# S T A R  T R E K  T E C H N O L O G Y

by Leon Myerson



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Warp numbers do not directly refer to speed, but to power. Warp 1 is the power level required to enter the warp continuum, and is known as Threshold power. Warp 2 is twice that power level, etc. Fractional warp is simply less than Threshold power while the ship, though traveling via warp field effect, is still "in" the Einstein space-time continuum at sub-light speed. The unit of power between whole warp factors for a given vessel is one "Impulse", as in the ST:TNG episode "Conspiracy" when Geordi answers Riker's command to increase from Warp 5 to Warp 6 by acknowledging the addition of yet another full impulse to the power already coursing thru the warp nacelles.

The formula relating the Warp number W to velocity in terms of C is not the hopelessly inadequate V = W^3. In Trek Classic's very first episode the Enterprise was seen at the edge of our galaxy. Even assuming this to be the near edge reached by going perpendicular to the galactic plane, it is still at least 1500 light years from Earth. At a cruising speed of Warp 6 = 216 C, the ship would have spent at least 7 years getting out there, then 7 more back.

Nor would that formula fit the size of the United Federation of Planets' Treaty Exploration Zone mapped in the "StarFleet Technical Manual". This zone was pictured as being approximately 12,000 light years in radius, with both the Klingon and Romulan empires located at the rim some 60 degrees apart. Clearly, Enterprise did not require an excess of 50 years to reach the neutral zone.

In the ST:TNG episode "Conspiracy", Picard and Riker confront the parasite mother creature in the guise of Lt. Cmdr. Remmick as he/it sends a beacon to the parasite beings' homeworld via StarFleet's own CommNet. The 3-D map of that network on the wall behind him fits almost perfectly the Treaty Exploration Zone of the Trek Classic Era.

Instead of V = W^3, velocity is defined by the sum of an infinite series known as the 3rd-order Cochrane function, which is applicable to Tertiary warp effect fields such as are utilized by major Federation vessels from the Tritium class onward. The first term of this series is the familiar W^3, the second term is the integral of the first term, W^4/4, the third is the

integral of the second, W^5/20, and so on, ad infinitum. Each term is the integral of the preceding term. Thus the common mistake so often made is to quote only the first term of the series as if it were the entire function.

The behavior of this series is such that the terms rise in value at first, then become increasingly smaller so as to converge on a definite value. This may be calculated by the equivalent formula:

$$V = 6 * \{ e^W - [ (W^2)/2 + W + 1] \}$$

where V = velocity, W = Warp factor, and e = base for natural logs 2.71828..

When calculated in this manner, this function gives the following values:

| Generated Power | Uncorrected Warp Speed x C |
|---|---|
| 1 | 1.31 |
| 2 | 14.33 |
| 3 | 69.51 |
| 4 | 249.59 |
| 5 | 779.48 |
| 6 | 2270.57 |
| 7 | 6384.80 |
| 8 | 17639.75 |
| 9 | 48315.50 |
| 10 | 131792.79 |
| 11 | 358809.85 |
| 12 | 976018.75 |
| 13 | 2653889.35 |
| 14 | 7214947.68 |
| 15 | 19613332.78 |

For starship designers, these numbers seemed too good to be true, and indeed they were. From the earliest days of starship operations, warp engines had always registered a small power loss as they were fed more than Warp 1 power. Defined as the difference between Generated Power and Delivered Power, this drain was ascribed to the faintly conceived notion of "continuum drag". It was Delivered Power that determined actual velocity according to the 3rd-order Cochrane function. As the phenomena was still too poorly understood for mathematical description, progressive increases in power generation capability had to be matched empirically with increases in Delivered Power via actual flight testing, and the term Warp Factor continued to refer to Generated Power.

The Dilithium breakthru made it possible to generate unprecedented multiples of threshold power, and led to the Federation's investment in the Constitution class vessels. Able to safely generate and sustain Warp 8 power, these ships found the drag/drain worsening rapidly at the higher levels.

It was the USS Enterprise, under Christopher Pike, that first challenged the "Warp Barrier". After three month's total overhaul at the Terran Orbital Shipyards personally supervised at every stage by Montgomery Scott, the ship went on speed runs pushing her anti-matter reactors as high as Warp 13 for a few seconds at a time. The resulting measurements at last permitted Scott to define the continuum drag equation:

$$CDF = G - \frac{\tan(A)}{} + 10$$

$$(G-S) + (\tan^2(A)+((G-S)^2)-1)^{(1/2)}$$

and thus

$$D = G - CDF$$

where D = Delivered Power; G = Generated Power; CDF = Continuum Drag Factor; A = 5.1050881 radians; and S = 9.8658770244 (Scott's constant). The corrected table of Warp speeds is therefore:

| Generated Power | Delivered Power | Warp Speed x C |
|---|---|---|
| 1 | 1T A 000 | 1.31 |
| 2 | 1.98354 | 13.91 |
| 3 | 2.96260 | 65.98 |
| 4 | 3.93509 | 230.94 |
| 5 | 4.89755 | 696.42 |
| 6 | 5.84370 | 1926.80 |
| 7 | 6.76140 | 4999.38 |
| 8 | 7.62571 | 12075.26 |
| 9 | 8.38615 | 26048.20 |
| 10 | 8.96633 | 46707.91 |
| 11 | 9.33067 | 67348.90 |
| 12 | 9.53548 | 82717.85 |
| 13 | 9.65322 | 93087.64 |
| 14 | 9.72615 | 100151.85 |
| 15 | 9.77477 | 105155.01 |

| Old Warp | New Warp |
|---|---|

A graph of Scott's equation plotting Generated Power as X against Delivered Power as Y, shows that at threshold power (Scott's equation and the 3rd-order Cochrane's function are not applicable below this point) X = Y = 1, and the graph line proceeds at an almost 45 degree angle assuming equal scales. (This graph is available as WARP10.RLE in DL2 for those with IBM PCs or compatibles.)

But as Generated Power exceeds 8 times threshold level, Delivered Power deviates ever more significantly and the graph curves sharply to the right. The curve is half of a hyperbola, rotated by angle A, with the significant asymptote line represented by the equation Y = 10, so that while the Generated Power may go arbitrarily high, the Delivered Power will only approach ever more closely but never equal 10. The speed value for Warp 10 from the uncorrected chart, 131792.39 times the speed of light, is the theoretical limit of the Tertiary warp effect, and can only be approached, never equaled or exceeded. This is also the velocity of such warp continuum energy transmission phenomena as sub-space radio and the standard phaser effect. (The complete hyperbola is graphed in WARP_X.RLE, also in DL2.)

By the time of ST:TNG, it had become standard practice to quote Warp factors in terms of Delivered, rather than Generated, power. This explains the apparent discrepancy between the eras. Overall Generated Power capabilities are still crucial to military vessels, as even a few dozen extra C's may mean the difference between success and failure when outrunning or persuing an opponent. Here then is the standard warp factor scale used in the 24th century:

| Delivered Power | Generated Power | Tertiary Warp |
|---|---|---|
| 1 | 1.0000000000 | 1.31 |
| 2 | 2.0167653720 | 14.33 |
| 3 | 3.0383208502 | 69.51 |
| 4 | 4.0670614879 | 249.59 |
| 5 | 5.1072983806 | 779.48 |
| 6 | 6.1676537197 | 2270.57 |
| 7 | 7.2682459514 | 6384.80 |
| 7.5 | 7.8487197368 | 10628.50 |
| 8 | 8.4694304149 | 17639.75 |
| 8.2 | 8.7364919027 | 21588.78 |
| 8.4 | 9.0203187626 | 26414.32 |
| 8.6 | 9.3280961537 | 32310.48 |
| 8.8 | 9.6717993420 | 39514.34 |
| 9 | 10.0729838055 | 48315.50 |
| 9.1 | 10.3071067812 | 53422.73 |
| 9.2 | 10.5747605008 | 59067.65 |
| 9.3 | 10.8903152831 | 65306.85 |
| 9.4 | 11.2777216596 | 72202.80 |
| 9.5 | 11.7800905867 | 79824.61 |
| 9.6 | 12.4836439773 | 88248.61 |
| 9.7 | 13.5895662949 | 97559.17 |
| 9.8 | 15.7014109302 | 107849.55 |
| 9.9 | 21.8369448362 | 119222.79 |
| 10 | INFINITE | 131792.79 |

| New Warp | Old Warp | Velocity x C |
|---|---|---|

To calculate the Generated Power corresponding to a given Delivered Power level, use the formula:

$$G = S - \frac{((D-10)^2*(\tan(A)^2-1)-\tan(A)^2}{2*(D-10)*\tan(A))}$$

An interesting aspect of the 3rd-order Cochrane function is that Warp 1 is not C but 1.31 x C. Taking the reciprocal of this number, 0.763, gives what is known as threshold velocity. Under fractional warp power, a starship "accelerates" as the power is steadily increased. At Warp .99999 etc., the ship is traveling at 0.763 x C. Transition occurs, an explosive event accompanied by the hauntingly beautiful phenomena known as the Chromatic Detonation, the optical analog of a sonic boom. In the next micro-instant, the ship is on "the other side", traveling through the warp continuum at 1.31 x C. The ship is never observed at speeds $0.763 < V < 1.31$ under normal conditions.

It should be noted however, that the boundary layer of the warp field effect creates an envelope of 4 dimensional Einsteinian space-time within which the ship travels. Therefore, all the familiar physical laws of the "ordinary" continuum still apply within the envelope. From the outside, it

appears as though a space-time anomaly were manifested sequentially along a linear path. Fleeting, multiple images of the vessel in the center of the anomaly are created at widely spaced intervals which grow more distant at higher warp factors. Light coming from within the envelope gathers at the boundary layer until it reaches optical crossover threshold, at which point it "pulses" through, thus re-entering normal space-time to project the image of the ship. This effect was nicely filmed for the climactic scene in ST:TSFS when we see the Enterprise fleeing the detonation of the Genesis Device.

External light enters the envelope via complex optical interaction with the warp field boundary layer. The micro-instant lost for photons in front of the ship's path to cross the boundary layer causes them to appear to originate from directions shifted away from the line of motion in favor of apparent origins perpendicular to the direction of travel. While an optical blind spot exists directly behind the ship along the direction of motion, due to the superluminal velocity involved, the tear-drop shape of the overall warp field minimizes the area so blanked out to a vanishingly small region.

The overall effect is curiously symmetrical to that observed by vessels approaching light speed in normal space-time. Such a vessel would see its 3-dimensional field of view collapsed into twin circles of light in front of and behind the ship, with a band of darkness around its mid-section. A vessel in the warp field traveling at superluminal velocities experiences a tunnel-like effect in which the dark region consists of circles in front of and behind the vessel, and its view of the universe is projected onto a cylindrical tube which the ship appears to travel through.

Of course, the ship's computers correct for this effect to present an intuitively "normal" view upon the bridge and other viewscreens. Windows facing port or starboard reveal a relatively normal view without sophisticated correction, others have internal holographic layers which serve as the functional equivalents of corrective lenses to keep the view at least intelligible, if not exactly accurate.

Sometimes a foreign body, such as small pieces of asteroidal rock or chunks of cometary ice are pulled into the forming continuum envelope as a starship achieves transition. Usually this is a harmless occurence, unless the "dragger" is massive enough to damage the hull if it should collide with the vessel. If so, the ship will usually power down below threshold to release the object, otherwise it can remain within the influence of the warp field effect and go along for the5.84o the starship's scheduled destination. An unusually extreme instance of this effect occurs in ST:TMP when the old Enterprise, bucking wildly from her imbalanced engines, pulled a whole asteroid into the warp envelope formed around herself, and was forced to pulverize it with a photon torpedo.

Old space junk from various inhabited systems often gets distributed about the galaxy in this fashion, centuries in orbit about their star of origin affording plenty of time for a chance encounter with a transitioning starship. Some of places identifiable objects ultimately turn up can be downright humorous. Items too small to possibly damage a vessel thru its deflector shield are usually ignored, especially when they have no possible salvage value.

An example would be the cryonics satellite found just prior to the NCC-1701-D's recent visit to the Neutral Zone which originally WAS orbiting Sol, minding its own business for centuries. People in the future tend to leave space junk that old alone, the objects most popular as tourist sights actually being protected with "landmark" status. A sleeper ship such as Khan's would certainly have been detected, but the cryonauts registered NO life signs at all, so no one ever knew what was in this craft. Eventually, a starship pulled it into its envelope and carried it thousands of light years

out to the vicinity of the starbase Enterprise was visiting for Captain Picard's conference with StarFleet authorities regarding the apparent loss of stations near the Neutral Zone.

This is also now considered the most probable explanation for the early 1990's Voyager 6 probe having reached a black hole capable of sending it to the "machine" planet, as various research ships have made many voyages directly from the Sol system to known black holes since warp drive was first employed. Its return to the Sol system as "V'ger" prompted some talk off a system wide clean up of old hardware, but nothing ever came of it.

The relativistic time dilation experienced at Tertiary threshold velocity is such that time passes at 64.6% per cent, or roughly 2/3's, the "normal" rate of objects "at rest". This time dilation factor goes along with the ship as the warp effect envelope separates from normal space/time in crossing over the threshold, and remains stable thereafter, so that all the time spent under way at superluminal velocities is discounted by 1/3 for those on the vessel vs. those staying behind. The effect is rather conveinient for starship crews, as it effectively cuts by 1/3 the travel time between stop-overs, and since all Tertiary warp vessels experience it, there is no disadvantage in reaction time against opponents.

There are social aspects to the cumulative effect of a lifetime career devoted to star travel, in that one's age starts falling behind that of friends, family, and above all spouse's left behind. In the 2nd, 3rd, and 4th feature films, we see James Kirk wearing four bars and three dots on his sleeve, indicating 23 years service in StarFleet. Yet his birthday depression in ST:TWOK and the presence of the fully grown David Marcus all point towards a 50th birthday. Assuming Kirk graduated the Academy at the normal age of 22, adding 23 years leaves a 5 year gap. The gap is simply the cumulative effect of the time he's spent cruising at warp speed. For married personnel, this "age gaping" becomes a serious problem over a lifetime, and was a major factor in StarFleet's decision to allow families to go along on its latest vessels of the ST:TNG era.

A very important aspect of this effect derives from the behavior of the threshold cross-over phenomena in the presence of intense gravitational fields, such as would be found near stellar bodies. The intense warping of space/time already imposed upon the region of the continuum nearest the star causes it to become more tolerant of extreme profile skewing than normal space. As a nearby ship accelerates, the threshold velocity is reached, but cross-over does not occur, one has to increase the degree of skew with still more power. This means going nearer to lightspeed while still in the normal continuum, thus the time dilation factor increases. Since the time dilation at cross-over remains in effect throughout the period spent in the warp continuum's sub-space, it is possible to retard one's own rate of time passage to an arbitrarily high degree to assist in making extremely long voyages.

Some of the early Federation exploration ships, such as the famous USS Horizon, used this sort of maneuver on occasion, but more often avoided it due to the detrimental effect upon shipboard reaction time it causes. Merchant vessels sometimes tried it, but the extreme danger of maneuvering so close to a star led first to uninsurability and finally to outright regulatory prohibitions against the practice. Ships full of colonists almost always housed them in sleeper chambers, an old and proven technology dating as far back as the late 20th century, leaving only the crew awake.

One of the greatest scientific discoveries made by the original NCC-1701 Enterprise was that if a ship went EXTREMELY close to an object of stellar mass while in the normal continuum, then poured on maximum

power to force its way to threshold before putting significant distance between itself and the gravity field of the celestial body in question, then the effective threshold velocity could actually be slightly above lightspeed, and the associated time dilation not only extremely large but NEGATIVE. This is the essence of time travel under what has become known as the breakaway maneuver.

The class of phenomena known as "time travel" are extremely complex and remain poorly understood. Most recorded incidents have involved multiple effects which, in the absence of a fully developed theory of time, are often difficult to untangle for separate description and analysis. The Enterprise's unintentional journey to the Terra of the late 1960's began with an accidental encounter with an uncharted black hole. The unusual properties of this particular hole had attracted their attention, resulting in the Enterprise making a low warp speed sensor pass. The anomalous readings prevented them from realizing the nature of this object until it was too late. The hole's intense distortion of the continuum pulled the Enterprise out of warp, where the ship was in iminent danger of being sucked into the hole itself.

On Kirk's orders, Sulu applied full emergency power in a desperate attempt to fight their way back to threshold so as to to re-enter the warp continuum, but even as the mighty starship trembled under the effort, the threshold power level was moving higher and higher as they neared the event horizon. With seconds left before the end, Mr. Scott in engineering surmised the nature of their situation. Knowing the ship could never make the rising tertiary warp threshold in time, he engaged the emergency circuit breakers to take the tertiary booster coils offline, and diverted 100% of the reactor output into what was now a lower threshold secondary warp field system. The collapse of the tertiary field into a secondary one "collided" with the rapidly growing overall power level, kicking the ship into the warp continuum with such explosive force that she briefly left sub-space itself on a kind of "ballistic arc" OVER rather than thru the warp-space she would normally traverse.

It would take Spock many weeks of theoretical study and analysis before he would devise a tentative explanation for their seemingly miraculous appearance within the Terran atmosphere. Ultimately, his explanation for their movement thru space as well as time rested upon two major points.

First, time travel does not permit violation of the conservation of mass law. One cannot simply send 200,000 metric tons of starship back in time to coexist with an "earlier" copy of the same 200,000 tons of matter without in some way compensating for the effect such functional duplication of mass will have on the overall gravitational process of the cosmos.

Second, in this particular incident the mode of compensation took the form of an exchange or displacement of the 20th century matter that would one day be the Enterprise and her crew, this material swapping out of the normal plane of existance to reside in the hyper-continuum the ship had traversed to reach its destination. Therefore, in a manner related to the phenomena of "symmetry breaking", the cosmos "selected" as the ship's re-entry point a location determined by the whereabouts at that time of the raw materials which would one day be the Enterprise and her crew.

As most of this material would be found on Terra in the 1960's, that is where the ship materialized. Fortunately, not quite all of the material constituting the Enterprise was of Terrestrial origin, or the ship would appeared at the center of the Earth instead of 5 miles above

its surface. That it wasn't 5 miles below the surface instead was simply good luck as to the total net effect of the mass-origin location factors. When the Enterprise returned to its proper place in time, the older version of her material constituents resumed their proper place in the continuum as well.

Later studies of the "breakaway maneuver" and its associated parameters revealed that had this early incident not involved such extreme conditions, the time traveling starship would have remained "linked" to the net gravitational influence of the star used as the initiator mass. This would have caused the celestial body itself to assume the role of adjusting its own impact on the expansion of the universe to compensate for sending a vessel back in time, and would permit such voyages thru time while retaining the ability to target spatial destinations as well. This type of controled temporal translation was successfully demonstrated by the Enterprise via Sol during the mission Kirk's log describes as "Assignment: Earth", and was later employed from a captured Klingon cruiser to solve the "Whalesinger" crisis.

Given the operational parameters of starship reactor systems, the time it takes to build up power applied to generating the warp field effect normally requires an initiator mass the size of a star or greater to perform the breakaway maneuver. A planetary mass is just too small under most circumstances as the vessel will have already moved too far from the center of its gravitational field before attaining threshold power where the time dilation effects are manifested. This does not mean it isn't possible to use a planetary mass as the initiator, only that the ship in question would have to bring up its power output in an incredibly rapid surge to do so. The only known means of doing this is the all but suicidal technique of deliberate implosion to "cold-start" completely shut down power systems. Only one ship, NCC-1701, is known to have ever survived this procedure. Historians remained baffled as to why the crew dubbed the gambit an "Irishman's Chance".

Were you to travel back in time without triggering some form of gravitational impact compensation for your mass, the continuum would soon destroy you via an effect strikingly similar to the manner in which a living creature's immune system destroys that which does not belong. The unfortunate time traveler would experience progressive disintegration as the particles of his/her body are randomly pushed back to their own correct time.

An advanced form of such compensation was an integral part of the Atavachron, which functioned by actually forcing open "portals" between times. As Kirk, Spock, and McCoy went through the portal but bypassed the compensation stage, they were in grave danger and had but little time to return. Sarabeth could not return with them unless they could have learned to use the machine to compensate for her entry into their era, but alas there was no time for that before the star in that system went nova.

Just as the 3rd-order Cochrane function is known as Tertiary Warp, the 1st and 2nd orders represent Primary, and Secondary Warp. Primary Warp is the function consisting of the sum of the infinite series begining with X plus (X^2)/2 plus (X^3)/6 etc. As with the 3rd-order series, it may be calculated with the equivalent formula (e^W)-1. This was the first type of warp field effect propulsion system developed, and it is still in use on later vessels as the Impulse Drive sub-system.

When Secondary Warp drive systems were developed, governed by the 2nd-order Cochrane function consisting of the sum of the infinite series

begining with X^2 + (X^3)/3 +(X^4)/12 etc., equivalent formula: 2*((e^W)-(W+1)), it was learned that they, and all higher order warp fields, were dangerously unstable at low fractions of threshold power. This forced the retention of some form of Primary warp drive, though it need not handle enough power to go superluminal.

All warp field effects are created via the use of superconducting Cochrane coils, which are wound according to the complex topological patterns defined by Impulsor Calculus, the branch of mathematics developed by Zephram Cochrane to express the new kinematics and mechanics resulting from his successful unification of gravity with the electro-strong-weak force of quantum physics. As this essay is intended for a 20th century audience, ethical constraints place severe limits on the range of comments that can be made on this subject, but the inference should be obvious that if theoretical physics has mastered the unification of the primal forces of nature, it becomes possible to use a force easily generated and controled, such as electromagnetism, to manipulate phenomena normally governed by another force, such as gravity.

Cochrane's mechanics superceded Einstein's, as his in its time supplanted Newton's. Each is "true" or at least acceptably valid, within its range, and may be thought of as a special case approximation of its successor, which is itself regarded as a superset of its predecessor. The following clues to Cochrane's accomplishment, paraphrased from the preface to his own textbook, are deemed safe for 20th century humans.

The first is that while current attempts to build ever larger particle accelerators will lead to the unification of the strong nuclear force with the electro-weak force, this approach will not be successful with gravity. The reason is that while accelerators of sufficient power approximate the fantastic extremes of temperature and pressure found during the era immediately following the Big Bang, it was not these aspects of the early universe but rather the extreme curvature of space-time then in force which wedded gravity to the other forces. As space-time expanded, or flattened, gravity was the first force to de-couple from the others.

The second clue is that while Newton's mechanics were based upon the Euclidean model of geometry, and Einstein's was grounded in 19th century alternatives such as that of Riemann, Cochrane found the mathematical tools he needed to join the probability functions of quantum physics to the structures defined by distortions of space-time in the "strange attractors" of Fractal Geometry's framework for the study of "chaos".

The warp effect itself derives from Cochrane's advanced concepts of gravitation under which the interaction between the mass of a physical body and the surrounding space/time matrix defines a complex mathematical field known as a continuum profile. On a purely theoretical level, Cochrane was able to establish a new understanding of the term velocity by demonstrating an intriguing difference in the continuum profiles of moving objects versus those stationary relative to the observer. All objects having mass distort the space/time continuum around them, but when an object is in motion relative to the observer, the pattern of the this distortion, known as the continuum profile, becomes skewed along the direction of travel.

Space/time is not infinitely malleable, it takes a minute but finite interval for gravitational distortions to be fully manifested upon newly encountered regions. Because of this propagation-time factor, the region of space/time in front of a moving object at a given instant is not as distorted as it would be had the object in question been excerting its gravitational influence on it for an arbitrarily long period, and the region behind the traveling body shows excess distortion because of the time it takes to flatten back to its undisturbed state. The concept of relative motion remains in

force, for the skewing of the continuum profiles of all objects in the universe is measured from the vantage point of the observer's own comparably skewed line of travel. In measuring the velocity relative to himself, the observer is actually noting the degree of continuum profile skewing relative to his own, and an inertial frame of reference becomes one with a constant degree of skew.

In astrophysics, this effect is largely muted by the ability of space/time to "remember" repeated transits, so that all cyclic motions, such as the orbits of planets, literally "groove" their paths into the very fabric of the continuum, diminishing the skewing effect to almost vanishing levels. Also, such circular motions involve the interaction of mutually influencing bodies, so that each experiences far more change in the direction of its skewing factor than in its absolute magnitude.

But for non-cyclic motions, such as that of spacecraft executing huge linear translations thru the continuum, the effect is sufficiently pronounced to impact observations made from onboard instruments. Generations after Cochrane, the ability of the space/time continuum to store such information-laden "memories" would be used by Dr. Carol Marcus to establish the theoretical basis for the long suspected existence of morphogenetic fields, and would lead her to attempt the exploitation of this phenomena via the "Genesis" technology.

In creating his unified field theory, Cochrane opened the door to full-scale interaction/exchange between the primal forces of nature. Using the analytic tools of his carefully derived Impulsor Calculus, he has able to map out complex yet stable forms of interwoven electro-magnetic fields which would cross "the line" by manifesting part of their effect in the form of gravitational phenomena. He was then able to follow the conceptual trail back to the actual design and contruction of field generating coils that could transform his theories into useful technology. In his first great practicle success, he proved that if his coil systems were used to reconfigure the continuum profile of a "stationary" object so that it acquired the relative "skew" of a moving one, it moved accordingly.

This led first to the developement of the long wished-for "jetless" space drive, ultimately called "Impulse drive", in which designers no longer needed to bother about reaction mass carried onboard only to serve as kinetic exhaust. Later studies revealed that the application of sufficient power to the skewing field would produce a degree of skew effect so highly pronounced as to be insupportable by the familiar Einsteinian continuum. Attaining this "threshold" level would so stress the ordinary continuum that a vessel and its surrounding field envelope would literally be ejected into a higher order continuum in which the speed of light was no longer relevant as a limiting factor. Cochrane himself visualized our familiar continuum as "floating" above the larger realm, and so described the transition process as "dropping into sub-space" rather than apply an upward linguistic bias and the overused "hyperspace".

A gentle, private, and in some respects almost old-fashioned man, Cochrane lived far enough into his twilight years to see his work send humanity to the stars, before he mysteriously vanished. Some say that the warp-driven space yacht presented to him by the greatful governments of several worlds disappeared at the same time, fueling speculation that he headed into unknown space on some final adventure. While historians argue over his ultimate fate, none dispute the enormity of his contributions, without which the very founding of the Federation could never have occurred.

Just as the 20th century's mastery of undreamed of natural forces such as electricity produces technological wonders inconceivable to 17th century minds, so did Cochrane's breakthru set the stage for a vast family of related

discoveries and devices that seem almost magical to residents of our time. In the decades following the construction of the first "impulsor drives", further experimentation and theoretical studies led to totally different, often unexpected, applications of the basic Cochrane coil system. The coil itself would become as basic a concept to an entire branch of technology as the "circuit" is to the field of electrical engineering.

Physicist Alicia Chalmbers interwove two coils, one wound clockwise, the other anti-clockwise, and sent twin currents thru them in opposite directions. The "Chalmbers" coil did not move, as its external effect upon the continuum was balanced between opposite and equal influences, but within the dual-coil itself a profound disruption of space/time took place. Wave like patterns of variation in the "topological gradient" or distortability of space/time, went out equally in all directions. A second Chalmbers coil, though unenergized, reacted to the distortion pattern by converting part of its energy content back into electricity.

Of course, modulations in the current flow to the first Chalmbers coil were echoed analog fashion in the current output of the second "receiving" coil, giving birth to sub-space radio. The effect propagates at the theoretical limit of the warp effect, Warp 10, the actual speed depending on whether the Chalmbers coils are of the Primary, Secondary, or Tertiary variety. All StarFleet, and virtually all modern civilian vessels, use Tertiary Chalmbers systems, allowing communications at 131792.79 x C. Passive listening for natural occurences of this phenomena, and the active use of a form of sub-space radio in "radar" mode, constitute much of the sensor technology of Starships.

Another variation of the basic Cochrane device bends the coil away from its "barber-pole" configuration, to double back on itself full circle, in effect coiling the coil in a single loop. The result is an artificial gravity field projected perpendicular to the plane of the loop, in either pull or push mode depending on the orientation of the windings and/or the direction of current flow. Within its housing, the loop coil is physically anchored or it would simply spin in a warp driven circle rather than impart its effect to the gravity field. Such units are always paired so that the torque from each cancels the other rather than be imparted to the vessel via the structural elements holding them in place.

Other variants of the Cochrane coil take the form of conical shaped pairs of coils nested within each other facing in opposite directions. The conical shape causes the warp field's skewing effect to be projected away from the coil system rather than centered upon it. By using the two coils in tandem, one can induce any desired combination of push or pull force up to the system's operational limits on a distant object, moving it arbitrarily close to the starship's hull and holding it there. Known as a tractor beam, this piece of equipment is indispensable for modern spacecraft operations, without it sleek warp-driven starships would be reduced to reliance upon primitive manipulator arms such as the one found on the 1980's space shuttle. When holding a derelict vessel via tractor beam, it is possible to apply the the repulsive force against selected portions of the outer hull, concentrating the attractive force thru the vehicles' center, so as to not only retrieve and stabilize it, but provide artificial gravity as well for the comfort of boarding parties.

In man's first experience with interstellar combat, the technological level of the participants had the vessels of both sides drop into sub-light speeds to maneuver against each other in a tight volume of laser crossfired space. These primitive battles were analogous to the way in which late 20th century fighter planes would reach a combat zone via supersonic travel, then go subsonic for the actual dogfight. The advantages of a weapon that could unleash its effect at warp speed were so obvious that an all out technology

race to build such a device began even before the first Romulan War was over.

Ultra high velocity missiles carrying powerful matter/anti-matter warheads were already in use. As the M/A anhilation produces a shower of photons in the extremely high energy gamma ray portion of the spectrum, these missiles were dubbed photon mines. Though their highly developed fusion thrusters could accelerate them at hundreds of G's, they were still so slow compared to even the sublight capabilties of impulse driven starships that one had to use them in the manner of depth charges, simply deploying them in the expected path of the enemy ship and hoping for the best. Attempts to replace the fusion thruster with a warp engine enjoyed some success against vehicles moving at sublight speeds, but against vessels traveling at warp speeds what was needed was a weapon that could travel substantially faster than any ship.

The answer was ultimately inspired by the ancient submarine torpedo, which used steam power pumped into the torpedo by the submarine rather generated onboard the weapon itself. The modern analog of the torpedo tube emerged as an inside out warp engine coil which generated its field within its own interior and imparted an enormous skewing effect on any object placed inside. The specially designed warhead pod would zip out of the tube at extremely high warp speeds, having an unprecendented degree of skew, but free of the mass of any onboard warp field generating equipment. Though the warhead pod is designed to retain its imparted skew as long as possible, it does begin to decay immediately after leaving the tube. As this takes at least several minutes, the effective range is quite adequate for the tactical role these weapons play. Note that these devices have almost no steering, only a slight course correction capability, and so must be carefully aimed. The parallel to ancient submarine weapons was so close that the term "photon torpedo" became permanently attached to these deadly implements of celestial combat, which in the ST:TNG era are capable of as much as 10 to 15 minutes travel at speeds approaching warp 9.9.

Early experiments with Dilithium crystals found that two such crystals, a mirror, a semi-reflector, and a light source made a marvelously efficient laser, as Spock once demonstrated in escaping from Gestapo headquarters on the planet Ekos. When Science Officer Bruno Wilhelm placed a dilithium laser setup inside a Chalmbers coil, the crystals synchronized so as to overlap the coinciding lightwaves exactly out of "phase" making the light energy effectively vanish from our continuum, only to reimerge as a uni-directional highly intense disruption of the space/time continuum now known as the "phaser effect". Such synchronization of the crystals required a super-luminal transfer of coordinating influences, and so was only possible in the context of a coil-induced sub-space environment. Within the coil, one can reasonably construe the laser as being "in" sub-space.

When fully powered, the phaser effect travels at the Warp 10 limit for the type of Chalmbers coil used, be it Primary, Secondary, or Tertiary. Naturally, StarFleet vessels are armed only with Tertiary phasers, anything less would produce a "beam" literally too slow to catch a Tertiary warp starship with Dilithium focused anti-matter reactors.

However, hand phasers don't have access to quite enough power to energize the coil component to its equivalent threshold power level. The result is that the phaser beam produced travels at a speed dependent upon the power level applied to the coil. Whereas a beam emitted from a coil at threshold power would always move at Warp 10, with additional coil power just boosting the intensity or striking power of the beam, at just below threshold power the beam's speed is the reciprocal of Warp 10. This is a mere 7.58766 x 10^(-6) x C, or approximately 7300 feet per second from a Tertiary coil, therefore hand phasers use Primary coils so that the phaser effect

propagatation velocity is proportional to the reciprocal of the Primary warp field's Warp 10 limit of 22025.47 x C. The reciprocal value is therefore approxiamately 8.45 miles per second. At still less coil power, the speed diminishes in direct proportion to the fraction of threshold power applied to the coil. Operational maximums for ST:TNG hand phasers take their coils to about 1/3 of threshold velocity, so that the weapons full power effect moves at roughly 2.82 miles per second.

One can vary the proportion of coil vs. initiating light energy levels only so far without overloading the hand phaser, causing burnout or even detonation. Thus to moderate the phaser effect down to stun levels, the beam in some models of hand phaser may travel as slowly as 200 or 300 feet per second. We've seen this effect quite clearly when Kirk once fired his phaser set for stun at the metabolically accelerated Deela of Scalos, who simply stepped out of the way. Hand phaser on stun is definitely a close quarters only weapon, where speed is not significant.

Unlike sub-space "radio", which simply attenuates under an inverse square law, phaser beams have a much shorter range due their propensity to "decay" by losing their energy to the creation of visible spectrum photons all along their path of travel. This is what the observer sees, not the phaser beam itself. The actual phaser effect is one of micro-range random space/time fluctuations in the topological gradient of the space encountered, imparting warp impulses to the atoms encountered. The effect tends to spread and propagate thru solid matter, so that material objects are likely to distribute the effect throughout their particularly shaped volumes.

At high power, the effect is so severe that all molecular bonds are snapped, and all of the particles are "impulsed" in random directions. What had been a solid object becomes an expanding cloud of particles moving fast enough to penetrate other solid matter to an enormous extent. A body so "disintegrated" on a ship would pass right thru the hull like a burst of gamma rays, but because the particles are traveling via impulse rather than momentum, their behavior apes that of neutrinos in that they do almost no damage to the matter they pass thru.

Lower power simply streches the molecular bonds without breaking them, their rebounding motions translating into simple heat. In this manner, a hand phaser may be used to heat rocks for warmth, cook food, or even act as a very precise cutting torch. At the lowest useful power, the jolting of molecules is too slight to really impact inanimate matter, but does tend to produce neurological shock as large numbers of synapses have their firing threshold randomly raised or lowered. The vast number of additional versus inhibited synaptic firings causes a biological equivalent of "systems crash" leading to unconsciousness, as the nervous system becomes hopelessly confused and overloaded by spurious signals. As no actual tissue damage is sustained, the nervous system "reboots" itself eventually. Somewhat higher power can do permanent, even lethal damage to the nervous system however, and can cause a seizure-like muscular convulsion. This minimally lethal effect is not unlike electric shock.

To residents of the 20th century, the transporter is perhaps a more incredible application of Cochrane's Unified Field Theory than superluminal travel, since the later affords no real Terrestrial gauge for appreciating the effect, whereas the wonder of instantaneously materializing elsewhere has been part and parcel of Earth's mythology/magic belief systems for millenia.

Building on the ability of the "looped coil" to project gravitational fields, experimenters eventually learned to handle gravity d sues in ways that parallel optical technology's capabilities with light waves. Ultimately, command of these techniques was sufficient to produce a gravitational wave "hologram" in which the system literally captured the continuum profile of an

object down to the minutest detail of atomic constituents and molecular bondings in the intersection between its stationary "reference beam" and the rotating "scanning beam". Sophisticated split beam techiniques permitted the "projection" of a second "continuum profile image", which, depending on the operational limits of the equipment, could be located at an arbitrarily large distance and direction from the source. These experiments were originally conceived in pursuit of improved medical technology following the progression of X-rays, ultrasound, nuclear magnetic resonance, and positron emmision tomography, with the result enabling Dr. Crusher to obtain a clear view of the parasite creature embedded in Admiral Quinn during the "Conspiracy" period.

The transporter breakthru grew out of experiments attempting to manipulate matter via alterations of the continuum profile associated with an object. If a continuum profile projection were maintained long enough, it began to fill itself in with atoms picked up from the environment. Eventually, it would recreate the original, though in the meantime, if sufficient power was used to intensify the projection, this profile construct could behave like the original, even appearing to be solid matter, as long it remained within range of the projection radius. At the same time, it was shown that changes in the profile of the original were reflected in the original object as well in the projection, establishing the real-time linkage between the two. Early attempts at matter manipulation were usually destructive, not until the early 24th century would the raw computer power be available for such things as the holodeck, where the projection could be based on computer simulations rather than real life / real time models, but in these pioneering efforts, the ability to project a profile back on its own source object, while maintaining an independent second projection elsewhere, was developed.

Dr. Janet Hester of the Deneva Research Station first conceived the idea that if one reversed the "topological polarity" of the image projected back upon the source, in effect FLATTENING the impression it made in space/time, while simultaneously boosting the gravitational intensity, and thus the DEPTH of the spatially projected image, one could create a situation in which the probability of finding any given constituent of the source object at the original location could be reduced to zero, even as the probability of finding it at the projection's location went up to unity. Every component of an object, its atoms, the chemical bonds between them, even the ongoing molecular processes, would cascade back and forth between the twin loci of probable locations, finally coming to rest at the one brought to unity. Of all the marvels that have sprung from Zephram Cochrane's insights, none more clearly demonstrate his success at unifying gravitational space/time continuum phenomena with quantum mechanical probability functions.

It would take another four decades of dedicated experiment and study before Science Officer Winston of the USS Moscow became the first human to transport across to the USS Tehran. Still more work was required before the ability of the tranporter to project a "virtual" yet functional copy of the active components of the scanning and projection processes to envelope the retrieval site would eliminate the need for physical hardware at both ends of the transport linkage, and theb to learn to bend the projection around the surfaces of planets using the natural gravitational field so that transport could be free of line-of-sight restraints. The depth of dense planetary matter the transporter can penetrate is still limited, but the often life-saving speed and conveinience of transport in general has proved well worth the time, cost, and often sacrifice it took to perfect.

The Secondary Warp field effect was originally achieved by winding a

second-stage "booster" coil around a specially designed Primary coil. The early versions of this system would energize the Primary coil first to navigate at low percentages of threshold power. Once clear of stellar and planetary gravitational fields, they would engage the booster coil reconfiguring their warp field into the 2nd order type. When this was accomplished, power would be steadily increased until the threshold level was attained and transition to the warp continuum occured. The Primary and the booster together constitute the Secondary coil. Should the booster fail under operational stress, a fairly common occurence in the early days, the Primary alone could be used and could operate above its threshold level to take the ship to superluminal velocities.

While later vessels retained the above system layout, experience proved it far more efficient to energize the whole Secondary coil system as a single circuit, and to navigate at very low power and speeds with an independent miniature Primary system. This became known as the Impulse Drive. As it was intended only for low speed operations, this system would not normally be capable of handling the power load it would require to bring the vessel past the threshold point. However, engineers took advantage of this dual propulsion system to split the vessel itself, letting each major sub-division of the hull house one of the systems. It became customary to place the major living quarters in the hull with the smaller Impulse Drive, both to better shield the crew from the higher radiation levels the more powerful Secondary system created, and also with the idea of better accomodating the entire crew should "coil burnout" force the abandonment of the other hull.

The terminology of vessel design adopted the convention of referring to the hull housing the Secondary coil system as the Secondary Hull, and the other housing the Primary coil only Impulse Drive as the Primary Hull. Tertiary drive systems simply wound yet another type of booster coil around the Primary and Secondary stages nested inside it, but as there were still only two drive systems and two main hull sections, the one with the large engine system continued to be called the Secondary Hull.

In the event of separation, the Primary Hull's Impulse Drive, freed of the weight of the entire Secondary Hull and the even more massive main drive engine nacelles, is usually large enough for superluminal propulsion. This has been shown quite clearly in ST:TNG during the initial encounter with Q, when the Primary Hull found its way to Farpoint after the entire ship spent some 10 minutes pushing itself to its operational limits while going in exactly the opposite direction. It is equally well implied by Geordi's instructions to Engineer Logan to take the Primary Hull to a Starbase if unable to re-establish contact with him after performing the saucer-sep manuevar in the "Arsenal of Freedom" incident.

The first three orders of warp field phenomena correspond to the first three "generations" of warp drive technology in the "Spaceflight Chronology". Logically, a "Fourth generation" designation should have waited for the developement of Quarternary warp, the sum of X^4 + (X^5)/5 + (X^6)/30 etc., equivalent formula 24*((e^W)-((W^3)/6 + (W^2)/12 + W + 1)), but the impact of Dilithium on power generation, and thus overall performance, was so great that the "Fourth generation" label took hold for the Constitution class. All orders of warp field phenomena remain subject to the Warp 10 limit on Delivered Power, but higher order warps produce greater velocity for the same Delivered Power than lower orders. (See Appendix for tables of Primary, Secondary, and Quartenary Warp Factor Equivalent Velocities).

The term "Fifth generation" is usually applied to the abortive attempt to harness "Trans-Warp", a misbegotten application of the Interphase phenomena first observed by the Enterprise NCC-1inguchurg the "Tholian Web" incident. The abandonment of this dangerous system was made doubly disappointing by the continued failure of Federation science to perfect a workable Quartenary warp

drive. The seemingly insurmountable difficulties encountered in the early attempts at Quarternary drive design were the prime reason for the costly "Trans-Warp" interlude.

However, in the intervening decades advanced theoretical studies have led to vastly simpler, more reliable Tertiary drives which can be pushed, and above all held, far closer to the Warp 10 limit of Delivered Power than the original design multi-stage units. These single stage "integrated" units were first used in ship's of the NCC-1701-C's Ambassador class, and marked the arrival of warp technology's "Sixth generation". A highly refined and advanced version of this type of drive serves as the main propulsion for "Galaxy" class starships such as Enterprise NCC-1701-D. Gone are the inefficientcies of the nested, three coil approach, advances in Impulsor Calculus theory and supercomputer simulation techniques having found a single coil equivalent.

As the early efforts at Quarternary warp floundered on the complexities of a four level multi-stage approach, the success of the single stage "integrated" approach for Tertiary warp has scientists of SF:TNG's era once more confident of eventual success, and aggressively paced research programs are again under way in the race for the Quartenary drive. It should be noted that the extra heavy warp nacelle mountings and overall structural strength rating of the Galaxy class design should easily permit retrofitting of Quarternary Warp engines when they become available.

Montgomery Scott correctly predicted the crippling deficientcies of the Trans-Warp system, but was unable to dissuade StarFleet from investing in it. Rightly convinced that Quartenary warp would have to await improvements in warp theory permitting "integrated" designs, he attempted to convince StarFleet to allow him to challenge the Warp 10 Barrier itself. Alas, Scott was never able to secure StarFleet backing for his proposal, and only a handful of ST:TNG era technical persons who've studied his original notes even know what he had in mind.

Realizing that the "SuperWarp" scheme was far too radical for his era, Scott dedicated his leisure time engineering studies to the design of the ship he felt StarFleet should build in place of more "Excelsior" class vessels. Yet this project also offered too many radical advances, as Scott was allowing for upgrades to integrated Tertiary or even Quartenary main drives in his huge dreamship. But while the Galaxy class would ultimately be larger and incorporate advances beyond his wildest imaginings, even a cursory glance at Scott's old plans and drawings reveals the striking similarities that mark the true lineage of these greatest of all StarShips. NCC-1701-D's operational status is the way Scott would most have wanted StarFleet Engineering to acknowledge its continuing debt to its greatest practitioner.

As for the mechanics of SuperWarp, the mathematically inclined are invited to contemplate the significance of the other half of the hyperbola relating Generated to Delivered power, which most Federation scientists dismiss as a mere geometric curiousity. Of course, scientists once thought that C itself represented an impassable barrier, yet as Spock would say, "There are always possibilities".

Without giving too much away, I can offer the following clue, that the Constitution class USS Enterprise NCC-1701 under James Kirk, once broke through the Warp Barrier by accident, the result of her Captain's famous propensity for taking desperate gambles in otherwise hopeless situations. Students of warp physics correctly identifying the occassion are eligible to win a scholarship to StarFleet academy, which, alas, may not be used until the 23rd century.

-Leon Myerson; 72157,3432; 6/23/88

## APPENDIX 1 - PRIMARY WARP

| Generated Power | Delivered Power | Primary Warp x C |
|---|---|---|
| 1 | 1.00000 | 1.72 |
| 2 | 1.98354 | 6.27 |
| 3 | 2.96260 | 18.35 |
| 4 | 3.93509 | 50.17 |
| 5 | 4.89755 | 132.96 |
| 6 | 5.84370 | 344.05 |
| 7 | 6.76140 | 862.85 |
| 8 | 7.62571 | 2049.24 |
| 9 | 8.38615 | 4384.92 |
| 10 | 8.96633 | 7833.82 |

Theoretical Limit = 22025.47 x C
Threshold Velocity = 0.5814 x C
Time Dilation at threshold = 0.813205

## APPENDIX 2 - SECONDARY WARP

| Generated Power | Delivered Power | Secondary Warp x C |
|---|---|---|
| 1 | 1.00000 | 1.44 |
| 2 | 1.98354 | 8.57 |
| 3 | 2.96260 | 30.77 |
| 4 | 3.93509 | 92.46 |
| 5 | 4.89755 | 256.13 |
| 6 | 5.84370 | 676.42 |
| 7 | 6.76140 | 1712.18 |
| 8 | 7.62571 | 4083.24 |
| 9 | 8.38615 | 8753.06 |
| 10 | 8.96633 | 15649.70 |

Theoretical Limit = 44030.93 x C
Threshold Velocity = 0.6944 x C
Time Dilation at threshold = 0.71793

## APPENDIX 3 - QUARTERNARY WARP

| Delivered Power | Generated Power | Quarternary Warp |
|---|---|---|
| 1 | 1.0000000000 | 1.24 |
| 2 | 2.0167653720 | 25.34 |
| 3 | 3.0383208502 | 170.05 |
| 4 | 4.0670614879 | 742.36 |
| 5 | 5.1072983806 | 2617.92 |
| 6 | 6.1676537197 | 8218.29 |
| 7 | 7.2682459514 | 24167.20 |
| 7.5 | 7.8487197368 | 40826.52 |
| 8 | 8.4694304149 | 68510.99 |
| 8.2 | 8.7364919027 | 84149.66 |
| 8.4 | 9.0203187626 | 103286.47 |
| 8.6 | 9.3280961537 | 126697.69 |
| 8.8 | 9.6717993420 | 155331.49 |
| 9 | 10.0729838055 | 190346.01 |
| 9.1 | 10.3071067812 | 210676.62 |
| 9.2 | 10.5747605008 | 233155.87 |
| 9.3 | 10.8903152831 | 258009.95 |
| 9.4 | 11.2777216596 | 285488.88 |
| 9.5 | 11.7800905867 | 315868.94 |
| 9.6 | 12.4836439773 | 349455.49 |
| 9.7 | 13.5895662949 | 386586.00 |
| 9.8 | 15.7014109302 | 427633.43 |
| 9.9 | 21.8369448362 | 473009.97 |
| 10 | INFINITE | 523171.18 |

Theoretical Limit = 523171.18 x C
Threshold Velocity = 0.8065 x C
Time Dilation at threshold = 0.590200

For comparison, here is a chart of Quarternary Warp Factor equivalent velocities keyed on the older "Generated Power" scale.

| Generated Power | Delivered Power | Quarternary Warp x C |
|---|---|---|
| 1 | 1.00000 | 1.24 |
| 2 | 1.98354 | 24.41 |
| 3 | 2.96260 | 159.92 |
| 4 | 3.93509 | 680.00 |
| 5 | 4.89755 | 2315.80 |
| 6 | 5.84370 | 6908.99 |
| 7 | 6.76140 | 18761.08 |
| 8 | 7.62571 | 46527.25 |
| 9 | 8.38615 | 101833.70 |
| 10 | 8.96633 | 183948.24 |
| 11 | 9.33067 | 266146.24 |
| 12 | 9.53548 | 327403.32 |
| 13 | 9.65322 | 368752.42 |
| 14 | 9.72615 | 396927.10 |
| 15 | 9.77477 | 416884.29 |
| 16 | 9.80915 | 431599.84 |
| 17 | 9.83463 | 442835.76 |
| 18 | 9.85421 | 451667.92 |
| 19 | 9.86971 | 458779.77 |
| 20 | 9.88225 | 464622.34 |
| 21 | 9.89262 | 469503.75 |
| 22 | 9.94445 | 494688.02 |

-end of line