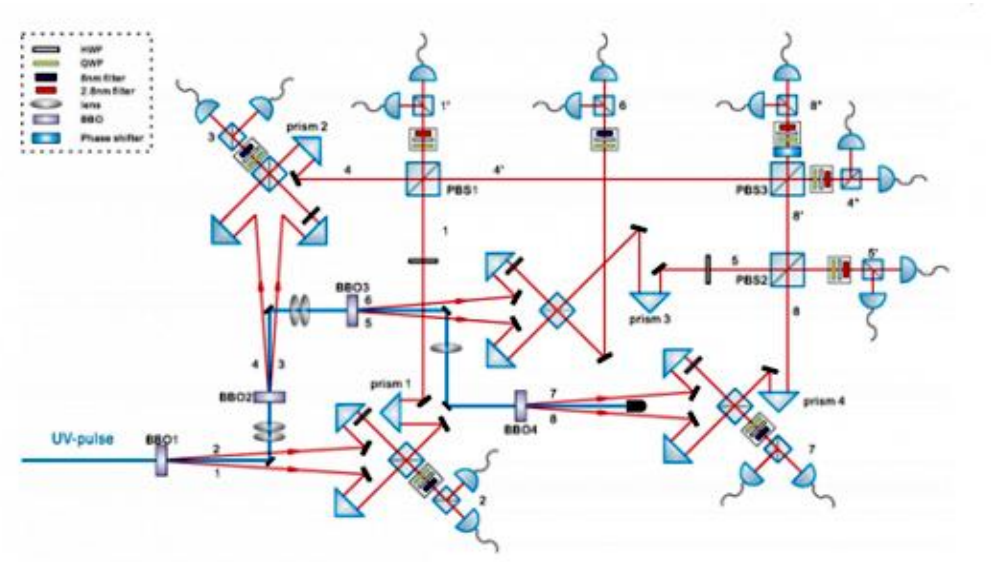
The third method utilises the properties of quantum entangled particles, a technology that is used in the quantum computers utilised in the highest power AI modules.



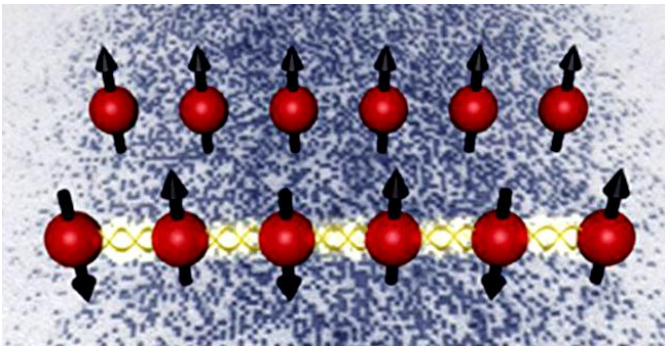
The method is based on the creation of pairs (or pairs of pairs or pairs of pairs of pairs etc) of quantum entangled photons using a quantum cloning system.

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 the that the particles can only 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 replaces by the isotope of hydrogen called deuterium. Hydrogen atoms, the simplest atoms, contain one proton and one electron; deuterium atoms are 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.

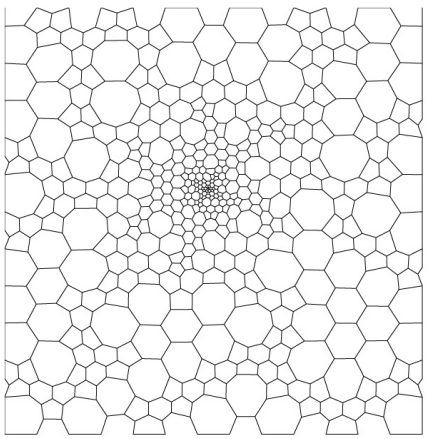
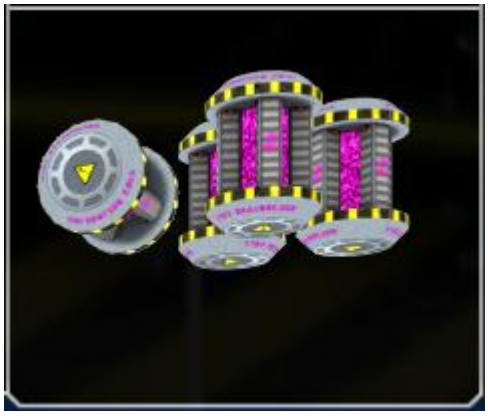


Diagram of a dendritic fractal structure

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.



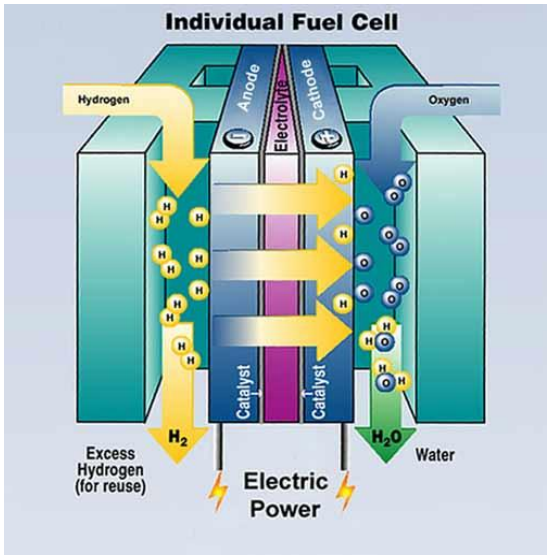
Antimatter cells use a micro-QVee unit to extract antimatter from the quantum vacuum. This is used in nanogram scales in a matter/antimatter reaction cell, releasing very high quantities of energy. The antimatter extractor isn't very efficient but given the amount of matter released by even a gram of 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.
	

Section 8: Background History of Evochron

The History of the Establishment of The Evoverse

For Humanity the discovery of the first exoplanet in the early 21st C had nurtured the possibility of a fresh start on an unsullied planet. Many groups dreamed of starting over on their own unpolluted Eden. Humanity also pondered on the chances of meeting other sentient life. With the discovery of Earth-like planets a few decades later, dreams had given way to more concrete ambitions. Time, effort and most importantly financial resources were directed into a single practical goal – reach out to other "Earths".

It took many decades of research and technical developments to create working technology from the theoretical equations developed in the early 21st Century. The creation of the first working *Fulcrum Jump Drive* in 2178 fired the human race with visions of new unspoilt paradises waiting to be settled and explored. Jump Drives capable of being fitted into ships that could carry humans took significantly longer to develop, however. The earliest jump technology was in the form of paired gates.

By 2182 Gates had been constructed at strategic places within the Sol system permitting it to be colonised. Due to the lack of jump capable ships, the sequence of development was to survey vessels to identify possible site for colonisation. The next step was to send reaction drive ships to the area for colonisation. The crews of these construction vessels spent extremely long periods of time in transit and during the construction of the gate, being away from home for years. However the financial inducements were substantial. A jump gate was built in the most strategic location, paired with a jumpgate near Earth. At that point colonists and large amounts of material could be transferred through the gates between Earth and the developing colony. Normal reaction drives we (and still are) used within each of the colonised areas.

Once the expansion of Humanity beyond its cradle - Earth, out into the Sol system was well developed, thought turned again to other star systems. A major technical hurdle had to be overcome. Jump distance, vehicle mass and energy requirements are related. Research focused on creating more efficient jump technology to permit jump enabled ships and in parallel building small cheap probes that could jump far enough on each transit to reach local stars in a reasonable time period. Size and mass limitations meant that cargo/people carrying capacity was still impossible. These mini-probes were somewhat utilitarian, even primitive in design and construction, but they could reach the nearby star systems in a few (rather than a few tens of thousands) of years, utilising a fusion nuclear energy source.

The probes sent back images of beautiful planets. The images in particular galvanised the human race. The survey reports were general, lacking detail, but gave enough information to identify possible targets and eliminate lethal ones. Resources were poured into the project. Orion was chosen as the most promising area to explore. The sequence of colonisation was

2190: probes sent Orion system – they map the system and relay data back
2195: data received on Earth and the Orion sector confirmed as a candidate for colonisation
2197; automated nanotech based constructor drones with upgraded Fulcrum Jump drives are sent to Orion to construct a gate. when they arrive, the nano-constructors follow a sequence of creating larger and more versatile constructors and finally create the parts required for the gate as well as the construction drones needed to assemble it.
2200: Trailblazer Units sent through the gate to prepare for colonists
2205: first colonists arrive in Orion

This is actually a phenomenal achievement – 15 years from starting the exploration to the first colonists arriving! The impatience had also stimulated rapid developments in jump drive technology. During this frenetic period no resource limits were accepted by any Government within the Sol System.

The exodus began.

But all too soon Humanity was shocked by the reality they found when they arrived. It seems that Earth really was, if not as unique as humanity had always thought, certainly rarer than had been expected. Earth-like did not mean Earth! Sapphire might be beautiful from space, but living on the surface was more akin to living in the Mars Colonies than living on Earth.

Humanity had arrived in the Evoverse expecting a string of Earth-like planets resembling their visions of paradise. Instead they were greeted with virtually flat planets. Earth is actually smoother scaled down than a billiard/snooker/pool ball; typical planets in Evochron make the Earth look very rough! Exoplanets that had formed within the Goldilocks Zone, where liquid water could be found, did support life but the variety was limited – very limited. Compared to Earth they were stuck in the Archean Eon. Most of the planets were similar to Earth three and a half billion years ago! A very limited range of simple plants had developed. Bacteria was the dominant life form. Planetary surveys have as yet found no native fauna beyond very simple worm-like creatures living deep in the ground and even they are extremely rare.

The geology is very unlike Earth's as well. Small planets with no mountains – just very low hills. No proper seas (as defined by the Earth norm) – just shallow lakes, though enormous by Earth standards. No evidence of tectonic activity – no volcanoes, continental plate drift and so on.

After the initial devastating sense of disappointment, Humanity rallied. There were no Arcadian paradises ready to inhabit but we did find many planets in a state of virgin readiness. It would take many generations of terraforming to bring them to fruition, but faced with necessity/reality of escaping the solar system to ensure the future of the species coupled with the enormous costs in time, resources and wealth already committed, Mankind realised that it had to commit to outcomes experienced only by future generations. Terraforming research and development gained the same support as jump drive technology had done before it. As part of developing the most appropriate terraforming techniques much research was carried out as to why the Evoverse had developed as it had.

Timeline : Mankind leaves Home

- 2178: Humanity finally succeeded to travel long distances in space due to the construction of working Fulcrum Jump Technology
- 2190 – 2197 – 2205 :Alliance astronomers started to map the Orion sector in 2190. In 2197, the first drones were sent to begin building Fulcrum Gates there. After the gates had been constructed exploration teams was sent. These "Trailblazers" mapped the sector over the next five years and began the creation of the first colonies. Colonists reached the Orion sector in 2205.
- **2229 – mid 2230s** The Orion sector was quickly colonized and the Alliance declared it part of its territory. However, unrest about the Alliance control started to rise with one of the colonies in the Orion sector. The colony separated from the Alliance over the rights to exploration and ownership of systems they had settled. They wanted exclusive colonial control over planets and systems they lived in, including the abundant resources they had found. This led to political disagreements and increasing hostilities. Several other neighbouring colonies decided to unite for the same reasons and formed the Colonial Federation around 2229. But it wasn't until about a dozen different colony groups formed together in the mid 30's that the Federation truly became a united group, though there was still disagreements between various Federation factions.
- **mid 2250's – early 2270's** By the mid-50's, the Alliance-Federation civil war had begun and continued until the early 70's
- 2212 Under a secret research and development project, the Alliance developed a version of the jump technology that was physically much smaller and had vastly improved energy efficiency. Even so these new jump drives could be fitted into capital ships no smaller than battleships and large carriers. The drives had limited range requiring multiple jumps to travel between systems
- **(2220-2300) Rise of the Mercenaries**
- March 12th 2252: In one of the earliest examples of cooperative action (Rebel) Federation ships attacked the (Terran) Alliance Aros Base, in orbit around Jupiter. However Federation action was held back by infighting among Federation factions that continued until early 70's
- **(2254-2284)The Lexington** – commissioned by the Alliance 2245 – revealed publically 2254
- Alliance also started building other large combat carriers (named Bismarck, Zenith and Victory), which would be completed by 2259
- mid 2270's Alliance-Federation war ceases in practice due to Lexington's overwhelming firepower and fighter capacity
- 2277 war officially ends in favour of The Terran Alliance
- The 8 year 'peace'
- **(2285-2287) Enigma**
- 2285 the Federation's flagship, the ***Richton***, was mysteriously attacked and destroyed while on route to a peaceful colony establishment meeting. Federation blames the Alliance
- The Alliance ship ***Becker*** was attacked on April 14, 2287. It was apparently destroyed in a matter of a few seconds. The Alliance blames the Federation
- late 2286 the Vonari are discovered as the true perpetrators!
- 2287 Vonari attack Earth (first attempt) July 1st – intention: Invasion. The attack is repelled by heroic efforts of the defence forces

. . . continue

- **Reviction (2288)**
- 12 October 2288, the Alliance ship ***Lexington*** is destroyed by a surprise attack by a Vonari force
- In early February 2288, Dr. Adam Shefeld developed a new warp-gate device that could open a temporary fulcrum field pathway capable of transporting an entire ship from one region of space to another without the need for a receiving gate. This was revolutionary and his technology was as yet only built into one specific gate, the so-called Shefeld Gate near the Rucker asteroid field. It would be many years before the technology could be fitted to capital ships, increasing their range phenomenally.
- 2288 Vonari attack Earth (second attempt) 30th October second attack – 15 months after the first Intention: Destruction
- **(2274-2288) Riftspace** An ancient Vonari artefact was discovered in December 2287, (two months after the second Vonari attack) telling a story of an outsider who would find a paradise world hidden in a realm called 'Riftspace'.
- **(2288-present) Evochron**
- In November of 2288, the Alliance discovered a new system that included an Earth-like planet. Although lifeless, the world had an abundant supply of water along with the right gravity and atmospheric conditions for terraforming. The planet was named 'Sapphire' after its brilliant colouring and nearby solar system were linked together through a network of jump gates. The entire quadrant of space was then named after the exploration satellite that discovered the central solar system, Evochron.
- **(2292)The end of an Era**
- By 2300, Humanity controlled 4 sectors: Sol (since the year 2100), Orion (since 2156), Riftspace (since 2288) and Evochron (since 2288). The human race was still divided into Federation and Alliance, and it was clear that true peace is still far away.
- **(2292 - 2346) Calm** The founding of the Seekers in late 2292, was a result of a defection of an Alliance communication expert, Jonathan Marchant.
- **(2344 - 2347)The Depression**
- **(2320 - 2340)Lost Paradise** 2330 Riftspace abandoned as a colony location but was still being explored by 2340
- **(2321 - 2363)The Seekers** In 2324, Alliance investigations uncovered evidence of a substantial "underground" organisation calling themselves "The Seekers" a modern day "secret sect" of conspiracy theorists that believed that the governments were keeping much about Riftspace secret. They were on a mission to find the truth.
- **(2361 - 2363)The Renegades**
- **(2408 - 2415) The Beacon Trail**
- **(2402-2408)The Arvoch Conflict** started on January 7, 2402, when Federation forces threw up blockades in the Evochron sector, leading to renewed tensions between Alliance and Federation
- In late February 2408, a fighter squadron of the Phantom succeeded in locating and obtaining a powerful Vonari weapon, an upgraded version of the weapon the Vonari tried to use against Earth. Using the wormhole in Pisces, humanity attempted to retake the Arvoch system from Vonari control. Final messages from the carrier's transmitted activity log indicate the crew attempted to activate the Vonari weapon. The fate of the carrier is unknown.

Section 9 : Alien Species in Evochron

Unproven but persistent rumours about Aliens in Evochron

Perhaps it's simply a manifestation of wishful thinking, perhaps it's Government cover ups (as the conspiracy theorists believe) but there are persistent, unattributed rumours concerning a truly Earth-like planet – not in the core but in one of the satellite areas. There are also rumours of two alien species alongside the Vonari;

A long gone highly advanced race. The Ancients aka The Elders. The evidence for their existence is the (very rare) examples of technology they left behind. It is suggested that before they left/disappeared/evolved to a higher plane of existence they seeded the galaxy with life. This is one of the explanations for the panspermian theory of how life developed on Earth – particularly the 'directed panspermia' hypothesis.

Panspermia is a Greek word that translates literally as "seeds everywhere". The panspermia hypothesis states that the "seeds" of life exist all over the Universe and can be propagated through space from one location to another. Some believe that life on Earth may have originated through these "seeds".

Many mechanisms for panspermia have been proposed; two of the three most popular variations of the panspermia hypothesis propose uncontrolled random events. These two are lithopanspermia (interstellar panspermia) where impact-expelled rocks from a planet's surface serve as transfer vehicles for spreading biological material from one solar system to another and ballistic panspermia (interplanetary panspermia) - impact-expelled rocks from a planet's surface serve as transfer vehicles for spreading biological material from one planet to another within the same solar system. They are basically two views of the same thing. The third is more interesting.

Directed panspermia is the intentional spreading of the seeds of life to other planets by an advanced civilization. Countering objections to the lack of evidence of any such civilisation, a mirror suggestion points to the intentional spreading of the life from Earth to other planets by humans in our efforts to terraform colonised planets in Evochron. However, none of the theories provide an explanation for evolution or attempt pinpoint the origin of life in the Universe, but they do attempt to solve the mysteries of the origin of life on Earth and the transfer of life throughout the Universe.

'LGM'. Throughout the 20th Century after rocket flight was established stories abound of UFO's and alien visitations. Aliens seeded life on Earth. Aliens (Little Green Men are a common description) visit Earth and for reasons known only to themselves choose to perform rather dubious experiments on uneducated farming folk in the backwoods of the USA. As opposed to landing carefully on the lawn outside the White House. Aliens have been observing humans for millennia, waiting to see if we develop sufficiently to be invited to join the galactic club before we make ourselves extinct. Aliens actually control the world governments

The stories have followed mankind to Evochron with unproven reports of flying saucers in certain (uncharted systems) near Cerulean (in particular)

These aliens are thought to be secretive because they are paranoid and/or afraid of humankind and our aggressive nature. Or they are planning to take over Evochron so they can expand their experimentation. Or they are intending to annihilate the infection that is humanity.

Stories that are hard to dismiss because there is a growing collection of tenuous evidence from reliable sources, rather than from uneducated rural dwellers. There is a consistency in the stories that is hard to dismiss.

And finally there is the irrevocable evidence that aliens exist in the Evoverse. We are at war with them. We have met the Vonari . . . and they are not friendly.

The following two intel reports are said to have been compiled by a secret agency perhaps Government controlled, perhaps not. The information presented has been redacted- heavily in the case of the Vonari report - and cannot be verified. Read them, analyse the data and decide for yourself whether they could be true.

Intel Briefing: Vonari [redacted]

Background
Vonari history is shrouded in secrecy. It is difficult to understand how such a hostile species could cooperate sufficiently as a society to develop any significantly sophisticated technology, let alone inter-system space travel. [Information has been removed]

Until recently it was believed that the Vonari are simply extremely xenophobic and that their hostility towards mankind arises from this. Humanity's first interaction was the unprovoked destruction of the Federation Flagship **Richton** in 2285. Recent developments showing cooperation between Vonari and Actarians, demonstrate clearly that the Vonari are not merely xenophobic. Consequently the reason for their extreme hostility to humanity requires a major and urgent rethink. Vonari Physiology

This is the first mention of a second alien species – the Actarians

The original image was taken in opportunistic circumstances in starlight only (no artificial light sources nor any in-camera enhancement at any part of the emr spectrum). This image has been enhanced to maximise detail.

General Description of Vonari Physiology:
[Information has been edited] humanoid - 'animal like', between feral canine and a somewhat 'bat-like' appearance but nothing very definitive in one direction or the other - large eyes - compact and well muscled - around 150cm - 160cm tall

Detailed Description of Vonari Physiology: [Information has been removed]

Vonari Psychology, Objectives and Motivations Origins of the Vonari race: [Information has been removed]

[Military Intel – unconfirmed – of an autopsy of a badly damaged upper body cadaver, thought now to be Vonari reported *the left hand* side *of the brain (analytical centre - occipital lobe - somatosensory cortex) is well developed and the hippocampus suppressed*] This information permits the resulting cognitive and empathetic IQ's to be estimated [error range: ± 30 normalised]

C-IQ (Reynolds Cognitive scale - normalised 100): >180
E-IQ (D'Kusi Empathetic scale - normalised 100): <30
It is emphasised that the provenance of this Intel is poor, but it fits with known Vonari behaviour patterns. Psychologically, the Vonari are a warrior species. They are very intelligent and resourceful emotionless killers.

They are driven by a desire to revenge themselves on humanity because [Information has been removed] and also to defend Vonarion (and several uncharted Vonari systems of which humans are officially unaware) against human expansion from Talison - Sierra - Cerulean – Arvoch. This expansion is perceived as a great threat to Vonari security. The Vonari want to expand their sphere of influence into human space, enslaving humanity in the process and so achieve their revenge. The Vonari have allied with the Actarians in return for access to Actarian offensive and defensive technology. Whilst respecting their technology, the Vonari despise the cowardly nature of the Actarians. Attacks on human space have been a central part of the Vonari's aggressive defence of Vonari space. The Invasion of human core systems will give the Vonari access to the gate network and to details of gate technology, making their invasion of Evochron easier. After the subjugation or genocide of humanity, there is a high probability that Vonari intend the subjugation or genocide of the Actarian race and bring the whole of inhabited space under the control of a Vonari Empire
Vonari Technology

This section is common knowledge after human/Vonari many experiences of conflicts in the Warzones

1. Similar level to human technology in many aspects.
2. Offensive and defensive technology equivalent to human - better in some ways, weaker in others
3. Flight technology is slightly in advance of humans, for example they developed the Mantis Drive.

The author is hoping to obtain a fuller version of this briefing in the near future

Intel Briefing: Actarians

Background
There have consistently been sightings of "flying saucers" in uncharted systems particularly in the North Western Quadrant of Evochron in the region of Cerulean. The system where most sightings have been made is Actarius which has given the aliens the name Actarians. The location and name of the Actarian homeworld is unknown. The Actarians own name for their race is unknown.

Actarian myths claim that they are an old race and initially explored Evochron more than 10000 years ago, immediately after the last ice age on Earth, and around the time humans were beginning the transformation from being nomadic hunter-gatherers to adopting early forms of farming.

In an attempt to extend their lifespan, Actarians experimented with genetic manipulation. This lead to an atrophying of all physical, psychological and emotional links to gender. By the time they realised the pitfalls of such extreme genetic manipulation it was too late to revert to normal reproduction. To prevent their own extinction, Actarians are forced to reproduce asexually, by cloning. A negative outcome of their dependency on cloning is having a very stable genotype, with only epigenetic* changes in the phenotype to allow adaptation to new environments. This has resulted in the Actarians fearing direct interaction with alien species. Actarians are severe xenophobes - it is a reflection of the strength of their fear of humanity's expansion out of the Evochron core that they felt forced into an alliance with the Vonari. A group of genetically engineered Actarians were grown in 'acceleration cloning tanks' to interact with Vonari during negotiations and during subsequent communication. Actual contact between members of the two species is not normally necessary.
It appears that all alien species are xenophobic, though some argue that since humans are xenophobic as well it's a psychological norm!

* **Epigenetics**: *the study of changes in gene expression or cellular phenotype, caused by mechanisms other than changes in the underlying DNA sequence. It refers to functionally relevant modifications to the genome that do* ***not*** *involve a change in the nucleotide sequence. Specific epigenetic processes include*

*paramutation, gene silencing, X chromosome inactivation, reprogramming and (of particular concern to the Actarians, technical limitations affecting **parthenogenesis** and **cloning**.*

Actarian Physiology

No actual image of an Actarian is available. However it was possible to create a graphic sketch from descriptions given to the diplomatic team by Vonari who had seen (interrogated) Actarian bodies.

It's not clear who the sources mentioned here are or the context that they are working in

The head has a large cranium and narrows to a small chin - looking somewhat like an inverted teardrop.
The brain is larger in proportion to the body than in humans.
Eyes very large in proportion to the head. Eyes are almond shaped arranged horizontally, black with no evidence of pupils.
Centrally and below the eyes are two small vertical nasal slits
Below the nasal slits is a small thin lipped mouth. Actarians do not have teeth. Their food is liquidised as the final stage of its preparation.
Skin is smooth, rubbery in texture and looks wet. It is mid grey green with delicate pale, dirty blue mottling.
They might be evolved from amphibians. This is supported by the fact that they prefer relatively moist conditions and become distressed in a very dry environment. This may be relevant in informing any search for their homeworld.
Homoeothermic (warm blooded) with a magnesium atom oxygen carrier system and hence blood is blue green in colour.
Phenotype: humanoid; skinny. Around 90cm tall. Physically relatively fragile. Limbs are thin and are longer than human in proportion. Hands end with four long, slim digits - three fingers and an opposed thumb and feet end with four slim toes.

Actarian Psychology, Objectives and Motivations

Psychologically, Actarians are fear driven, hence their extreme xenophobia. They are very secretive and prefer subterfuge and 'behind the scenes' manipulation to open conflict. This explains why their technological development is focussed on stealth and an ability to destroy opponents without warning employing overpowering firepower.

Their primary motivation is a very strong desire to maintain the secrecy of the location of Actarian space (which includes several uncharted systems). Actarian objectives are complex. They are playing a dangerous game for such risk averse mentality.

Human expansion from Talison - Sierra - Cerulean - Arvoch is perceived as a great threat and hence they are working towards weakening human influence in the core. They are using the Vonari's reputation as aggressors towards humanity to shield their involvement whilst achieving their goals of pushing humanity back into the central core and to weaken it sufficiently to stop future expansionist development.
However, they are becoming more and more fearful of the future intentions of the Vonari after humanity has been dealt with. Their solution as to how to weaken the Vonari sufficiently to stop their expansionist development is as yet unknown.

Actarian Technology

Similar level to human technology in many aspects.
Offensive and defensive technology significantly more advanced than human and Vonari
stealth technology
cannon technology including cooperative and coordinated multi-ship fire control systems
planet buster technology is very much more advanced that Vonari. (Human's do not possess planet buster capability)

The Ancients

There are many myths about a highly advanced race that either became extinct or left the Galaxy or even transcended from this plane of existence many millions of years ago. From the dawn of humanity every culture has had its creation myths and most include a god or gods. Although details are sparse there is reason to believe that the Vonari and the Actarians share this fundamental need to believe in superbeings.

Evidence: The Ancients left behind a few examples of their advanced technology. Conspiracy theories believe that the discovery/invention of Fulcrum Jump Technology was triggered by the discovery of a FTL Ancient's ship. There have been a few pieces of technology unearthed that are well beyond the limits of our present scientific knowledge and technical ability. There are the famous 'beacons' and reports of an advanced analytical module hidden in one of the asteroid caves for example.

The hard evidence is designated as secret by government agencies; its more apparent in its absence.

Section 10 : Development of Cargo Transport Ships

Cargo is handled in-system and between system by an integrated set of transporter/carriers.

- bulk transport between systems is carried by Capital Transport Ships (CTS's)
- large scale in-system and inter-system cargo loads that are too small for CTS's and too large for mercenaries are handled by Cargo Hauler Vessels (CHV's). These were the original 'big boys' for all bulk cargo movement before ship installed jump drives were developed.
- small loads are carried by mercenaries and forms a large proportion of mercenary commerce in the Evoverse.
- Orbital Cargo Tugs (OCT's) unload the big cargo ships and move the cargo pods to either the local station or construction station for subsequent unpacking. If the cargo is required on the planet surface the cargo pod is split in half as it is taken off the transport and the half pods are taken by Orbit to Ground/Ground to Orbit vessels (O2G/G2O) variable-angle thruster ships – what used to be called VTOL's
- on planet surfaces large low-bed loaders move the half cargo pods to where they are stored or processed.

Cargo Haulers – CHV's – can land on planetary surfaces but their mass and size makes planetary landing a solution of last resort. (See details below). They are able to carry large cargo pods in system, but the bulk of their work is between systems, especially to and from ungated systems. Systems that haven't developed sufficiently to merit a gate rarely have sufficient transport capacity needs to merit a visit by a CTS. CHV's fill the niche.

CHV's also carry smaller loads between core systems. Their original design parameters was determined by the diameter of jump gates – they had to be small enough to use inter-system gates and natural wormholes. However the stresses imposed by transiting a blackhole to access its wormhole is far too high for their modular structure to handle. Transport to uncharted systems is via Gates to reach the nearest gated jump off system and jump drives from there.

The rise of the Capital Transport Ships

Prior to the development of jump drives that could be fitted to ships, mass cargo movement was handles by CHV's. They were obviously limited to gated systems. Colonisation was very limited due to the time taken to reach and survey new systems. Inter-system travel was Gate only.

The first jump drives small enough to be carried on a ship required so much energy and was so physically large that a new class of transport ships were designed for mass cargo transit – mainly between systems. To have sufficient cargo space they were unable to fit though jump gates. These were the forerunners of the CTS's we have today. They were a little smaller but with much smaller cargo capacities due to the inefficiency of the early jump drives. They were also much slower than today's CTS's due to the limited jump range of early drives. However, their ability to jump without gates coupled with the sheer volume of cargo space they had allowed them to carry very large amounts of cargo quickly between systems compared to CHV's and they could visit ungated systems as well.

They were an instant success, boosting the economic development of the Evoverse, allowing much easier and more economic colonisation and stimulating a flurry of jump drive development work. Theoretical research pointed to increased efficiency which in turn drove technology and engineering to manufacture smaller and cheaper drives, often with a range increase as well. This in turn increased cargo capacity

when retrofitted to older ships. Economic growth stimulated a cycle of theoretical, technical and engineering developments which stimulated further turns of the cycle.

However the size of CTS's also limits their economical use to carrying very large volumes of cargo between specific points between core gated systems. The power and range of their jump drives renders their inability to use gates irrelevant. Their sheer capacity is usually far beyond the needs of the ever increasing number of ungated colonies or even worlds in established systems. The cruise between the cargo holding facilities of an established system collecting a full load of cargo pods (the load cycle) and them jump to their destination where they unload at the systems cargo holding facilities.

For a colony to 'get gated' is a major milestone in its evolution – in living memory only four colonies to have developed sufficiently to justify the creation of gates linking to the 'core ' systems; Merak, Iota, Atlas and Deneb. The warzones were gated for strategic military reasons despite it being economically unviable. There are the very necessary buffer between Humanity and the Vonari. Apart from when setting up new colony, and acting as resupply vessels for Navy capital ships there is little economic reason for them to move away from gated systems. For some marginal colonies, CHV's are employed by the Colonial Development Authority.

The number of CHV's diminished as the CTS's took over a significant part of their roles, being able to jump between systems far more efficiently and economically than the gate-limited CHV's. However as jump drive size and energy requirements both fell, it became feasible to retrofit CHV's with jump drives. These are nowhere near a match for the inter-system jump capacities of capital ships but at four sectors per jump they are feasible for travel to and between ungated systems. So instead of disappearing because their uncompetitiveness against CTS's they found a new niche that capitalised on their smaller size and capacity. A colony could afford to hire a CHV when it couldn't afford a CTS.

After the initial setup of a colony, CHV's usually handle the first couple of centuries of a colony's development needs. CHV's evolved a new role – that of carrying medium amounts of cargo between systems via gates and, more slowly, to ungated systems via jump drives. They also took over the niche of rapid and economic movement of relatively large amounts of cargo in-system. More importantly it became possible to move cargo to and from and between ungated systems more economically than the massive CTS's. However their limited energy generating capacity and stringent size restrictions limits their jump drive capacity to four sectors per jump and their recharge time between jumps is around 30 minutes. When using IDS drive their acceleration is poor but once at speed they can cruise on inertial economically. A few CHV's have been used to try out a development that minimises the velocity losses experienced when coming out of a jump into inertial flight. The idea was that since the economics of cargo movement is cutthroat and sometimes cruising at a high inertial speed can increase profit margins by a few points, achieving a fast inertial speed could be worthwhile. On the whole the idea didn't take off for CHV's. However, modifications to create a retrofittable module to mercenary craft has proved very popular! Mercenary pilots ensure that their pitch and heading is correct and set their throttle to maximum and inertial prior to a jump. They can then use their afterburner to boost speed further if they require it after the final jump, but the big attraction is entering potentially hostile space at a high velocity. This mod also allows them to quickly and easily build up a very high inertial speed from a single jump.

Gate and ship size limits and the evolution of Cargo Haulers

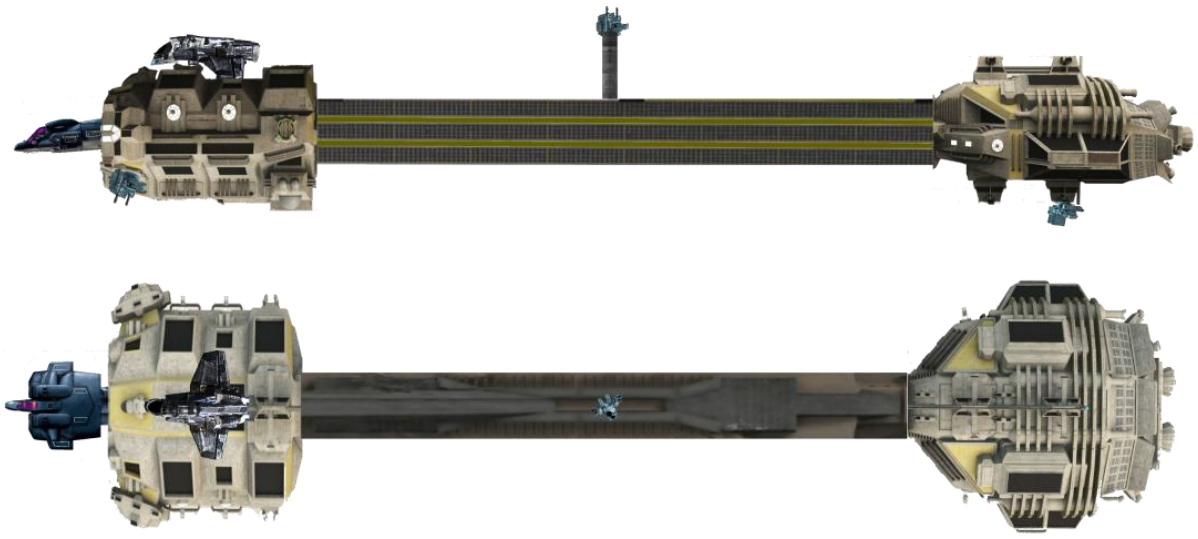
The size of a jump gates limits the cross sectional area of CHV's. The active diameter of a gate wormhole is 225m – this drops to an accessible diameter of about 200m due to the stabilising projectors protruding around the gate. With a stringently applied safety margin, the absolute maximum width of a ship is very strictly limited to 125m (63% of the active width of a gate). This working limit is determined by the maximum permitted length of the ship since they have to enter perpendicular to the gate field and near to its centre. Margins of error are calculated by allowing an off perpendicular axis approach run of less than 2 degrees and off centre entry of less than 10 metres. Thus the absolute legal maximum length of a 125m diameter cargo transport is limited to 400m

These limitations determined the design of cargo haulers from the early days of the colonisation of the Evoverse. Modern CHV's are still very much as they were then. They are modular and consist of;

A ***forward section*** comprising cockpit/control/navigation/communication which links to the accommodation unit. Also incorporated in the forward section are medical facilities, sensor arrays, computer cores, remote weapon control and escape pods. Overall CHV's carry four twin multi-barrel railguns/twin Excalibur missile packs. Two of these defensive units are located on the bow, ventrally at starboard and port locations. .

There is access/docking to the modified Talon that acts as a shuttle/scout. This is carried on a docking mount above the accommodation unit. CHV's also carry between one and three MkIII 'permanent' Terrain Walkers that don't require constitution when needed. They are also able to function for short periods in a vacuum. The Talon scout can be equipped with a standard Mk II deployable TW of course. These scouts are usually equipped with one cargo bay and basic accommodation for two people.

A modular ***central access corridor*** links the front accommodation/piloting module to the rear engineering module and allows access to free cargo holds if they have been fitted. Each corridor module can dock a pair of cargo containers. It also carries all the necessary two way utility and energy wiring, conduits and pipes. The image below is an empty Six-pack.



The economics of running a CHV has resulted in the 'normal' cargo capacity being three pairs of mcp's, nicknamed a 'six pack'. Two pair capacity (Quads) is not uncommon, but tends to be limited to more valuable cargoes – and the conformation is a clear advert to that! It is very rare than a single pair is used (Twinning), though in an emergency they can double as O2GS's. Similarly, in exceptional circumstances four pairs of mcp's can be fitted (Octopus). However this increases the total length of an Octopus to

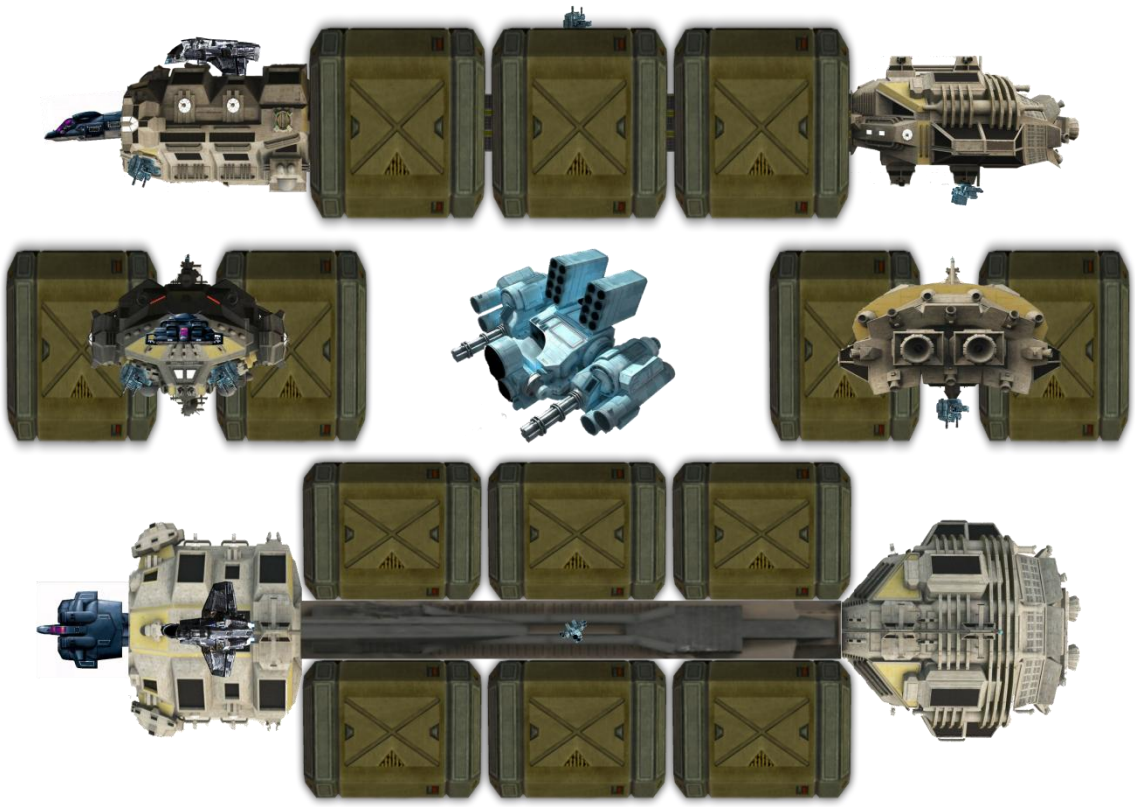
360m – too close to the maximum safe length limit for regular use. Taking and Octopus through a gate ('threading the needle') requires the highest level of skill and precision flying from the pilot. It' s considered too sensitive to allow AI assistance, never mind AI control. Sorry ***ANNA***! It is possible to reconfigure the ship to carry two or even one pair of cargo pods, reducing the length of the ship in the process.

A twin particle cannon/twin missile unit is located half way along the corridor tube protecting the dorsal segment of the ship. To raise it level with the top of the cargo pods it's mounted on a telescoping tower.

It is normal for cargo pods to be carried in pairs for flight stability. However one or both or of a pair of cargo pods can been replaced with an open plan, versatile *Cargo Bay*, accessible from the central corridor, with external airlocks and its own loading ramp. The more balanced the side to side mass of the ship is the more stable the ships flight and the more predictable its manoeuvrability. Therefore is highly recommended that mass matched pods are fitted. Hence for permanent use it would be strongly recommended that a pair of Cargo Bays be fitted

The ***rear module*** contains engineering control, fuel tanks, energy generation modules, in-system reaction drives and the jump drive. It also has the fourth, ventrally mounted twin cannon/twin missile module to protect the stern.

Therefore the total defensive fire power consists of eight multi-barrel railguns plus eight Excalibur missile packs



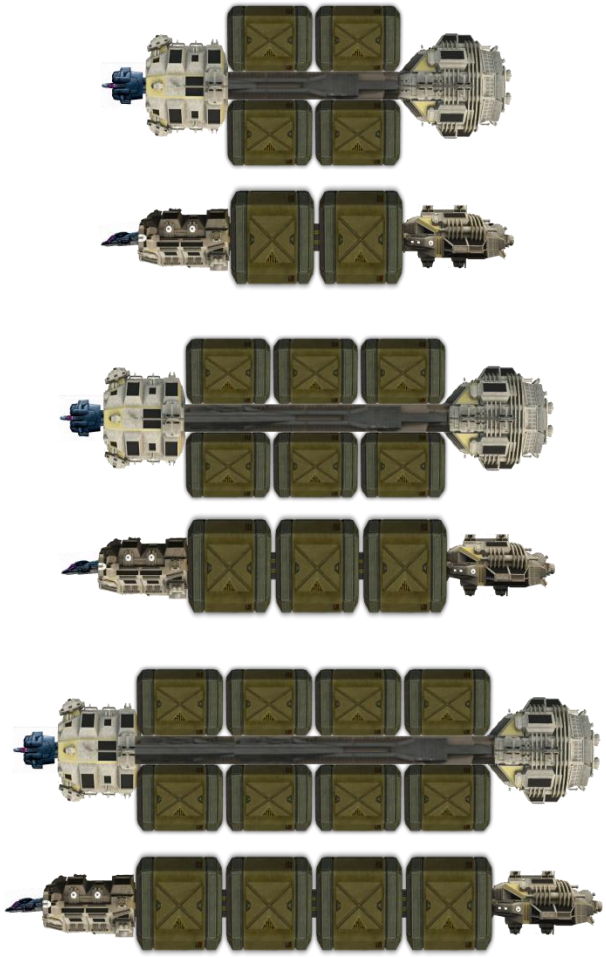
There is a small self contained accommodation section plus a single three man escape pod in engineering section for the convenience of the engineer(s) during overhauls, maintenance, routine operation *etc*

Each conformation has attracted a distinctive nickname: 'Twin', 'Quads', '6-pack' and 'Octopus' for one pair to four cargo pod pairs respectively. Twins and Octopi are very rarely seen. 6-packs are the commonest and are reputed to get their name from the way alcoholic beverages were sold in the past!!

Taking the modular design of cargo ships;

- 80m = cockpit + living accommodation
- 62m for the 60m cargo pod plus spacer gap
- 30m engineering + fuel + engines + jump drives

gives lengths of 295m for a 6-pack CHV; the minimum length – a Twin – is 175m and an Octopus is 360m



The role of the mercenary

Although mercenary ships are tiny in comparison they are so numerous and versatile that they carry the bulk of in-system cargo. They also act as a very rapid transport / taxi service between gated systems for small amounts of cargo. They are often used for small deliveries to and from and between gated systems where speed of delivery is important enough to justify the high carriage costs and it isn't necessary or economic to use the services of a cargo hauler. A good mercenary pilot in a decent ship also provides protection for the cargo.

Summary of roles of capital ships, cargo haulers & merc ships

Each level of the cargo transport infrastructure has its own niche;

- **capital transport ships**: super large volumes of cargo between systems – gated and ungated - though the latter is rare because the less developed colonies rarely require the capacity on offer.
- **cargo haulers**: medium volumes of cargo in system, rapidly between gated systems and more slowly to, from and between ungated systems.
- **mercenary craft**: mainly in system, but occasionally as a person or parcel taxi service between systems. In fact most mercenary contracts are in-sector
-

As a consequence, the presence of mercenary ships is ubiquitous in the Evoverse. Capital transport ships are seen commonly in gated systems and also occasionally in ungated systems usually in a resupply / refuelling role in support of Navy capital ship. Cargo haulers are rarely seen in gated systems and are not common even in ungated systems because the amount of available work limits the number required. They often carry a mix of cargo picked up from various systems and delivered to various other systems.

Relative cargo volume capacities:

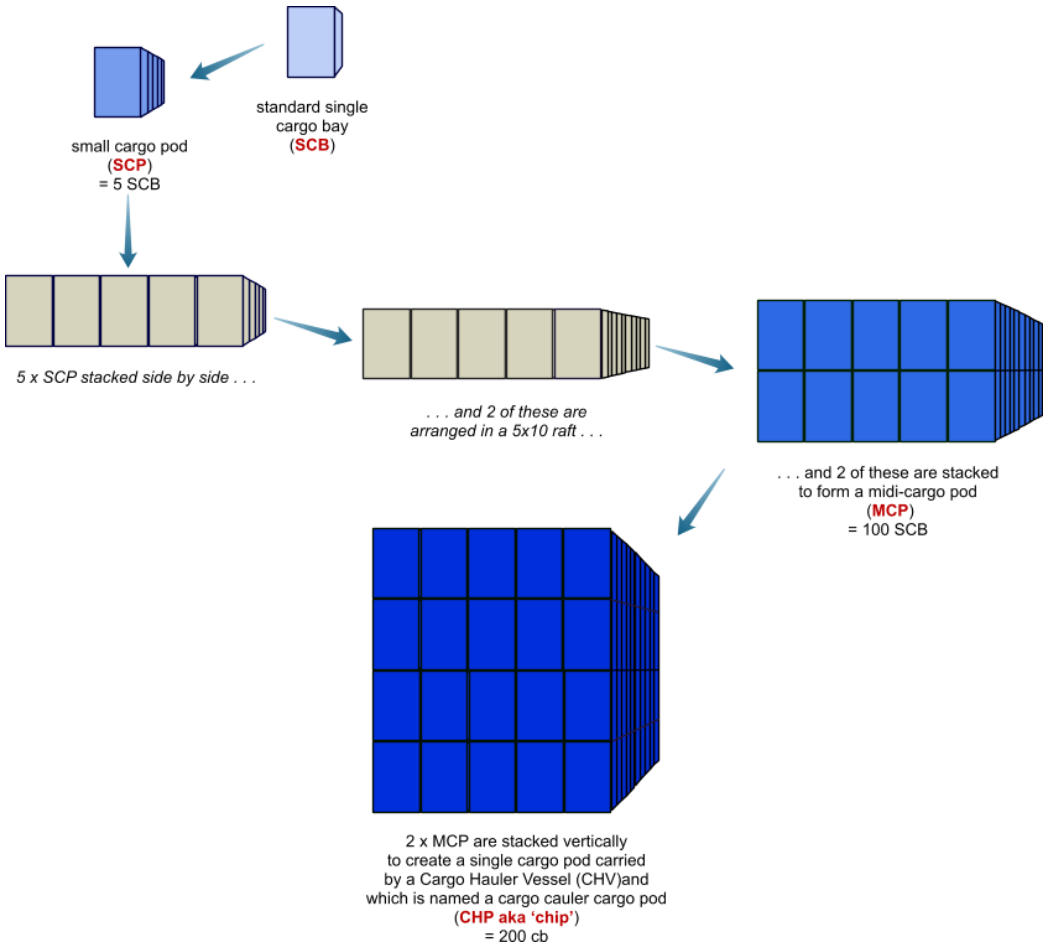
All sizes are w x h x d in metres

The cargo bays Mercenaries carry are the basic cargo unit in the Evoverse;

- 1 standard cargo bay (**SCB**) = 10x15x6m = 900 m^3
- 5 SCB = 10x15x30m = 4500 m^3 known as a small-cargo pod (**SCP**) – it is the max Merc capacity
- 20 SCP's arranged in a 5 x 2 x 2 array forms a midi-cargo pod (**MCP**) and contains 100 SCB's
- 2 MCP's are stacked vertically to for the basic cargo pod carried by CHV's and are called cargo hauler cargo pods (**CHP**) = 60 x 60 x 50m = 180 000 m^3 and contains 40 x SCP's = 200 SCB's. These are often called 'chips'
- 1 pair CHCP's = 360 000 m^3 and contains 80 x SCP's = 400 SCB's
- 3 pairs of MCP'S = 1 080 000 m^3 and contains 240 x SCP = 1200 SCB's
- One CTS can carry 1350 x 525 x 375 m = 266 000 000 m^3 of cargo
- Therefore a single CTS ≡ 246 6-pack CHV's ≡ 59 000 mercenary craft and
- 1 Six-pack CHV ≡ 240 mercenary craft

	transport ship	Six-pack CHV	merc ship
cargo volume m^3	266 000 000	1 230 000	4500
full load (bays)	multiple distributed cargo space	6 CHCPs	1 - 5 SCB's
equivalent SCB's	295 000	1200	5
equivalent to Merc ships with a SCP	59 000	240	

Expressing this visually gives . . .

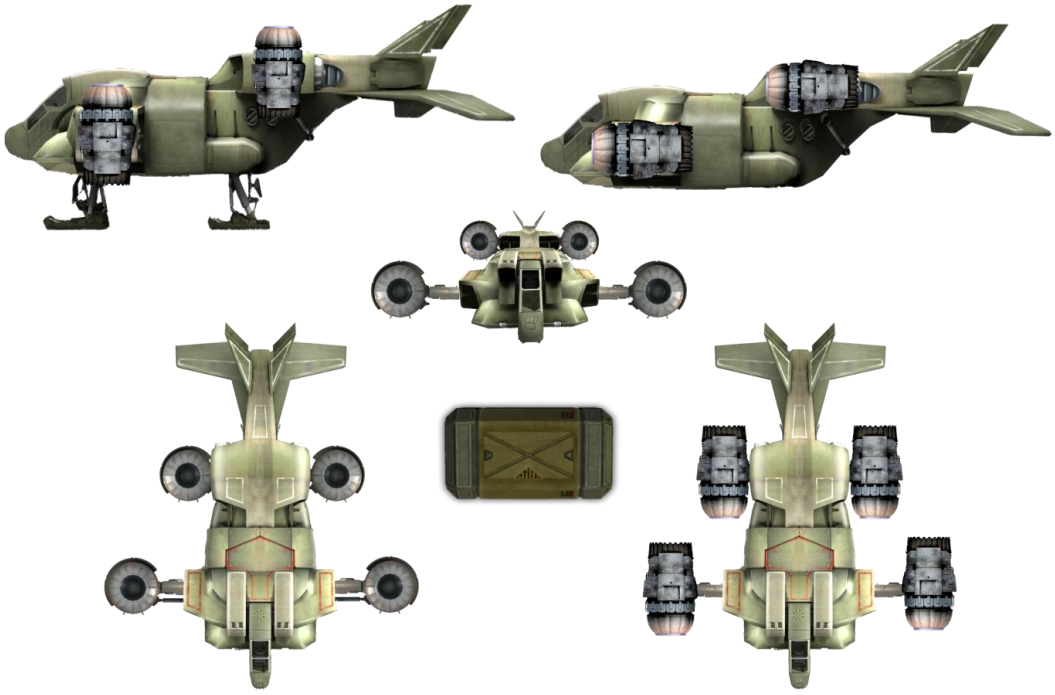


Once the cargo haulers arrive at the planet or station or processor orbital tugs transfer cargo into and out of stations and between transport ships

The orbital tugs are a simple strong minimal framework with a cockpit at the front and two outrigger engines at the rear. They never enter the atmosphere

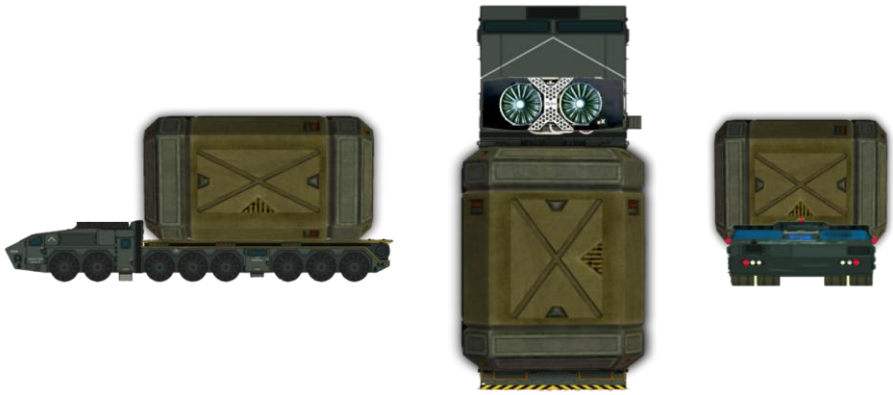
Cargo Haulers can land on a planet, but the manoeuvre is not easy because of their size and mass. Typically only a two module cargo hauler would attempt a landing. Unloading the massive pods is also difficult on the ground. However the pods can be replaced with open plan cargo space inside, allowing a lower cargo density but more flexibility in the loads carried. For example cargo to be delivered to several destinations in multiple systems can be carried in a 'free pod' and unloaded as appropriate.

Orbital ground shuttles (**O2G/G2O**) - *veetols* - carry material between a planetary surface and orbit

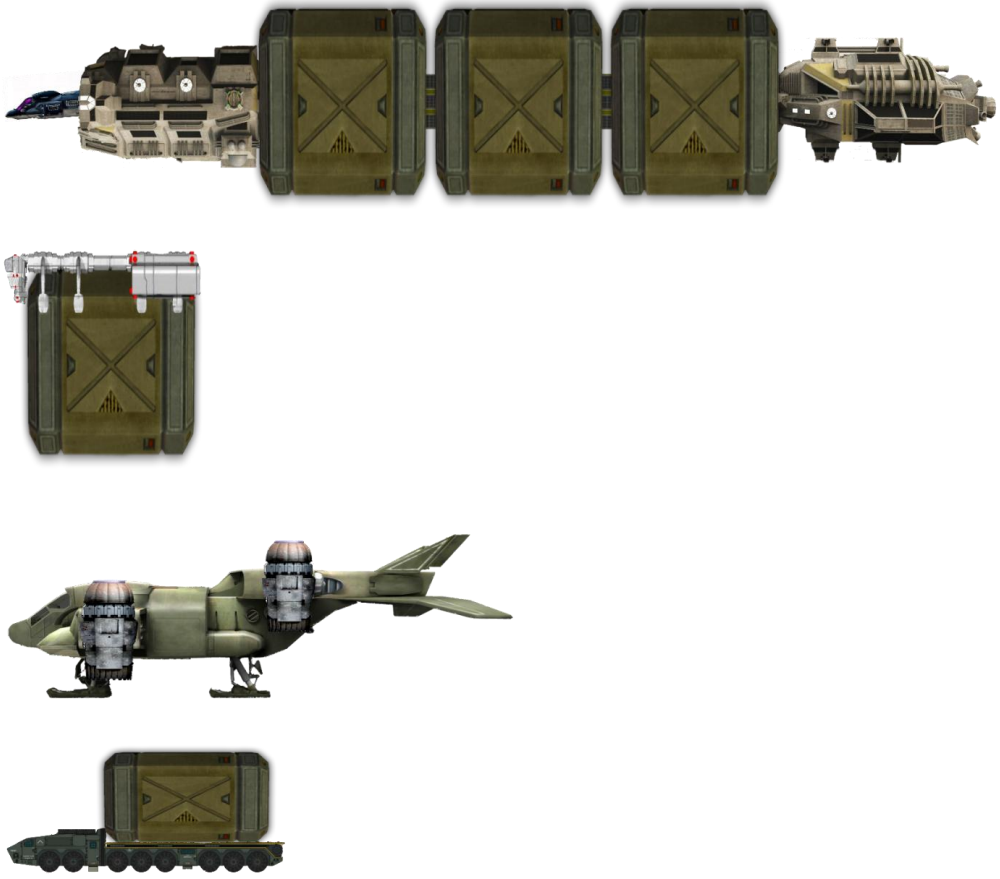


Transporting a single mini-stack pods (MSP) in the atmosphere requires more brute force than landing a mercenary frame or manoeuvring medium pods in space. Mercenary frames are light and aerodynamic in comparison and can be flown through the atmosphere. The orbital to ground shuttles in comparison are completely non aerodynamic. The weight burden of a MCP (equivalent to 200 standard cargo bays (SCB) fitted to a mercenary frame) is enormous. As a result they are fitted with engines that can swivel 180° . With the thrust facing forward they act as retro engines to brake and fall out of orbit. Changing the engines' angle to point down / forwards provides the main atmospheric braking to prevent the cargo pods being damaged by friction heating during the descent and to guide the *veetol* to its destination. Angled downwards they provide the vertical speed reduction and hovering capability required to land safely

- Once on the ground low bed load carriers move the ministacks as necessary

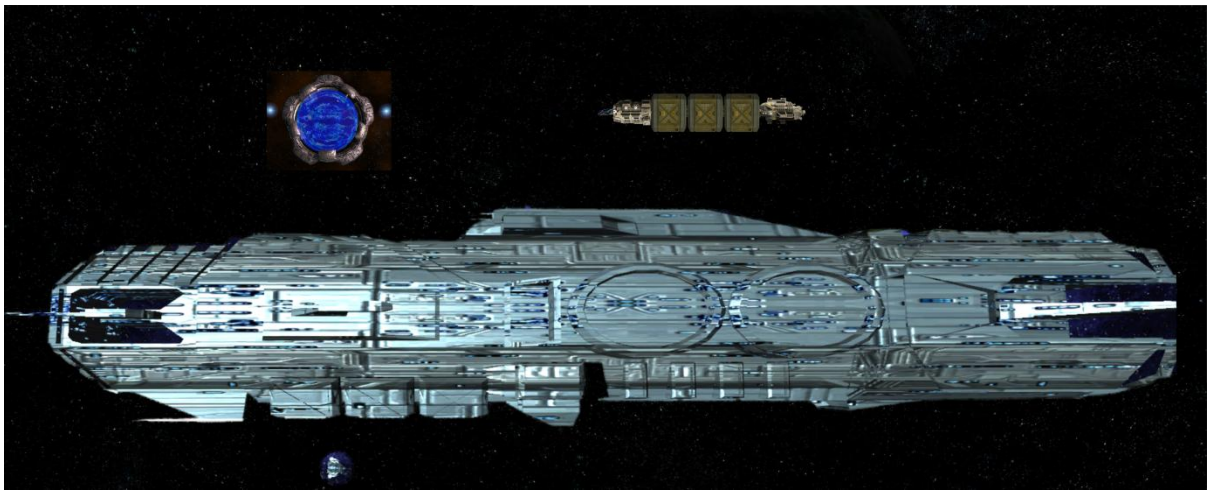


As can be seen in this size comparison chart, mass cargo transport is a big boys' toys enterprise.

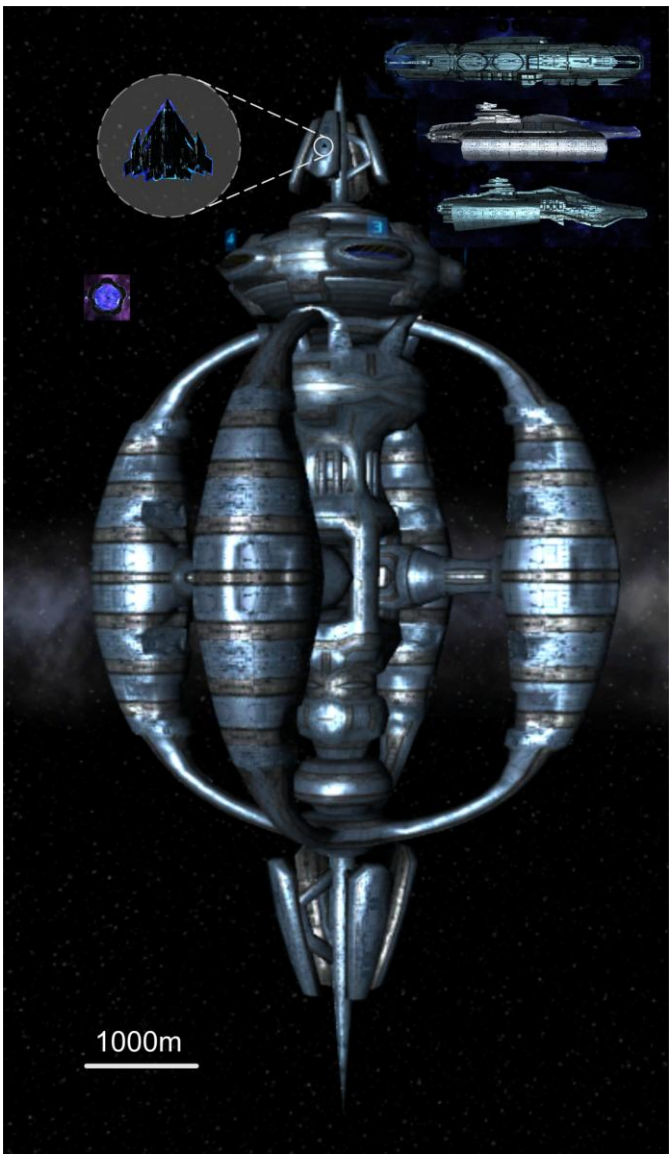


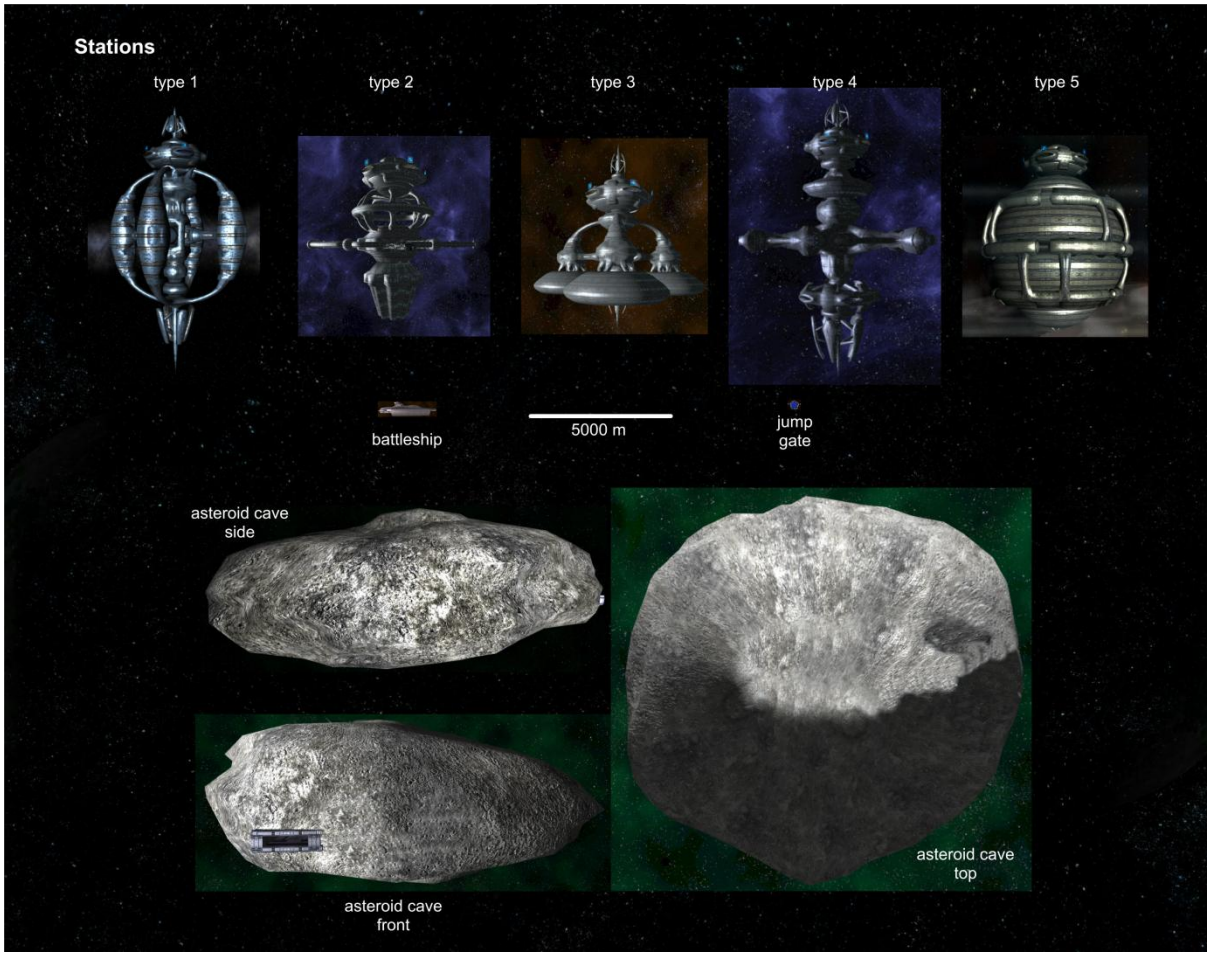
In comparison a person is about the size of a full stop !!

When a capital transport is added the true scale of cargo transportation becomes obvious. The small ship at the bottom is a Chimera



The final two scale comparison charts add stations and asteroid caves to the mixture.




Stations
type 1
type 2
type 3
type 4
type 5
battleship
5000 m
jump gate
asteroid cave side
asteroid cave front
asteroid cave top

Section 11: The Capital Ships of Evochron

Capital Ship in Evochron – Historical Context

The traditional role of the battleship was to fight with other battleships. They could also be used for shore bombardment. Consequently their main armament was the 'big gun'. For situations where a 380mm or 410mm gun was overkill, they carried secondary weapons – 150mm guns. These could be used for medium range defence and offence against attacks by destroyers and other smaller craft. Finally battleships were faced with an increasing number of more effective attacks by bomber and torpedo planes. As a result they were retrofitted with large numbers of relatively small, rapid firing antiaircraft guns in single, twin, quad and even octuple turrets. Typically these were 40mm and 20mm cannon and produced a wall of explosive steel between the ship and the attacking bombers/torpedo planes. As with all antiaircraft defence target spotting and aiming was visual.

Cruisers were designed to be faster and hence are smaller and lighter. Their main armament was designed to defend battleships and attack other cruisers, destroyers etc. A squadron of cruisers could take on a battleship but they were out ranged as well as outgunned. Cruiser secondary weapons (typically 100mm or 125mm") often double as part of their area suppression system which also included the relatively small, rapid firing 40mm and 20mm antiaircraft guns in single, twin, quad and octuple turrets.

Destroyers became more specialised as time went on but basically they carried a weapons loadout that suited their specific role. For attacks against larger ships they used 535mm torpedoes – the marine version of missiles. Their big guns (in single turrets) were either a trio of 75mm or a couple of 125mm. In the late 20th century they carried SA missiles and ASROC (which had developed from rocket assisted torpedoes) . They were fitted with between ten and twenty 20mm & 40mm cannon. If they had an antisubmarine role they carried depth charges

Evochron

In Evochron the roles of battleship and cruiser hare much the same as they have always been. New roles are Command ships and the super large destroyers we now use. The destroyers' main peacetime role is anti-pirate operations and support of civilian governments especially in outlying systems. In wartime their main role is the defend Command ships and battleships and cruisers in that order.

The antiaircraft guns have evolved into our **close-in weapon systems (CIWS)**, which are usually pronounced *C-whiz*. These point-defence weapons systems have dedicated AI control for detecting and destroying short-range incoming missiles and hostile fighters which have penetrated the outer defences.

Cruisers are also an important part of the command ship defence umbrella. As a result all capital warships carry weapons systems that let them firstly discourage enemy offensive capital ships from getting too close, secondly prevent enemy fighters from being able to mount large coordinated attacks on capital ships and finally destroy enemy missiles before they can hit their targets. They carry medium range missiles and a large number of whiz cannon (railgun and particle) as well as short range missiles. When flying in a coordinated squadrons destroyers can create a curtain of explosive steel to protect their capital ships.

Command ships and transports have to provide their own on their close-in protection during their peacetime roles but depend on other capitals ships in fleet combat.

What is the role of the Capital Ship in the Evoverse?

If we consider the enormous economic cost of building capital ships, economic constraints mean that there will only a few types of combat ships of this size. One obvious requirement would be for a ship with the capacity to destroy its enemy equivalents, fielded by both human navies and the Vonari; The can also be called on to destroy large orbiting and planetary targets – particularly defence platforms and fortresses. The modern battleship is well armed, shielded and armoured to deal with hostile warships quickly and effectively. In keeping with the general number one rule of space combat: "he who hits first, wins", Battleships are armed with weaponry and sensors able to fire first from long range and score a killer blow.

Given the number of populated systems in the Evoverse there is a role for a more versatile and less expensive capital ship with a slimmed down armament capability – for situations when a 'sledgehammer' isn't required. Enter the Cruiser. As in the past, there is a need for the Battleships and Cruisers to have a greatly enhanced close-in defence cover in very hostile circumstances, hence the third combat ship – the Destroyer. Finally because the Evoverse is a big place with many systems where opponents can hide, plot and gather and because the two human Navies are on perpetual alert against Vonari incursions or invasions, mobile Command, Control Communications & Intelligence Centres (C3I) – the Command ship is a vital part of peacekeeping and war preparation. It is dedicated to Intel Gathering & Interpretation, Fleet & Combatspace Coordination and Command & Control. With no heavy offensive weapons though a reasonable defensive capability it is even more dependent on Destroyer and Cruiser protection in major conflicts.

The design criteria and limitations of combat capital ships

The long semi official Civil War between the Alliance and the Federation lead to an arms race for space weapons. This, mirroring mid 20th Century naval history on Earth, lead to the design, development and construction of the first combat capital ships. The civil war formally ended with the Vonari attacks on Earth, though there is still some bad blood and suspicion between the two 'Governments'. However much was learned during the time they fought side by side against the Vonari. The level of Vonari technology taught some hard lessons;

- capital ships are needed in large quantities to cover the large number of core and uncharted systems in the Evoverse
- capital ships require strong offensive and defensive loadouts to counter the more developed technology of the Vonari
- creating and building capital ships of unique design and in sufficient number was and still is beyond the economic resources of either the Alliance or the Federation alone, particularly after the cost of the repelling the first Vonari invasion fleet and the losses incurred in the second attack.

As a result the Alliance and Federation agreed to use a common design for their capital ships. This allowed reduced research development and construction costs. It also allows the two fleets to integrate their ships more closely and to share crew expertise as necessary with minimum disruption and retraining of crews should further Vonari incursions occur. Many think that this is a 'when' rather than 'if' situation.

Furthermore it was agreed that the core shell of all military capital ship classes would be based around a common core frame. The difference between Command, Battleships, Cruisers and Destroyers is down to the equipment and weapons loadouts they carry – each tailored to its role in both the internal and external security needs.

Capital Transport Ships (CTS's), having a non combatant role, were designed to optimise their cargo carrying capacity. They require no heavy offensive armament, sufficient defensive systems to allow them to survive independently outside battlefield conditions. Their fleet support role requirement for enhanced defence is covered by Destroyer escorts with an added Cruiser screen if necessary.

As a consequence of this agreed philosophy only three basic combat capital ship external designs are commonly seen in the Evoverse.;

- the long winged ships – always under Navy authority
- the short winged ships – always under Navy authority
- the 'wingless' Transports – under Navy or Civilian Government control

Battleships require a heavy duty fusion energy generators and capacitor storage system to drive their shield generators and to recharge their heavy railguns as quickly as possible. Command ships have a vast array of energy hungry AI modules to handle the data mining, intel analysis and situation modelling they depend on. This quantity of processing power requires a large amount of energy.

Cruisers and Destroyers depend on the large number of smaller offensive weapons they carry and hence don't require as much space for capacitor banks and power generation. There is room required for the fighter squadrons they carry.

Data Table Notes:

1: In the following data tables

- CSC = Capital Ship Class
- SHE = Super High Energy
- ShRAPnel = Shield Reduction Armour Penetration warhead – the warhead breaks into multiple pieces on detonation making it more likely that the target will receive damage
- weapon types are identified in brackets : CSC(M) for example is **Missile Capital Ship Class. (R) = Railgun, (P) = Particle Cannon** (with the exception of shield arrays, Class 1 is better than Class 2. The most powerful ship borne shield arrays are Class 15)
- *CSC(M)2 systems are the largest ship borne missiles – C1 and C0 are restricted to asteroid and station based facilities
- *CSC(R)2 systems are the largest ship borne railguns – C1 and C0 are restricted to asteroid fortress, military HQ stations and Earth's Defensive Ring due to their extremely high power/current requirements
- the main range limiting factor for railguns is targeting accuracy. Even a capital ship at maximum range is a tiny target). In reality a railgun round will continue at a virtually unchanged velocity until it hits an object. Consequently the ranges quoted are for flight times of offensive railguns <0.02 sec and for slower defensive railguns < 2 sec

The Alliance and the Federation have developed their own versions of each weapon type, but the nature of their roles inevitably make them quite similar. The differences are the trade off between range, rate of fire and yield. There is also some differences in the exact number of each secondary weapon and point defence type deployed on ships'. ***The numbers given in the table are therefore typical.***

2: Civilian Government controlled Capital Transport Ships (CTS's) are the only civilian ships to be fitted with military specification shields and weapons. Eventually the Alliance and Federation Governments and Navies it was decided that in the event of major hostilities (Civil or Vonari incursion) 'civilian' CTS's would be immediately commandeered by the Military Authorities and therefore there would not be sufficient time to upgrade weapons and shield arrays to military specifications. It is for this reason that civilians industries nor ultra rich individuals are not allowed to buy or control CTS's, though they can hire space in them if the ships have surplus capacity. Many if not most do and for most of the time.

Equipment Loadouts for Capital ships

Table 1: Capital Ship Primary, Secondary and Point Defence Weapons

Class For railgun: round mass in kg – size of cylinder in cm	Name Alliance/ Federation	Range (metres)	Yield (equivalent tonnes TNT)	Rate of Fire /recharge time
CSC(M)2 Long Range Missile Type: Matter/antimatter SHE Warheads	Hurricane / Thor	30 000	5 000	5RPHr 10 mins reload time
CSC(M)3 Medium Range Missile Type: matter/antimatter SHE Warheads	Typhoon / Freya	15 000	2 000	15RPHr 4 mins reload time
CSC(M)5 - Point Defence Missile Type: matter/antimatter SHRAPNEL Warheads	Tsunami / Erebus	7 500	500	4 rounds / min 15 sec reload time
CSC(M)6 - Point Defence missile Type: matter/antimatter SHRAPNEL Warheads	Lightning/ Fury	4 000	50	4 rounds / min 15 sec reload time
CSC(R)2 Railgun Type: $100x10^6$ MJ Round: 90kg @ $1.5x10^6$ m/s = 0.5% SoL / 10x65cm	Cyclone / Mars	30 000 flight time - 0.02 sec	24 000	4RPM 15 mins reload time
CSC(R)3 Railgun Type: $30x10^6$ MJ Round: 75kg @ $0.9x10^6$ m/s = 0.3% SoL / 10x55cm	Icestorm / Ares	15 000 flight time - 0.01 sec	7 300	7.5RMP 8 mins reload time
CSC(R)6 Railgun Type: $3x10^6$ MJ Round: 67kg @ $0.3x10^6$ m/s = 0.3% SoL/ 10x50cm	Tornado / Horus	5 000 flight time - 0.02 sec	700	20RPM 3 mins reload time
CSC(R)9 Point Defence Railgun Type: 16 MJ Round: 5kg @ 2500 m/s - 5x15cm	Blizzard / Deimos	6 000 flight time - 2.4 sec	37 kg TNT equiv	60RPM
CSC(R)10 Point Defence Railgun Type: 6 MJ Round: 2kg @ 2 000 m/s= 3x15cm	Hailstorm / Phobos	4 000 flight time - 2 sec	10 kg TNT equiv	180RPM
CSC(P)5 - Point Defence Particle Cannon output 4 000MJ /s	Wildfire / Woden	2 500	1	continuous
CSC(P)6 - Point Defence Particle Cannon output 2 000MJ /s	Monsoon / Valkyrie	1 500	0.5	continuous

Table 2: Capital Ship Weapons by ship type

Battleship	CSC1 shield array network
Primary Weapons - Missiles	2 x CSC(M)2 Hurricane/Thor quad missile launch tubes
Primary Weapons - Railguns	3 x CSC(R)2 Cyclone/Mars railguns
Secondary Weapons - Missiles	CSC(M)3 Typhoon / Freya quad missile launch tubes
Secondary Weapons - Railguns	2 x CSC(R)6 Tornado/ Horus railguns
	CSC15 shield array network
Area Defence - Missile	6 x CSC(M)5 Tsunami/Erebus seven missile-launch tubes (Σ = 42) 7 x CSC(M)6 Lightning/Fury twin twelve missile-launch tubes (Σ = 168)
Area Defence - Cannon	50 x CSC(P)6 Monsoon/Valkyrie turreted twin particle cannon 150 x CSC(R)10 Hailstorm/ Phobos Twin railgun cannon
Area defence / interdiction	16 ship wing of Evoch-E Fighters
Cruiser	
Primary Weapons - Missiles	2 x CSC(M)3 Typhoon/Freya missile Quad-launch tubes
Primary Weapons - Railguns	1 x CSC(R)3 Icestorm/Ares railgun
Secondary Weapons - Railguns	1 x CSC(R)6 Tornado/ Horus railguns
	CSC12 shield array network
Area Defence - Missile	15 x CSC(M)5 Tsunami/Erebus seven missile -launch tubes (Σ = 105) 8 x CSC(M)6 Lightning/Fury twin twelve missile -launch tubes (Σ = 192)
Area Defence - Cannon	75 x CSC(P)6 Monsoon/Valkyrie turreted twin particle cannon 150 x CSC(R)10 Hailstorm/ Phobos Twin railgun cannon
Area defence / interdiction	8 ship wing of Evoch-E Fighters
Destroyer	
Primary Weapons - Missiles	2 x CSC(M)3 Typhoon/Freya missile Quad-launch tubes
Primary Weapons - Railguns	1 x CSC(R)6 Tornado/ Horus railguns
Secondary Weapons	none
	CSC13 shield array network
Area Defence - Missiles	12 x CSC(M)5 Tsunami/Erebus seven missile -launch tubes (Σ = 84) 8 x CSC(M)6 Lightning/Fury twin twelve missile -launch tubes (Σ = 192)
Area Defence - Cannon	75 x CSC(P)6 Monsoon/Valkyrie turreted quad particle cannon 250 x CSC(R)10 Hailstorm/ Phobos Quad railgun cannon
Area defence / interdiction	8 ship wing of Evoch-E Fighters
Command	
Primary Weapons	none
Secondary Weapons	none
	CSC15 shield array network
Area Defence - Missiles	12 x CSC(M)5 Tsunami/Erebus seven missile -launch tubes (Σ = 84) 8 x CSC(M)6 Lightning/Fury twin twelve missile -launch tubes (Σ = 192)
Area Defence - Cannon	50 x CSC(P)6 Monsoon/Valkyrie turreted quad particle cannon 180 x CSC(R)9 Blizzard/ Deimos quad railguns
Area defence / Recce	4 ship wing of Evoch-E Fighters

Table 2: continued

Transport	
Mil/Civ: Primary Weapons	none
Mil/Civ: Secondary Weapons	none
Military Version:	CSC6 shield array network
Area Defence - Missiles	12 x CSC(M)5 Tsunami/Erebus seven missile -launch tubes (Σ =84) 8 x CSC(M)6 Lightning/Fury twin twelve missile -launch tubes (Σ = 192)
Area Defence - Cannon	50 x CSC(P)6 Monsoon/Valkyrie turreted quad particle cannon 180 x CSC(R)9 Blizzard/ Deimos quad railguns
Civilian Version:	CSC5 shield array
Area Defence - Missiles	6 x CSC(M)5 Tsunami/Erebus seven missile -launch tubes (Σ = 42) 5 x CSC(M)6 Lightning/Fury twin twelve missile -launch tubes (Σ = 120)
Area Defence - Cannon	50 x CSC(P)6 Monsoon/Valkyrie turreted quad particle cannon 120 x CSC(R)9 Blizzard/ Deimos quad railguns

These weapon loadouts clearly reflect the roles of the different capital ships;

The battleship is the sledgehammer carrying three of the biggest ship mounted railguns ever produced. These are codenamed Cyclone and Mars by the Alliance and Federation respectively. A single round hit in optimal conditions is sufficient to cripple or destroy another capital ship. One or two hits will cripple and three hits destroy a Vonari capital ship. Battleships are also equipped with the largest ship borne missile systems (codenamed: Hurricane and Thor) and the smaller missiles (Typhoon and Freya) for when the bigger weapons would be overkill. Both battleships and cruisers are fitted with the medium sized Tornado / Horus railguns as their secondary weapons.

In terms of defence battleships have the highest class shield system, but their point defence loadout is less powerful than a Destroyer. In situations other than war a battleship can defend itself against any mercenary or pirate group with its CAP and close-in defensive cannon and missiles. In war it acts as the attacking spear tip of a fleet – the destroyers and cruisers provide its close defence.

Offensively, cruisers are scaled down battleships reflecting their greater numbers and main peacetime role of general patrolling and supporting civilian governments against pirates. Their main offensive rail guns (Icestorm/Ares) require multiple shots to take out a battleship or another cruiser, but under these circumstances they hunt and attack in coordinated packs. The skill in battle is to coordinate the hits against enemy capital ships efficiently so that they can achieve multiple hits quickly and ideally simultaneously.

Cruiser shield arrays are less powerful than a battleship, reflecting the pack nature of their warfare tactics. Their defence screen is better, reflecting their need to defend themselves in peacetime and provide defensive screening for other capital ships in war.

As mentioned above, destroyers are a serious threat to pirate incursions but their main role is as mobile defence screens in major combats. They are equipped with shield arrays almost as strong as a battleship to protect them whilst they place themselves between the main fleet and the enemy's fleet.

Command ships have a strong defensive loadout and strong shields. They are protected by all other ships in the fleet since they are the brains of the fleet.

Transports have reasonable defensive screens. Their shields are adequate for peacetime, though the military capital transports are better equipped than civilian ones. In war the military specced transports provide front line fleet support whilst the less powerful civilian ships provide back support. Both types depend strongly on escort ships to keep them safe in battlefield conditions.

Capital ship primary weapons – Part I - Railguns.

Note: *Although the naval gauss (electromagnetic) class of cannon are universally known as 'railguns' they are in fact 'coilguns'. Coil guns are far more efficient and have much less wear inflicted in the barrel meaning for a given size they can either deliver a higher yield per round or more rapid rate of fire with a longer barrel lifespan.*

The operation principle of a coilgun is that the cannon fires a 'massive' (that is high mass) metal projectile using a linear system of magnetic fields coils arranged along the gun barrel. The very high current is coordinated to create attractive/repulsive magnetic fields increasing the projectile's velocity until it carries an incredibly high amount of kinetic energy. Ship-based primary and secondary railguns use an iron/tungsten round. The tungsten provides mass at a reasonable size and the iron provides the magnetic susceptibility needed for the cannon to function. The high muzzle speed gives the slug the kinetic energy and momentum necessary to damage a target and partially mitigates the unguided nature of the slug and its lack of manoeuvrability. The time of flight even at maximum range is a fraction of a second. Kinetic energy is described mathematically as mass x (velocity)^2. This means that increasing the round velocity is far more effective than using a more massive round – doubling the mass doubles the energy but doubling the velocity increases the energy four times. Hence the larger railguns use relatively small masses at extremely high speeds. Close-in defence guns however are optimised for their kinetic shaking effect on smaller ships as well as their ability to deplete shield energy and damage ship armour and hulls. If their rounds travelled too quickly they would punch straight through a small fighter, doing relatively little damage. Hence, relatively speaking, they utilise high mass – low velocity; relatively in that the rounds travel at 2 000 – 2 500 m/s

Mounting

The size of primary and secondary railguns is such that it is an integral component of a warship's structure along the length of the capital ship. As described by Newton's laws, the force imparted on the round has an equivalent reaction force on the railgun, requiring strong, extensive mountings to prevent the railgun tearing loose. Aiming is primarily done by orientating the ship toward the target.

For long range shooting, up to ½° of adjustment from the centreline can be made by adjusting the orientation of the barrel within its mount. Shipboard railguns require an AI to aim the cannon, as the projectiles are unguided and are extremely hard to aim by manual fire.

Firing

The firing process uses electromagnetism to eject the ferromagnetic-tungsten round at high velocity. An extremely large current is put through the first Solenoid (coil of conducting wire). This creates a strong magnetic field which attracts the metal round. As it passes through the solenoid, the solenoid current is quickly reversed and the second solenoid, which is further along the barrel, is activated, attracting the now high velocity metal round just like the first solenoid did whilst the first solenoid now repels the round. The first solenoid is now switched off and a cooling cycle started – the second solenoid reverse and the third is activated. This sequential process is repeated along the barrel of the cannon. By the time the round leaves the barrel it has accelerated to a speed that is a significant % of the SoL. Regardless of distance the velocity of the round doesn't decrease – there is virtually no friction in the vacuum.

Ship borne railguns draw power from specially designed fusion power units that store charge in mega-capacitors. The coils can drain charge from these capacitors at a very high current creating the necessary massive acceleration in a very short time and distance.

It takes three shots from a CSC(R)2 hitting the shields perpendicularly to fully deplete the shields of a Vonari Battleship and destroy it, hence the triple mount of the battleship. The time it takes to bring the CSC(R)2 railguns systems to full charge is the deciding factor in the tactics employed in a conflict. Barrel cooling is significantly quicker than energy recharge. While a ship may not run out of ammunition (given the small physical size of the rounds), the Captain has to carefully evaluate the analysis of the battle situation and use shots strategically. Although the weapon can be fired even when not at full charge, the velocity and hence energy of the projectile is greatly diminished. In reality three simultaneous hits at the right angle is hard to achieve - the ideal tactic involves a coordinated attack by multiple battleships against a single target - again reminiscent of 'big ship' battle tactics used since the dawn of ‘big ship’ naval combat.

Primary and secondary class capital ship railguns

Battleships are equipped with three primary railguns and two smaller secondary railguns. A cruiser carries a single primary and single secondary railgun. Destroyers are designed to proved protection for battleships and cruisers in engagements Hence are equipped with a large array of turret mounted close-in defence cannon and missiles as well as a mix of primary weapons. Destroyers are capable of ‘distracting’ the enemy battleships and cruisers by being able to inflict significant, though non-lethal, damage. Their primary rail gun is the same class as the cruiser’s secondary. They are well equipped to destroy large formations of hostile fighters with their extensive arrays of close defence cannon and missiles

The Alliance Ship ***'Grim Reaper***' is reputed to carry four CSC(R)2 Cyclone railguns, most likely the most ever sported on a human ship. The ***Reaper*** is capable, in ideal circumstances, of taking down a Vonari battleship single-handed with a single salvo even with non-optimal hits.

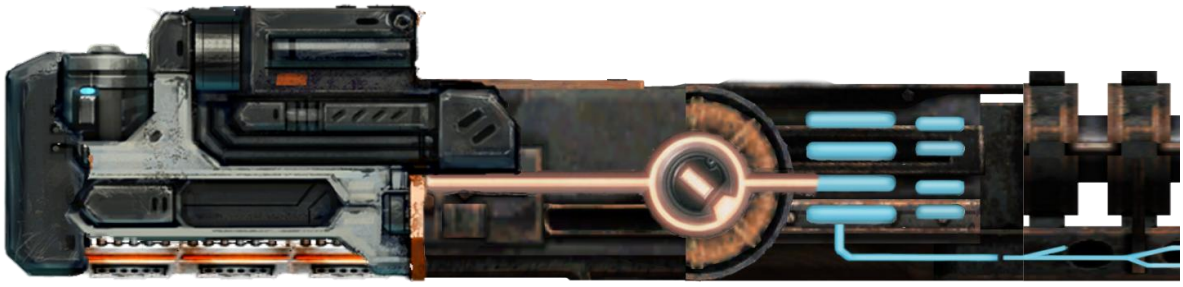
The railgun design balances the power stresses on the barrel against the current flowing through the coils. The Class 2 railgun is the minimal size for the coils to handle the current flow given the need to accelerate a large mass to such a high speed. The barrel has to withstand the radial magnetic force generated by the current.

The Class 3 & 6 railguns require fewer coils to achieve the required velocities. The use of the same design means that it is possible to use common ‘spare parts’ for the two. The class 6 railgun requires much less maintenance since it’s coils, barrel and mounting is operated at significantly lower stresses. However, it can be ‘swapped out’ to work as a Class 3 simply by mounting it in the more reinforced mountings of the Cruiser.

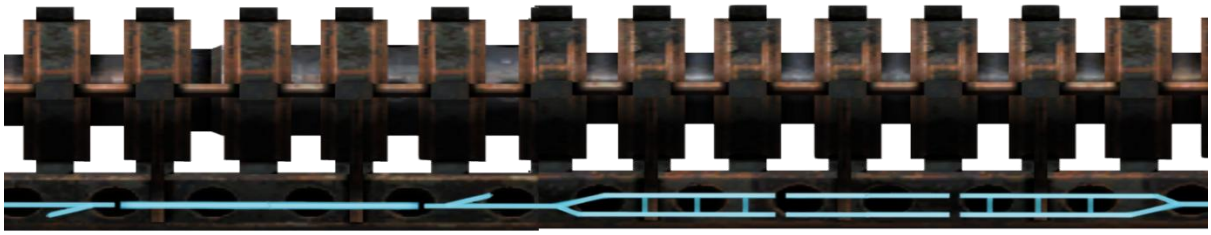
CSC(R)2 – Cyclone / Mars (total length: 1162m)

CCS(R)3 - Icestorm / Ares & CSC(R)6 Tornado / Horus (total length: 791m)

breech and energy distribution



section of coils



barrel tip showing size reduction – offline (retracted) and firing position

Note. To reduce friction the round is held in the centre of the barrel by super conducting magnets The tip bore diameter is significantly larger than the round diameter. When offline the tip of the railgun is retracted and is inside the ship, covered by a protective door

Railgun rounds & stats

Class	CSC(R)2	CSC(R)3	CSC(R)6	CSC(R)9	CSC(R)10
Kinetic Energy (MJ)	$100x10^6$	$30x10^6$	$3x10^6$	16	6
Mass (kg)	90	75	67	5	2
Velocity (m/s)	$1.5x10^6$	$0.9x10^6$	$0.3x10^6$	2 500	2 000
Size (cm)	10x65	10x55	10x50	5x15	3x15
Yield (equiv T TNT)	24 000	7 300	700	4	

Because they are used in a vacuum, the rounds do not have to be streamlined. When used for ground bombardment they are not in the atmosphere long enough to heat up sufficiently to melt. The flattened slightly dished tip is designed to cause the round to spread during the microseconds of impact. This is an idea copied from 'jacketed hollow point' ammunition from the twentieth century. This increases the transfer of the kinetic energy to the target, causing more damage, and inhibits the tendency for such fast projectiles to punch a small, neat hole through the target.

Because they are the same diameter Class 2, 3 & 6 rounds can be used in any of the railguns. Class 9 & 10 are not interchangeable.

Class 1 Railguns

There has only been one Orbital Defence Platform (ODP) built - the Defensive Ring (ODR!) around Earth in the Sol system. As well as a mixture of Class 2 and 3 railguns - being the equivalent of its close-in defence weapons - it also carries a number of larger and more powerful versions of the standard railgun nicknamed "the big stick"

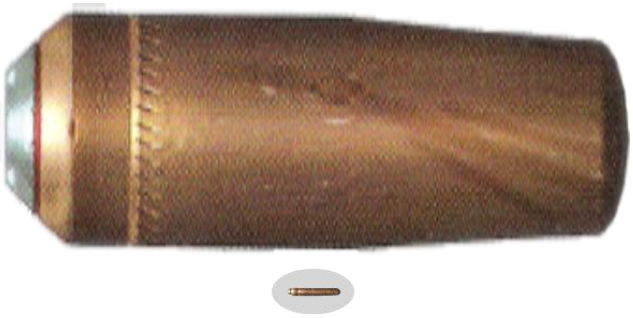
These cannons fire a 1000-ton ferric-tungsten round at 3,000 kilometres per second, or 1% of the speed of light, impacting with a massive amount of kinetic energy. The rounds are cylindrical, 3 metres in diameter and around 7.5 metres long.

According to the formula for kinetic energy, $KE = 0.5 * m * v^2$, the force of each shot will be;

$0.5 * 1\,000\,000 * 3\,000\,000^2 = 4.5 \times 10^{10}$ MJ

Given that a kiloton = 4 184 000 000 000 J (4.2×10^6 MJ), then each shot produces the equivalent of 11 MT of TNT – 700x the power of the first atomic bomb used in the 20th Century.

This picture shows the relative size of the ODPC(R)1 railgun round compared to a CSC(R)2 round - the largest carried by battleships.



Class	OPDC(R)1
Kinetic Energy (MJ)	4.5×10^{10}
Mass (kg)	1×10^6
Velocity (m/s)	3×10^5
Size (m)	3x7.5

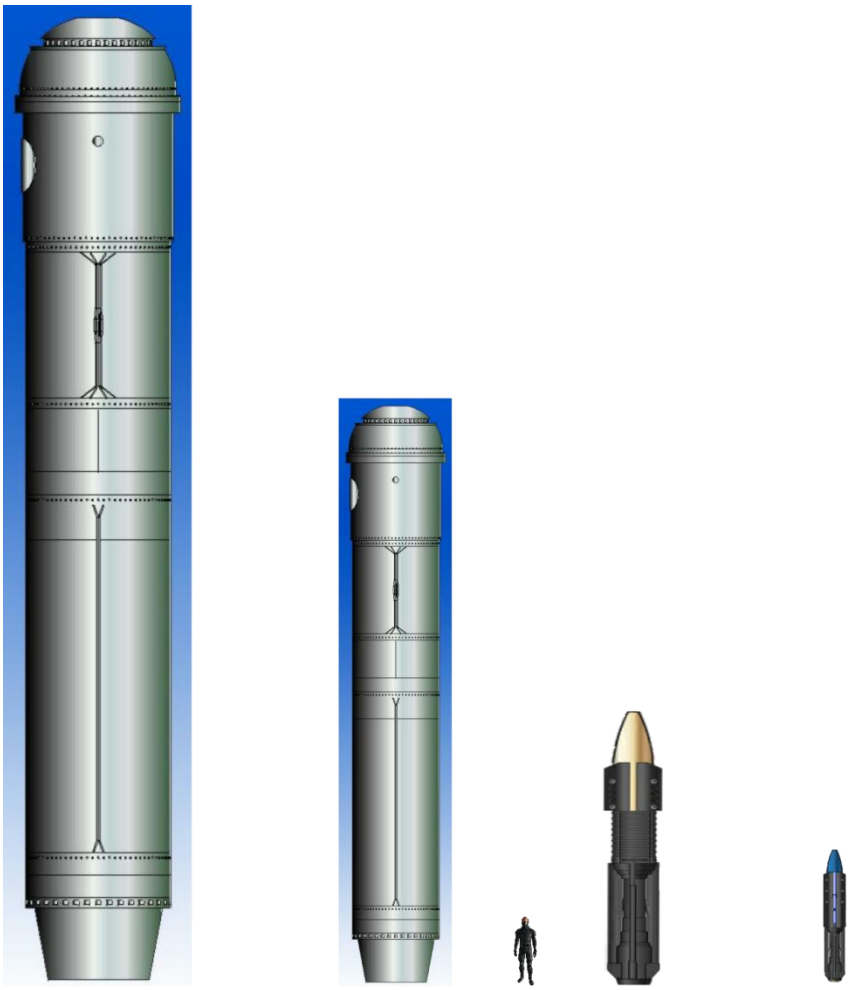
The Defensive Ring's sole role was to defend Earth against Vonari attacks. Against Vonari shield technology, the rounds possess enough kinetic energy to punch through shields, cut through a battleship, and a second battleship behind it and upon exit, still retain enough energy to cripple a third. Given the unlikelihood of such a fortuitous alignment of gun and targets the real advantage is that it is likely to remain a single hit Vonari capital ship killer for a the foreseeable future.

It is theorized that if a ship's armour or shields were to absorb all the kinetic energy of one of these rounds, the release of thermodynamic energy would still vaporize the ship. By receiving power from an enormous array of fusion reactors distributed around the ring, the ODR can achieve a phenomenally rapid recharge and reload times as short as 30 seconds if the energy can be channelled to a limited sector under attack.

Such a complex defence system requires significant AI control to provide its command and control. It is therefore possibly predictable that in the aftermath of the second Vonari attack on Earth, the damage inflicted on the ring might affect the AI. The resultant malfunction means that the AI considers ***any*** ship approaching Earth to be hostile. Warning are given and any ship that ignores them and continues its approach towards Earth is destroyed using the close-in defence weapons. In terms of landing on Earth, many have tried but very few have succeeded. The AI allows unhindered passage away from Earth and as a result of the almost self imposed blockade and its impact on the Earth economy most of the population has left and spread through the Evoverse.

Capital ship primary weapons – Part II - Missile Systems

- SHE = Super High Energy
- ShRAPnel = Shield Reduction Armour Penetration warhead – the warhead breaks into multiple pieces on detonation making it more likely that the target will receive damage



Class	CSC(M)2	CSC(M)3	CSC(M)5	CSC(M)6
Range (metres)	30 000	15 000	7 500	4 000
Yield (equiv t tnt)	5 000	2 000	500	50
Warhead Type	m-am SHE	m-am SHE	m-am SHRAPNEL	m-am SHRAPNEL
Reload Time	10 mins	4 mins	15 sec	15 sec
Max rate of fire	5/min	15/min	28/mount/min	96/mount/min

Close-in Defence Missile Systems

CSC(M)5 mount

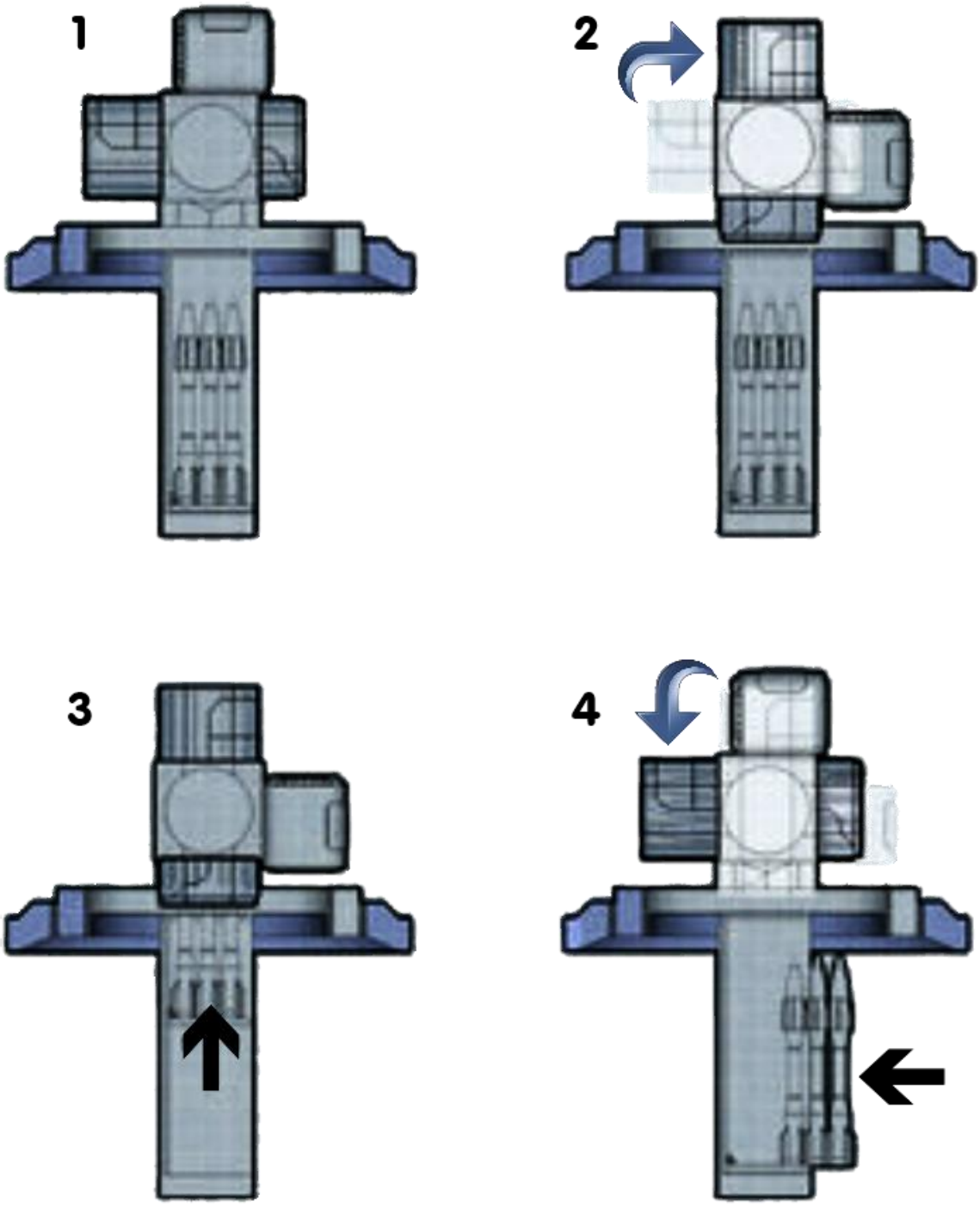
CSC(M)6 mount

Activation Sequence for CSC(M)6 mounts

CSC(M)5 mounts operate in a similar way. When not in use the missile pods are retracted within the hull. When required, the hatch opens and the missile pod is raised and locked. Since the pod protrudes beyond the diameter of the hatch it is stored pointing vertically downwards. When it is above the hull level it rotated upwards The pod then rotates upwards and around to its firing position. The pod mounting is capable of turning 360° and its elevation is between -5° and 90°, allowing it to track targets in its full range of sight.

After the missile salvo is launched the pod enters a reload sequence. Original designs required the pod to retract below the hull to reload but later (faster) modifications simply require that the pod orientate itself to point face forward and then rotate upwards to vertical. A new load of missiles is then pushed into the rear of the pod and primed. Reload times have been reduced to around 15-20 seconds allowing three to four salvoes of missiles to be launched per minute per mount – 28 Class 5 and 96 Class 6 missiles per mount respectively

Reload sequence

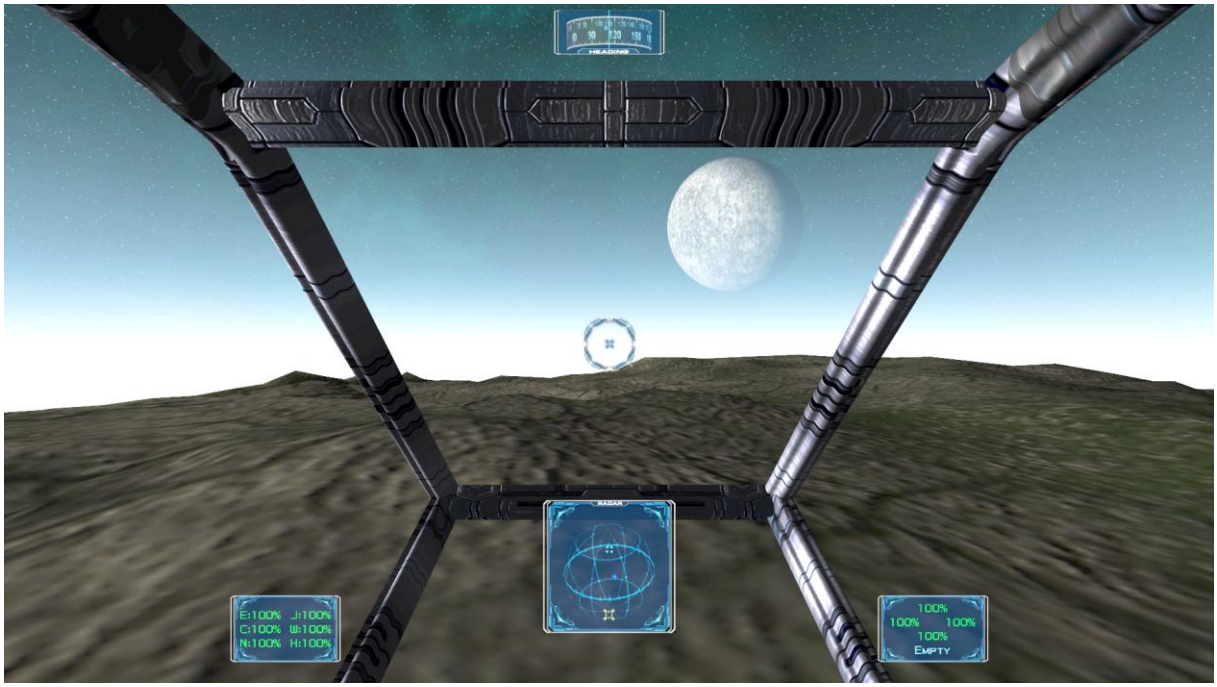


The quad railgun and quad particle cannon turrets are designed in a similar way; when orientated upwards perpendicular to the hull they are slim enough to be retracted into the hull. A protective hatch plate slides across to fill the hole. Reloading is continuous – energy supply and barrel cooling are the limiting factors for rate of fire.

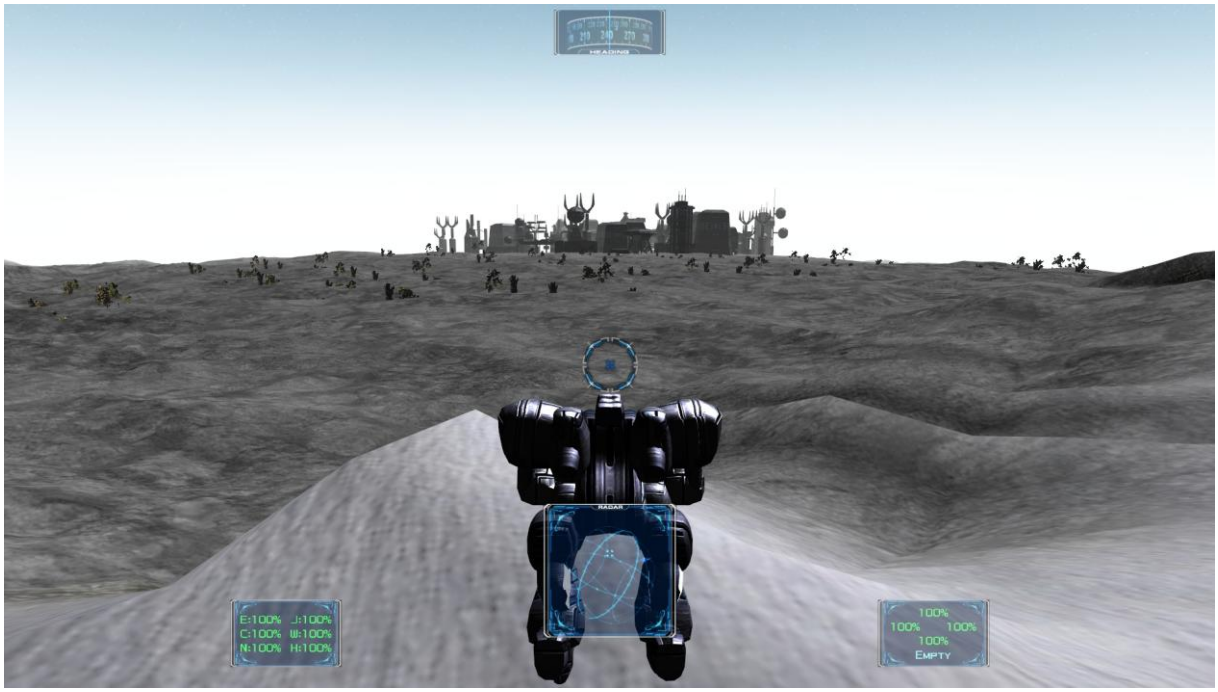
Section 12: Miscellaneous Technologies

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.

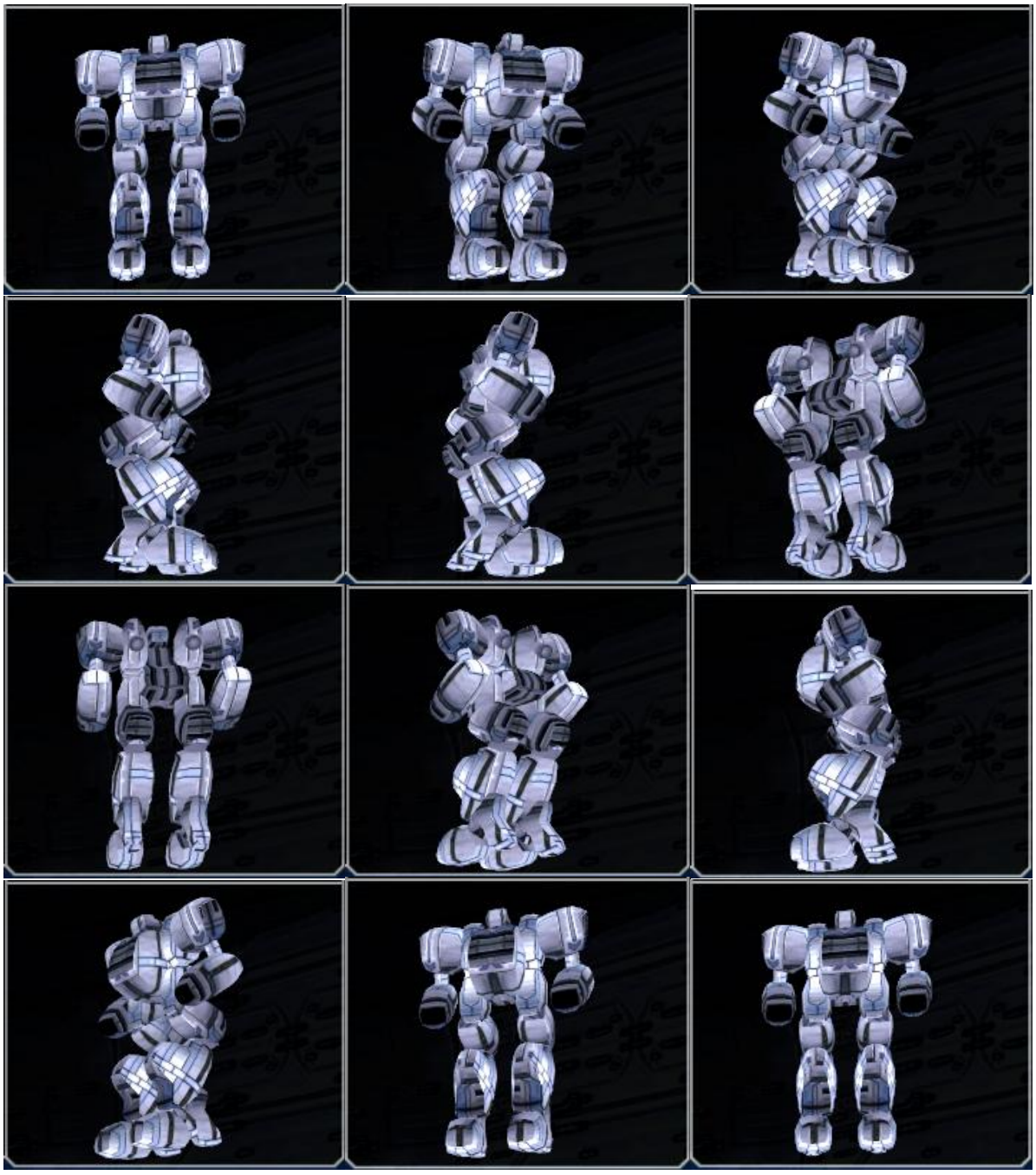
TW's are capable of functioning underwater - an enhanced image mode automatically cuts in when you enter a sea or a lake similar to ship carried units used in asteroid caves

At present TW's are not capable of accepting upgrades.

Terrain Walkers are equipped as standard with;

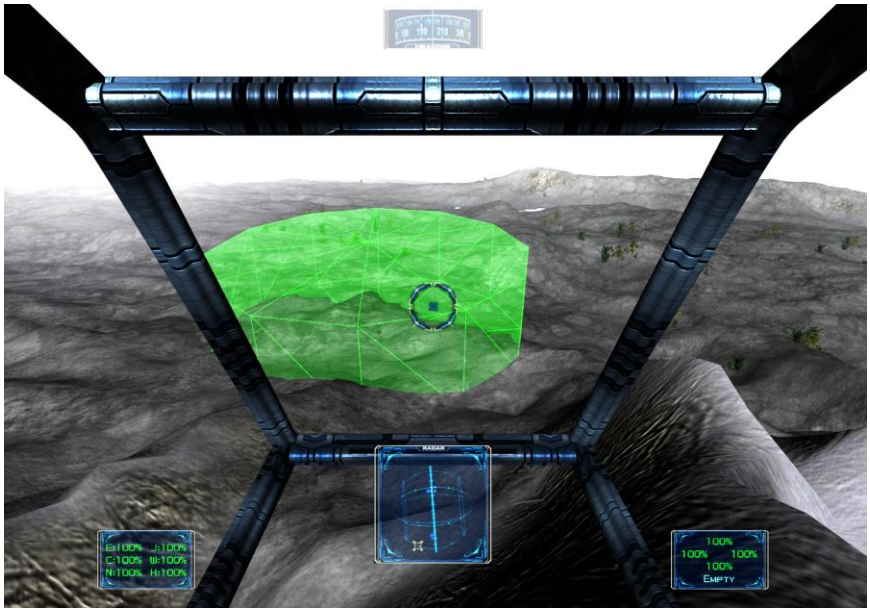
- shields (like a ship) - four projectors cover front, rear, left and right
- a pair of particle cannon of a higher spec than the best off-the-shelf cannon available from trade stations, carriers etc
- short range jump jets enabling fly in short bursts. They can provide a quick escape and a way to quickly 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;

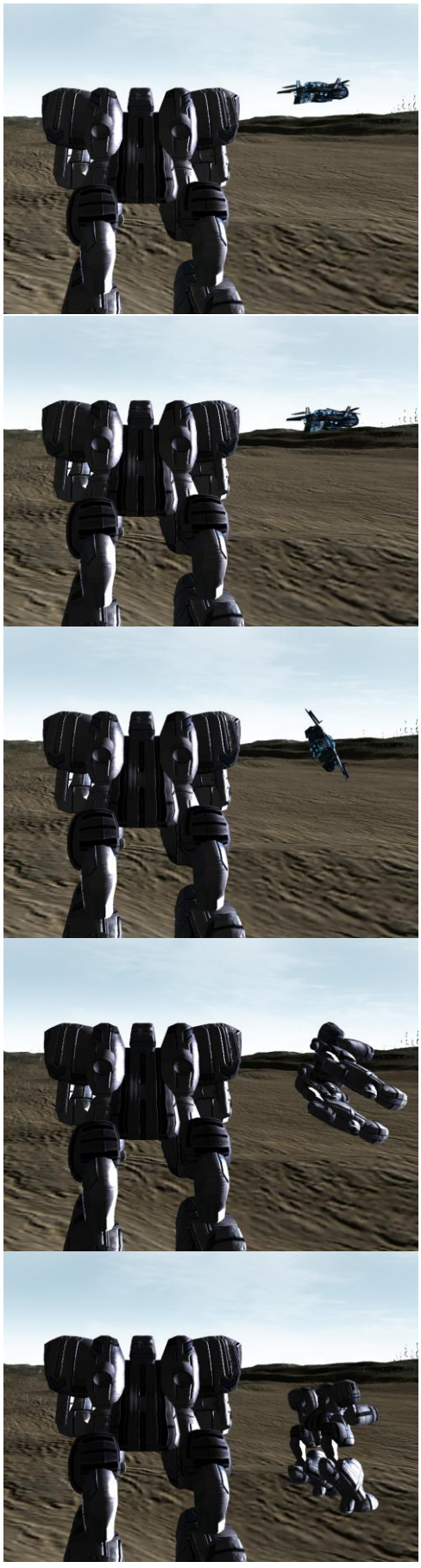
Engine damage level (%)	Jump Jet energy level (%)
Cannon damage level (%)	Cannon energy level (%)
Navigation System damage level (%)	Hull damage level (%)

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 compiles 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)

	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.
	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.
	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.
	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.
	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.
	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.
	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.
	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.

	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.
	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.

Appendix 2: Ship Frames (Civilian - Federation)

	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.
	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.
	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.
	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.
	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.
	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.

	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.
	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.
	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.
	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.

Appendix 3: Ship Frames (Military)

	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.
	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.
	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.
	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.
	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.
	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.
	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.
	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.

	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.
	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.
	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.
	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.

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.

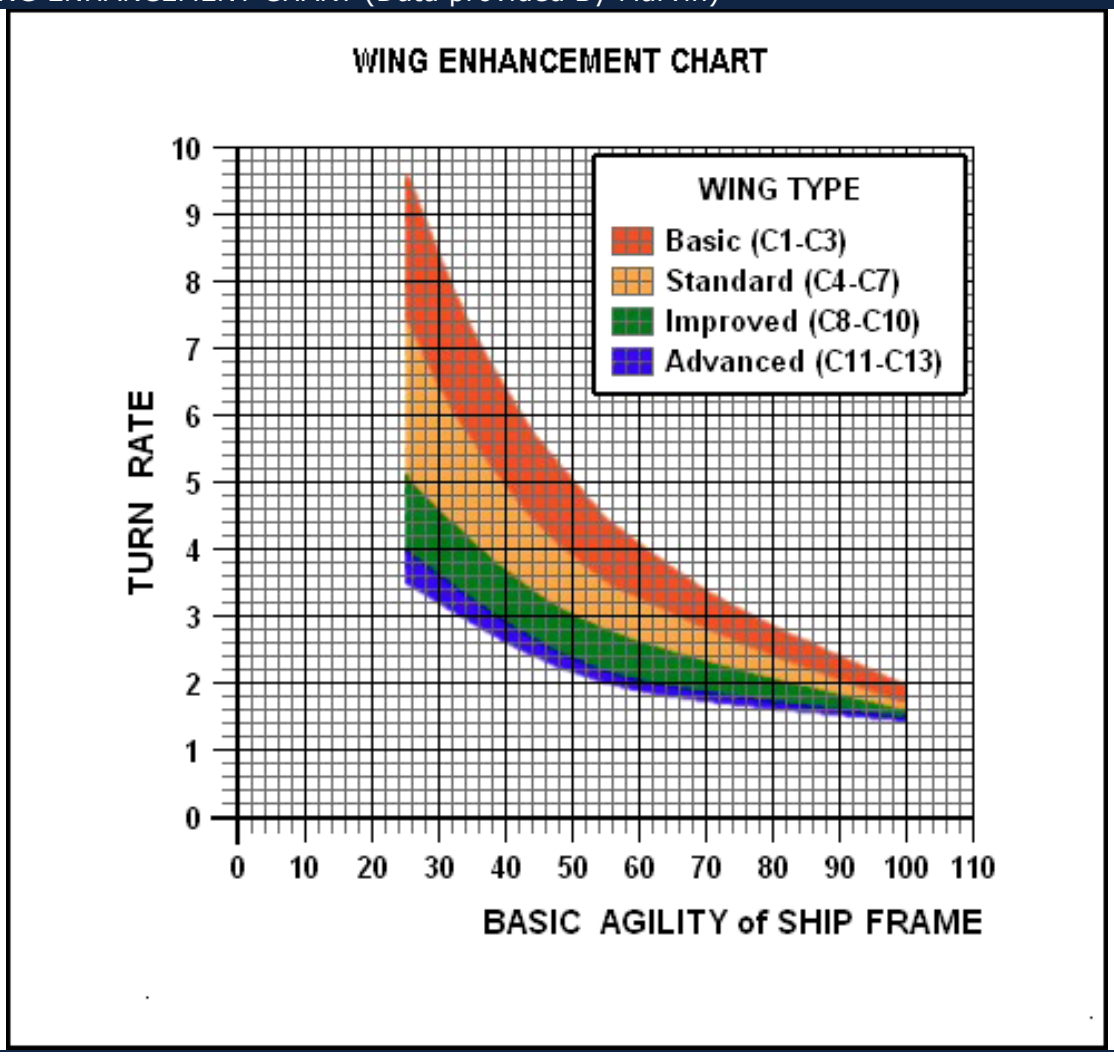
Wing Class 11 (assembly points: 150) The *NightHawk Mark I* wing may look very small in comparison to other wing designs, but it features a revolutionary advancement previously only used in military applications. Mounted on each wing is an anti-gravity pod that is used to generate additional power and 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.

WING ENHANCEMENT CHART (Data provided By Marvin)



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
* *The range of a beam weapon is linked to its particle weapon counterpart.*			

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	
	Aries	-3500	2000	
	Cygnus	-1700	1250	
	Merak	-2000	2500	
	Sierra	-2200	3500	
	SWZ	-2200	3800	
	Talison	100	2000	
	TWZ	100	2550	border
	Fauston	-500	800	
	Talison	100	2000	
NE	CWZ	2420	2500	
	Atlas	1000	1500	
	Cerulean	2400	2100	
	Olympus Prime	1250	500	
	Onyx	3500	1000	
	Sapphire	0	0	border
SW	Emerald	-3200	-550	
	Iota	-2500	-1500	
	Lambda	-1250	-400	
	Orion	-1000	-2400	
	Rigel	-3200	-2500	
	Sirius	-2300	-3700	
	Thuban	0	-500	border
SE	Alpha Centauri	1300	-3700	
	Aquila	1400	-2700	
	AWZ(Pearl)	3500	-1500	
	Capella	2000	-1000	
	Deneb	3500	-3500	
	Pearl	3500	-1800	
	Pices	1800	-300	
	Rucker	1800	-2000	
	Vega	500	-2200	
	Virgo	700	-1250	
Misc	Andromeda	2000	28000	
	Lost Rucker	5500	-1000	
	Riftspace	7000	9500	
	Sol	-1050	-5050	
	Vonari	1000	5000	
	Wolfzone	5550	5550	

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 favour 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: Why the Evoverse is as it is. (brief summary)

Support for the idea that Earth is unique in the Universe has ebbed and flowed throughout human history. The sequence of arguments started with the belief that Earth (and everything else) was created by a God or gods for humankind to rule and abuse as it wished. A parallel argument kept the god(s) and 'human rule' aspects but gave humans a 'stewardship' role. The development of world-wide economic markets and a world government, strongly influenced by the military/industrial complex, eventually ditched the god(s) part and bent the stewardship role to justify the unrestrained extraction of resources as quickly and cheaply as possible, despite the obvious damage being done to the biosphere.

Scientists and philosophers asked themselves about how unique life and intelligence was in the Universe – the 'Are we alone?' question. Scientific developments argued for the uniqueness of Earth (see 'The Uniqueness of Earth') below. A science based view for the reality of a solar system with a central star and orbiting planets started with Galileo and reached fruition with Copernicus. Further theoretical and practical scientific developments and discoveries swung back in favour of 'Unique Earth' again. Then in the late 20th Century the discovery of extra-solar planets and the overwhelming evidence that they were in fact very common shifted ideas towards a '(Fairly) Unique Earth' view. Due to limits of the search technology most of the earliest discoveries were gas giants, but a substantial number of smaller rocky planets knocked Earth off its 'unique' pedestal.

It was theory that the evolution of complex life and intelligence it is due to a series of interlinked factors, all of which are necessary (and rare) was well supported by detailed modelling. For Earth to be friendly to complex life there were several fundamental requirements. The following is a partial list, though it includes the major players:

1. orbital Goldilocks Zone; not too hot – not too cold. This is needed to permit liquid water to exist
2. medium sized star; large stars burn out too quickly to allow life to evolve. It's taken half the Sun's lifespan (and three quarters of the Earth's habitable lifespan) for us to reach this stage
3. a large moon; this is needed to stabilise the axial tilt of the planet. The tilt is required to create seasons and a variable though stable climate. Earth's Moon is 25% of the Earth's diameter – the Earth's axial tilt is 23.5°.
4. tectonic activity; This has two outcomes. It leads to the concentration of certain elements near the surface of the planet where they can be found and extracted relatively easily. It keeps the mantle well mixed to allow recycling of water and other chemicals back to the outer lithosphere.
5. a source of internal heat to keep tectonics going and to top the heat loss from the Earth into space. This heat loss actually exceeds the solar energy influx. Radioactive decay is the present compensating heat source.
6. A liquid metallic core – this creates the magnetosphere that deflects much of the solar wind which if it impacted directly onto the Earth would limit life to deep oceans and underground habitats
7. The molten metallic core driving the tectonic convection currents leading to a cycle of mountain building. This coupled with the protoplanet collision that formed the Moon in turn stabilised the resulting tilt of the Earth's axis and created weather patterns that watered the Earth and eroded the mountains and recycled the lithosphere. On Earth, evolution was given a major push. Out in the galaxy it would probably be more common for evolution to struggle very slowly upwards. Planets with Earth's youthful advantages would exist but would be vastly outnumbered by the 'laggers'.

During the time when exploratory probes were launched towards several promising stars, scientists who argued that too many things had to be just right for the Earth to be as it is were ignored. Humanity needed to believe it could have a second chance – a clean slate – another try with a new, unspoiled starting point. That dream was destroyed when we finally arrived in Orion.

It has long been argued that the 'super-Goldilocks' zone requirement for the development of intelligent (that's another argument!) life on Earth required so many fine tuned coincidences that it was exceedingly unlikely to occur more than once or twice in the Galaxy or perhaps even in the Universe.

The reality 'out there' in the Evoverse (Green is good – Red is not)

1. ***orbital goldilocks zone***; there are ice planets and desert planets but lots of planets in Evochron have substantial amounts of liquid water easily accessible. Interestingly no ocean planets have yet been reported.
2. ***medium sized star***; using technology we've bypassed the 'longevity to allow evolution' requirement and can be choosey about the type of star systems we opt to colonise – there are more available than we can foresee using
3. ***a large moon*** orbiting; this is rare – some planets do have moons but they are relatively small. The instability of axial tilt and subsequent climatic changes are (relatively speaking) long term - tens to hundreds of thousands of years. We are directing most of the growth of our cities underground and technological and scientific discoveries and developments may bring new solutions allowing future generations to live on the surface on open air.
4. ***tectonic activity***; We can bypass the requirement for local concentration of elements near the planetary surface by advanced mining technology (biomining for example) and harnessing the materials so readily accessible in the numerous asteroid fields. The need to keep the mantle well mixed to allow recycling of water and other chemicals is problematic. Virtually no planet has yet been discovered with active plate tectonics. Either they never had any or it has ceased. In the short terms (centuries) technology can compensate.

   Tectonics requires a substantial dense molten metallic core and these seem to be rare. Tectonics is responsible for mountain building. Consequently subduction in partnership with erosion to recycle mantle/magma material doesn't occur. Erosion alone without mountain building has lead to a more or less uniform landscape with low hills and shallow seas/lakes.

   The lack of stratification of chemicals coupled with the lack of mixing of the lithosphere has drastically slowed the evolution of those lifeforms that have developed.
   However, the lack of high concentration ores and (fertiliser) materials for plant growth can be overcome by our technology
5. ***a source of internal heat*** to keep the tectonics going. This is obviously not an issue since the other requirements for tectonics are missing as well.

   The Earth's internal heat source provides the energy for our dynamic planet, supplying it with the driving force for plate-tectonic motion, and for on-going catastrophic events such as earthquakes and volcanic eruptions. This internal heat energy was much greater in the early stages of the Earth than it is today. The internal heat has three main sources, all of which were most intense during the first few hundred thousand years of the Earth's history: (1) extraterrestrial impacts during heavy asteroid and comet bombardment,
   (2) gravitational contraction of the Earth's interior as the heavier elements, especially iron and nickel sank due to gravity.
   (3) radioactive decay of unstable isotopes. This is now the dominant heat source on Earth today.

   Earth's internal heat powers most geological processes and drives plate tectonics
6. ***a molten metallic core*** - we are expanding most of our cities underground and technological to shield colonies from stellar winds and scientific discoveries and developments may bring new solutions

Earth is not unique – it is just very very rare. Hence the majority of Evochron planets have:

- little or no flora
- very simple fauna
- relative flat with no mountains
- very shallow seas
- no seasons
- monotonous weather patterns (unvarying climate)

Appendix 11: Practicalities of Colonisation in Evochron

Mankind reached out to the stars and discovered multiple failed Earths. We were right all along – Earth is unique with its multitude of life forms and intelligent life – at least in this sector of our galaxy, our universe.

However, Humanity is committed to expanding out of Sol – out into the Galaxy. After all, there is nowhere else to go.

Summary of how it might work

The first step is to find suitable planet – one in the goldilocks zone for liquid water. Desert and ice planets are only considered for colonisation is they have a high strategic value location or a high value resource. Desert worlds must have a source of subsurface water either deep enough for it to have escaped evaporation or in the form of chemicals that can be treated to release water.

Phase	living conditions
1	outpost habitation: simple living quarters much created from the storage containers delivered to the surface. Underground shelters created to protect colonists during solar flare activity
2	surface towns as new accommodation is required and resources can be spared.
3	fairly quickly the habitation starts to burrow. This is to protect humans from cosmic radiation if the planet doesn't have a liquid metal core and hence a magnetosphere. This has an increased cost in resources but is required to make the colony habitable
4	buried town – at some almost arbitrary point a buried town begins to be considered as a buried city. This is usually the point where a radiation hardened superstructure can be built to ease access to the city/town and to permit spacecraft to land more easily

- The initial terraforming via greenhouse gases and orbital mirrors will re-warm the surface.
- As the temperature rises any subsurface ice melts. This water fills craters turning them into lakes and ponds, and rivers snake across the surface.
- Atmospheric dust slowly falls back to the ground, giving the sky a more bluish colour.
- The air is not breathable yet. Many bacteria, some plants and even a few animals can survive in low oxygen atmospheres. Humans would require a source of oxygen and could not breath the high carbon dioxide. However, natural evolution cannot create a self sustaining breathable (~20% O_2) atmosphere on a planet much smaller than Earth - as is typical in Evochron – the oxygen will be lost to space. This is because the oxygen levels at the beginning when the microbial population density is low never increases sufficiently to reach the tipping point when second generation photosynthetic – plants – can evolve.
- Artificially boosting the creation of oxygen to 20% and adding photosynthetic plants is still not naturally self sustaining – oxygen is still lost from the atmosphere. However, though this loss is 'quick' in geological timescales (100 000 – 1 000 000 years) once the oxygen concentration has been boosted to the target level, the genetically modified cyanobacteria can keep the oxygen levels topped up.
- Billions of tons of photosynthetic cyanobacteria will be injected in the atmosphere enhancing the creation of oxygen.
- An ozone layer will form filtering out dangerous ultra violet radiation.

Hundreds of years pass, the number depending on the intensity of terraforming efforts.

- Eventually the only frozen subsurface water is in the polar regions. The mean temperature is 10°C, and reaches 35°C in summer at the equator. In the top tens of centimetres underground, the temperature remains above freezing, even in winter.
- Plants and animals can be carefully introduced to create a rounded ecosystem.
- The sky is blue, rivers and lakes have invaded the planet. The ground is verdant, covered with thick moss and lichens, and even some grasses adapted to temperate conditions. Life has acclimatized. Now shrubs, flowers and even insects or fishes could survive.
- The air is breathable, so colonists do not need oxygen masks.

The planet has been turned into the paradise we hoped to find.

It is rumoured that there is at least one Earth-like green planet with flora/fauna developed to the point where (on Earth) flowering plants began to evolve. None are in the core systems. None have been confirmed in any of the uncharted systems.

Note: uncharted does not mean undiscovered. That task of terraforming the core worlds means that the myriad of discovered uncharted worlds are being mothballed for the foreseeable future. Those with any potential have been seeded (see above)

So, colonies have been set up. Terraforming has been started. It takes several generations before basic colonies establish themselves into cities and it will take many times longer until the terrain can be landscaped and farmed. If this hard road to creating a habitable surface is to succeed, the resources required to justify the creation of a jump gate will be found but it will be our children's children's children who will reap the rewards of new worlds where they can reject and avoid the mistakes their forefathers had made on Earth.

The second existential question tentatively answered when we arrived was the one that had occupied humankind for generations. Are we alone? The answer was no, but the life that we shared the explored galaxy with was either very simple or very hostile. We met the Vonari.

The information available about humanity's greatest competitor is very limited. Conspiracy theorists have suggested that the Vonari were created by either the Alliance or the Federation as a super-soldier, but they escaped or rebelled or were abandoned as a failure. Whether they have the same outward exploring drive as humans or whether they are simply seeking revenge against us for rejecting and abandoning them is in many ways irrelevant – Vonari seek and give no quarter. They have attempted to destroy Earth twice, resulting in the present embargo on visiting humanity's homeworld, backed by the Earth's defence Ring. Some would say that Earth is also ultimately the Vonari homeworld!

On Earth history shows us that when a new territory was colonised, the settlers move in with their tools and possessions and utilised the resources of their new homes to build and prepare land for their crops. They could live off the land until their own crops were ready. In Evochron, given the scarcity of resources this doesn't work.

Establishing a colony is still a multi-generational project. Planets were chosen that had a large enough concentration of a valuable enough resource to justify the economic input needed to create a colony. The first generation of colonists endured hard years, spent creating the structure of a good life for the generations that would follow.

Starting a new colony was and still is an expensive and risky operation. The Colonial Development Authority - CDA - "loan" a new colony the credit to hire a Pioneer Corps - PC - team (that is effectively a part of the CDA) for a couple of years and to buy the equipment they need along with sufficient food and other basics to get them through their first year.

The normal procedure was – and still is - to drop off the relatively small PC team - its role is to set up the basic settlement for the main group of colonists who arrive two years later. By that time the colony has to be functioning - no more help will be offered and no new colony has the credit rating to borrow more money. Once there they are on their own! Typically a colony is in debt to the CDA for the first fifty years at least and often more - a century wasn't uncommon.

The PC team laboured hard for the first two years to establish the colony infrastructure - they assemble the first basic accommodation units and fabrication units they bring with them. The cargo containers transported to the surface form the original core of the accommodation units. Fabrication units create the necessary extras. They set up the mining equipment to provide the raw materials needed for the construction of the colony. The planetary rock is rich in some necessary materials and poor in others.

The first priority is assembly of the fabrication units so that they can create more mining equipment which in turn leads to an increased flow of raw material which allows a greater number of more sophisticated fabrication units to be created. Nanotechnology had made the rapid push for colonisation economically feasible – it is still at the core of the establishment of new colonies.

On some worlds the barren regolith of the planet had the potential to be turned into a passable fairly fertile soil. This could obviously only be done on a small scale. Terraforming is a multi-generational project. Gen-engineered microbes are introduced, along with a carbon-based "char" that is the substitute for humus. The char is created from carbonate rocks or any other material available with a carbon content which is pulverised and heated. If necessary carbonaceous asteroids are mined, though expense makes it a last resort.

The sterile regolith rock gradually becomes a pseudosoil capable of supporting the gen-engineered wheat, rice and other staple cereal crops. The organic waste from the crops is converted into true humus to enrich the soil nutrient levels and improve its structure.

Initial surveys identified locations with readily accessible water. Colonies are located near the seas or wells are sunk using sonic drills into the deep aquifer systems identified by the initial planetary survey team a decade earlier. One blessing in the early harsh days for many colonies - water is plentiful.

Solar panels and robust vertical wind turbines are fabricated and installed to supplement the core energy produced by the small fusion generator.

Eventually, perhaps a century later, geothermal energy would be tapped if the planet's mantle is hot enough. This energy source mix had proved to be the most economic source of a colony's baseline energy needs. For most planets the heat source is the residual heat caused by gravitational contraction during planetary formation. This is sometimes supported by radioactive decay.

Two years after the PC arrive the real colonists arrive. The colony has to be self sufficient from the moment that they land. A colony has to be! The transport ships usually depart within a month - the time it takes to fly all the colonists and their possessions and equipment down to the ground and to evacuate the Pioneer Corps with all their equipment. The Pioneer Corps move onto their next colony set up.

The first generation of colonists get to christen their planet and the colony. The first year is usually very, very hard, the next five merely very hard.

Life is not luxurious, but there is adequate food (produced on the hydroponic farms and supplemented by fabricators), water, shelter and other basic essentials. With the larger labour force progress speeds up. Accommodation slowly becomes less spartan, industrial fabrication unit time can be spared to produce a few things beyond the bare necessities. A colonist's health depends on mind and soul as well as body!

The most important development is the start up of resource extraction – whatever that resource might be. Examples of worthy resources included minable concentrations of ores of "rare earth" minerals. Rare earths are vital in modern electronics and nanomachinery. Asteroids are more or less devoid of rare earths. In the early days of a colony's establishment 'The Resource' is the planet's main export. Normally each month a transport hauler arrives in orbit and is filled with the processed ore *etc* via shuttle craft. The trickle of credits this generates from the outside is vital to the colony's survival, its growth and its ability to pay back its enormous establishment debt.

Gradually the number of haulers per month needed increases two then three per month, then one per week – the long term survival of the colony depends on the inward flow of credit being invested towards increasing their export potential.

By the end of the second decade a colony needs to be looking healthy. Colonists can now start up their own businesses. On a mining planet these might include prospecting or trading in mining equipment and other necessities. Everyone still works with the security of the colony in mind – they are all in it together and leaving isn't a realistic option.

As the population expands it is normal to establish new ‘townships’ as well as increase the size of the original. This allows more area to be exploited – anything that increases resource quantity is good! The local "sea" are sometimes suitable to farm gene-modified kelp and krill – this supplements other sources of protein

If all goes well and no disasters occur a colony and its planet's future starts to look more secure. Or at least as safe as anything can be on the frontier of civilisation.

The uncertainty of colony success and difficulty of access to newly colonised planets - no jump gates - explains why Evochron maps tend to show only the established core systems. There were many systems that had been discovered and surveyed but not yet settled or deemed unsuitable for settlement. If they showed any potential the survey teams seeded them with genetically modified bacteria – even basic plants if the planets could support them. This is a cheap investment for the long term future – several centuries or even millennia in fact, but when colonisation finally occurs it will have a flying start!

Evochron is still a human frontier with all the dangers and unknowns that come with the status. One confirmed alien species has been discovered. The Vonari are still manically hostile to humans. Unconfirmed rumours of a second species of aliens persisted. The population of Evochron is growing year on year but is still relatively small. There is room for expansion for centuries to come.

Appendix 12: Long Term Development of Evochron – Terraforming Planets

Makeovers on a Planetary Scale - Terraforming – How? & Why?

At present colonies have utilise self-contained buildings that carry a bit of the Earth with them. As colonies grow they are expanding underground as large multilevel cities. Breathing and other protective equipment (for example Terrain Walkers) are required for working outside the cities.

Eventually, however, people envision transforming whole planets into ecosystems that can support life without the need for isolated containment facilities. This transformation is multi-generation in its timescale. However, such 'terraforming' has already begun

There are three classifications of exoplanets that are of interest to colonising authorities. These are;

• Habitable planets. This is what Star Trek liked to call a "class M planet", in which you basically step off your starship, take a deep breath, and pronounce the planet ready to go. This is a planet so like Earth that it can be inhabited just as it is, with minimal effort. None have been reliably reported in the Evoverse
• Biocompatible planets. Planets that have the necessary physical parameters (i.e., the chemical building blocks, energy, liquid water, and stability) so that it could eventually host a complex ecosystem if seeded with life. We will discuss various methods of such seeding below.
• Easily terraformable planets. Planets that could be rendered biocompatible with relatively limited resources, such as might be present on a starship or in a precursor robot mission rather than requiring a sustained armada of ships.

For a habitable planet, the job is already done for us. Maybe the atmosphere contains more argon than ours, or a bit more or less oxygen, but the planet by definition already has life and thus establishing a human colony there is no more difficult than it has been to put colonies on Australia.

Biocompatible planets are a bit of a paradox. It is an interesting question as to whether such planets exist, because by definition they have no life but could sustain it if the life were seeded there. Basically, we are asking whether the origin of life is difficult enough that it might not happen even given the right conditions. Could the early Earth have been like this? In any case, supposing that we have such a planet before us, what should we do?

The why is obvious. Earth-like planets are not the same as Earth. No 'habitable' planets have yet been discovered in Evochron. Colonies need to be sustained. Typical Evochron planets will not support a colony without a high flow of imported basic resources – these have to be paid for by a high flow of exported resources of value to the rest of Evochron. Consequently planets need to be changed so that they can support life, ideally in the open.

Ideally planet in the goldilocks zone for liquid water. Desert and ice planets are only considered for colonisation is they have a high strategic value location or a high value resource. Desert worlds must have a source of subsurface water either deep enough for it to have escaped evaporation or in the form of chemicals that can be treated to release water. Examples of the former is residual cometary water deep in the mantle and of the latter is minerals containing water in their structure are known as *hydrous* minerals

The solution to this issue is the large-scale modifications of a planetary environment. There are three basic methods, usually lumped together under the name 'terrforming'. They are :

- "Terraforming" refers to creating an Earth-like world and includes planetary engineering.
- "Ecopoiesis" is a term introduced to describe the initiation of a living, self-sustaining ecosystem in a hostile planetary environment.
- "Ecosynthesis" refers to the development of an ecosystem that includes 'succession' (ecosystem maturation by the replacement of organisms).

Terraforming captured popular imagination. Several terraforming systems were developed to the prototype stage but it quickly became apparent that it was economically unjustifiable for even a single planet, never mind the on the scale required in Evochron. Mercenaries exploring outside core systems may stumble across the abandoned remains of terraforming trials since they couldn't be profitably salvaged.

Terraforming Type 1: Mechanical Engineering

After several studies in the early 21st Century of how typical Evochron planets could be terraformed, the economic cost of building the required mix of structures couldn't be justified, especially given the necessity to fabricate them on site. The cost of bringing metallic and carbonaceous asteroid in from the asteroid fields to planetary orbit to provide the raw materials was viable but creating the construction infrastructure to build the parts and transport them to the surface was beyond the resources available. The sort of equipment required included (taken from early summary reports);

Atmosphere Processor (AProc)

This proprietary system is the hardest to make work and the most sensitive to initial conditions. It creates a localized environment in the lowest atmospheric strata by mining the surrounding atmosphere and water vapour from oceans and delivering intense electrostatic charges to correct the chemical composition of the planetary atmosphere. The system does this by converting toxic compounds plus water vapour into a breathable air ratio of approximately 1:4 oxygen-to-nitrogen ratio. Once stable equilibrium is achieved, the AProc continually monitors environmental gas compositions and corrects imbalances. By-products can often be isolated and condensed for use as fuel sources, industrial cleaning supplies or raw materials for manufacturing.

Igneous/Metamorphic) Rock Processor (IMP)

The IMP (Igneous/Metamorphic) Rock Processor is designed to improve the quality of life on off-world colonies with adverse indigenous terrain. Through high-powered mechanical disturbance, the introduction of proprietary enzymes and bioengineered bacteria, the IMP transforms inhospitable regolith into fertile soil for use in agriculture and bio-replication. It can be operated by a 4-person crew of planetary engineers or trained civilian colonists.

Atmospheric Pressuriser (APress)

This technology is intended for use exclusively in conjunction with Atmosphere Processors, and its role is to prevent injury, illness or discomfort on off-world colonies with marginal atmospheres where atmospheric pressure is significantly lower than optimal. For a planet to allow humans to live in open air, a standard atmospheric pressure of approximately 1.0 Earth atmosphere at sea level should been achieve, reducing the need for decompression treatments and additional medical personnel in the early stages of terraforming.

Nanotechnology

On a much more detailed level, nanotechnology could be introduced to modify the soil molecule by molecule, to transform indigenous flora and to integrate the Earth ones. This would require inconceivable amounts of nanites. This would only be possible if they were able to reproduce and multiply using raw materials found on the planet, and then systematically deconstruct and decimate themselves back into a manageable amount that can be recollected.

Terraforming Type 2: Geo-engineering

Asteroid impact

Another way to increase the temperature of a planet would be to direct small asteroids (carbonaceous and ice) onto the planetary surface. This could be achieved through use of space borne lasers to alter trajectories or by adapting other methods proposed for asteroid impact avoidance. The impact energy would be released as heat. This heat could sublime CO_2 or, if there is liquid water present at this stage of the terraforming process, could vaporize it to steam, which is also a greenhouse gas. Asteroids could also be chosen for their composition, such as ammonia, which would then disperse into the atmosphere on impact, adding greenhouse gases to the atmosphere. As weather patterns build up, lightning may build up nitrate beds in soil. Impacting asteroids on these nitrate beds would release additional nitrogen and oxygen into the atmosphere.

The suggestion that humanity took the long term view and bombarded potential planets with asteroids/comets was given short thrift. Governments – even the fledgling Alliance could not comprehend planning for a long term that spanned several centuries before habitation was possible. A blue sky think tank suggested an alternative that, whilst taking many decades would gradually improve the conditions on the planets. The deciding factor was that the planets would be inhabitable, though inhospitable during the terraforming and that the financial and resource costs were a fraction of the alternatives.

The chosen solution was the mix of Ecosynthesis and paraterraforming.

Ecosynthesis.

This is a term used to describe the use of introduced species to fill niches in the environment, with the aim of increasing the speed of ecological transformation. Alone this will still take many centuries to reach fruition. The initial plan was to introduce plants and animals that could survive on the planets being colonised to fill niches. Genetically engineered symbiotic plants/bacteria would initially create CO_2 to provide a greenhouse effect. This would start to melt the water locked up as sub-surface ice. It would also eventually have a cascade effect as the polar dry-ice caps or dry-ice embedded in the regolith 'melted' (technically, sublimed.) Modelling showed that there was little chance of a runaway greenhouse effect utilising typical planetary carbon dioxide concentrations .

Subsequent phases would use genetically modified bacteria to convert iron oxides and release oxygen.

The main issue is the time span of the project. Ecosynthesis alone would take centuries for phase one and a thousand years before a 'Green Planet' existed. Hence the plan required the development of paraterraforming technology along with some degree of fine tuning the ecosynthesis with basic terraforming. The latter would include the creation of a habitable climate by global engineering techniques. It short-circuits some of the longer stages.

Greenhouse gases, such as perfluorocarbons, appear to be the best method for warming the planet and increasing its atmospheric density so that liquid water becomes stable.

To search for potential colonizing species requires research requirements:

- Starting conditions to be studied on Earth should resemble those expected to exist at the best possible location on the surface of the target planet (a temperate location at low altitude or near potential water sources at the north polar cap).
- The regolith must be heated to a temperature compatible with the most robust form of terrestrial life at low temperature.
- The first organisms must derive energy from the mineral content of the regolith and/or sunlight, and their metabolism must produce a net increase in greenhouse gas(es).
- The first organisms must be capable of withstanding, or be protected from, the ultraviolet and ionizing radiation present on the Martian surface and the high CO 2 of the atmosphere.
- Organisms early in succession should produce significant amounts of O 2 .
- Higher plants late in succession will need to be studied under conditions that pioneer organisms preceding them can create.

Paraterraforming.

This is the construction of a habitable enclosure on a planet which eventually grows to encompass most of the planet's usable area. Thus planets can be colonised at the start of the terraforming process

Initial plans to create kilometre wide domed cities were rejected because of economics and inadequate technology. The solution chosen was to build cities downwards. A small section is visible above ground giving access to the major part of which is built underground. Present technology and engineering can provide protection for the above ground parts – the ground itself provides insulation and protection from cosmic rays in the event a planet doesn't have a magnetosphere. Planetary bedrock provides the structural integrity and straight forward engineering creates the internal structures – this should sound familiar to citizens of the Evoverse, especially those on more recently settled planets! On Sapphire for example less than one tenth of one percent of the city appears above ground.

Use of orbital mirrors

Mirrors made of thin aluminized PET film could be placed in orbit to increase the total insolation it receives. This would direct the sunlight onto the surface and could increase the surface temperature directly.

Albedo reduction

Reducing the albedo (amount of light reflection)of the planet's surface would also make more efficient use of incoming sunlight. This could be done by spreading dark dust from asteroids or by introducing dark extremophile microbial life forms such as lichens, algae and bacteria. The ground would then absorb more sunlight, warming the atmosphere. If algae or other green life were established, it would also contribute a small amount of oxygen to the atmosphere, though not enough to allow humans to breathe. The conversion process to produce oxygen is highly reliant upon water.

Appendix 13: Asteroid Cave Plan

Appendix 14: 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: