PART THREE: POWERING THE NEW SYSTEM

The Future Combat System (FCS):

A Satellite-fueled, Solar-powered Tank?

by Asher H. Sharoni and Lawrence D. Bacon

(This is the last in a three-part series exploring a conceptual future combat system.-Ed.)

The Two Man Crew - Is It Feasible?

The FCS must be significantly smaller and lighter than the M1 tank. Its crew ought to be smaller than the conventional four crew members in order to yield a lesser protected volume. Full automation, consolidation, and centralization of major functions performed by a conventional crew will eventually lead to dramatic crew reduction. The major functions of commander, main armament operator, weapons/self-defense suite operator, data processing, and driver/navigator could be alternately assumed by each one of only *two* crew members.

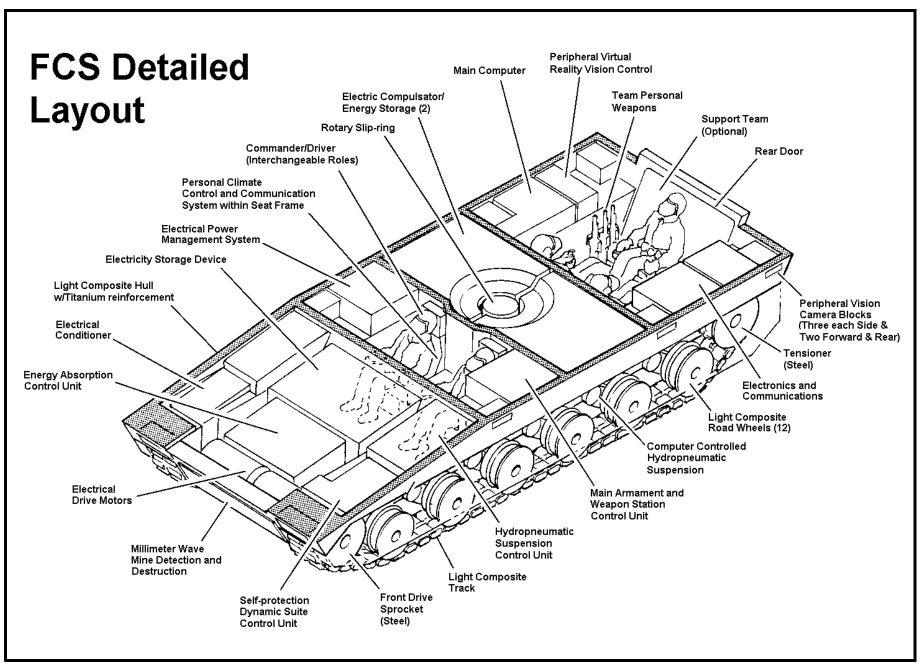
The adaptation of a reduced crew requires a dramatic departure from the underlying philosophy of conventional tank operation. The two crew members must be regarded as ‘pilots’ that could not and should not be expected to perform routine functions presently assigned to conventional tank crews. It practically implies that logistics, maintenance operations, sentry duties, and alike, should be *minimized* by virtue of highly-advanced technologies and extended reliability. The tank self-defense systems should operate intelligently and independently, continuously watching, monitoring and protecting, while the crew is asleep, recuperating, or inoperable.

Alternative Energy Propulsion Sources for Automotive Applications

A predominant FCS requirement is to significantly lessen the dependency on conventional fossil fuels, thus making the FCS more independent and capable of operating over long periods of time without resorting to periodic maintenance and logistical support. This requirement is extremely difficult to satisfy, and necessitates a dramatic departure from any conventional power source presently in use. As shown, the FCS power pack is configured for an all-electric front drive installation (see FMBT). Electrical propulsion for mobility applications is widely recognized today as the wave of the future, let alone the fact that another major system is also utilizing electrical energy for its operation.

• Hybrid Electric Power System

Last year, it was reported in *Defense Daily*[1] that DARPA is embarking upon a new venture to find a contractor team able to inexpensively develop and demonstrate the capabilities of a highly-effective, Hybrid Electric Power System (HEPS) for generation and storage of electricity. HEPS is intended for automotive applications as a prime-mover in advanced combat vehicles (FCS and the Future Scout Cavalry System - FSCS). In essence, HEPS is comprised of a diesel engine or gas turbine directly coupled to generators to produce electrical energy for storage and subsequent use by the vehicle systems. To promote industry participation, DARPA is contemplating that the development of electricity-producing and storage systems will give the contractor team a hedge on the worldwide competition in the developing commercial electrical vehicle market. DARPA has realized that, only through the economy of scale offered by the financial strength of commercial industries could it expedite the outrageously expensive development of such novel systems. Only with sound mutual commitment via partnership with industry, ag-



Sketch of the FCS concept vehicle shows a third, optional crew member who could relieve the two men necessary to fight the tank. Automated functions would also provide self-defense during rest periods, and the crews would be relieved of many current logistic and maintenance tasks.

"Present commercial and military nuclear applications are considered unpopular because they contradict the current trend towards diminishing civil nuclear applications, and in particular, the trend toward banning the proliferation of nuclear weapons...."

gressively pursuing the Pentagon's new *Streamlined Acquisition Reform* (SAR) and *Integrated Product Team* (IPT) processes, along with the promise of significant potential benefits to the commercial worldwide market, could such an enormous endeavor come to pass.

DARPA has announced its intention to invest more than $40 M(!) to develop and test the HEPS over the coming few years. Competing teams will develop and demonstrate an integrated HEPS for a 15-ton vehicle (e.g. FSCS), but they will also be required to demonstrate, by computer simulation and computer virtual modeling, that a more powerful version of the HEPS could be integrated into a 40-ton vehicle (e.g., FCS). Granting industry the prerogative to come with its own designs, without stringent directives from DARPA, is another fine idea that has great merit and will pay handsome dividends in terms of shorter schedules and overall reduced developmental costs. Nonetheless, though same basic technology could be used to power the FCS, it is not in accordance with the requirement for simplified and reduced logistics. Integrated HEPS are more efficient, and have improved performance compared to contemporary diesels or turbine-based power packs. They operate with less noise and with reduced thermal signature, thus improving survivability. It remains to be seen whether integrated HEPS will come out less costly in production and deployment than contemporary power packs. Attempting to capture the best of two worlds, HEPS seem to be more applicable, as a near-term solution, to the lighter FSCS and similar vehicles, and less so for the longer-term, heavier FCS. HEPS is still going to require diesel or turbine fuel for its operation, and would add a piston engine or a gas turbine, in addition to a sophisticated electrical power generating system, to worry about.

• Nuclear Energy Propulsion As a Prime-Mover Energy Source

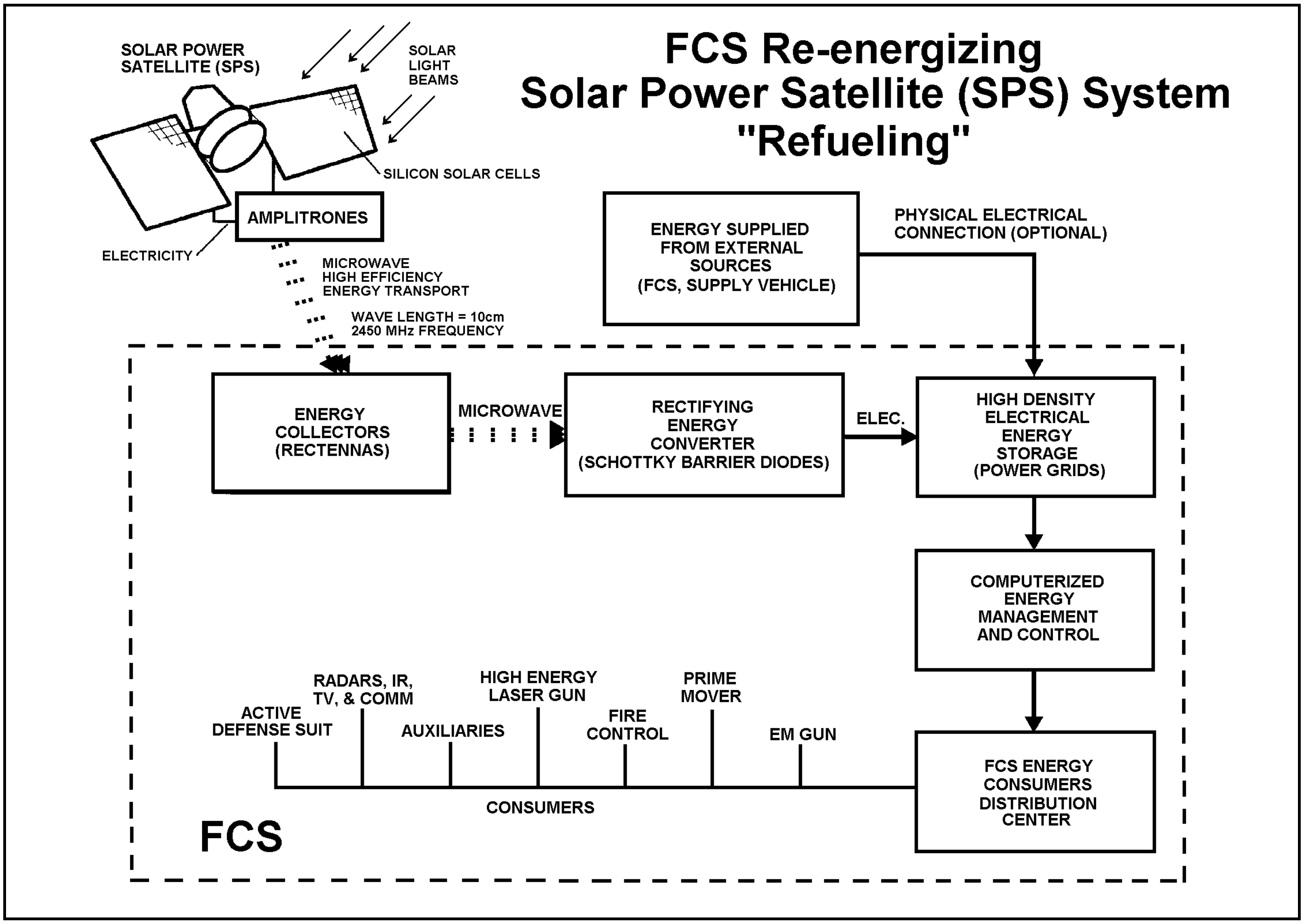
When one thinks of feasible options, *nuclear* propulsion for ground automotive applications immediately comes to mind. The energy produced by a nuclear reactor is released by the fission of atomic nuclei in a controlled and self-sustaining manner, and appears as heat, which is then converted to electrical energy by using conventional turbine generators. As an example, the *Fast Breeder Reactor*[2] (FBR) now under active development, uses fast neutrons produced by fission without slowing them down, such as in a conventional Thermal Reactor (TR). The fuel used has a higher concentration of fissile material (plutonium-239 and uranium-235) with the high concentration resulting in a much *smaller* core. Molten sodium or high-pressure helium are used as coolants. In essence, the FBR generates more fuel than it burns, so it could continuously operate for extended periods of time. By processing the burned fuel, it is possible to use up to 60 pecent and more of the energy stored in the uranium, as opposed to just a few percent with thermal reactors. The energy potentially available from the fissioning of uranium and thorium in FBRs is at least a few orders of magnitude greater than that of all fossil fuels sources combined.

The emergence of nuclear power as a viable energy source for automotive military applications comes at a time when additional environmentally acceptable sources of energy for civil and military consumption are sorely needed to meet continued rapid increases in demand. Despite its undeniable potential, the authors decided to reject this alternative up front on both environmental and political grounds. It is primarily because of the inherent difficulties and safety hazards involved in dealing with radioactive radiation in peacetime, accidents, and war.

Another drawback will be the formidable demilitarization problems associated with discarding radioactive products and radioactive residual materials. Furthermore, there are insurmountable difficulties in cooling the nuclear reactor and 'purifying' the working liquid when the only available coolant in abundance is ambient air (a poor heat conductive substance with a much lower heat transfer efficiency than water), rather than the unlimited sea water supply commonly used in submersible and surface naval applications. The reactor under armor must be ruggedized, and the control rods — which regulate the speed of reaction — must be stabilized to account for the jagged motion over typical cross-country terrain. In addition, the nuclear reactor and its auxiliaries — its insulation, cooling, pumps, controls, monitoring and redundant safety devices — must all be made inexpensive to produce in order to make any economical sense. Present commercial and military nuclear applications are considered unpopular because they contradict the current trend towards diminishing civil nuclear applications, and in particular, the trend toward banning the proliferation of nuclear weapons. This option may be regarded as feasible if there was a *safe*, practical, and economical way to neutralize radioactive radiation and demilitarize residual nuclear materials while preserving the natural environment.

• Solar Power Satellites In Space: A Possible Long-Term Energy Source Solution For The FCS

Solar energy is considered by many as an ideal energy source. It is clean; it produces no pollution,[3] and there are none of the nuclear residual radioactive wastes that make nuclear energy so unpopular in the public eye. It is practically unlimited, so it will still exist in abundance long after fossil fuel reserves become scarce, sometime during the next century. And best of all, solar energy is free, short of the cost of harnessing it for human consumption. A Solar Power Satellite[4] (SPS) is placed in a *geostationary* orbit (36,000 km) above the equator, similar to the orbit being used for communication satellites. The SPS is so positioned in space that it revolves at the same rate as the Earth spins, being relatively fixed to the equator, and can intercept at least four times as much solar energy as the sunniest spot on Earth. The SPS intercepts unobstructed sunlight (no clouds, bad weather, or darkness in space), converts it into microwaves (short-wavelength radio waves) and beams them back to collector arrays on Earth where they could be converted with *high efficiency* into electricity. Depending on its size, the SPS could deliver thousands of millions of watts, practically in a continuous manner. In 1980, a joint study conducted by NASA and the U.S. Department of Energy



(DOE) concluded that it was feasible to construct a fleet of 60 solar power satellites, the first of which will be in operation in 2010 and the last by 2040.

A SPS could reach a mass of about 50,000 tons, but it is weightless in space. Solar cell arrangement is preferred, because there are no moving parts to malfunction, and the use of solar cells in space is already well established. SPS subsystems and structural components must be lifted off the face of the Earth while overcoming gravity, and subsequently positioned in orbit. Solar cells, made of silicon (or gallium arsenide for better efficiency) convert sunlight directly into electricity. Remotely-controlled and operated *'space robots'* could construct the lightweight structures which support the array of solar cells. Whether the SPS uses turbines or solar cells, the electricity generated will be converted into microwaves by devices known as *Amplitrons* (also *Klystrons*) and then beamed to Earth at an area of limited diameter. At a wavelength of 10 cm (2450 MHz) this type of microwave radiation passes through the atmosphere virtually unabsorbed. At the ground, receiving arrays termed *Rectennas*, installed on the FCS as shown, will collect the microwaves to convert them very efficiently (83+ %) into electricity. The rectennas will consist of panels studded with T-shaped aerials linked to rectifying devices known as *Schottky* barrier diodes, which convert the microwave beam back into electricity. One of the arguments against beaming power to Earth is that microwave beam radiation might damage humans. This problem could be mitigated by using a beam that is stronger in the center, but it must be very accurate. The accuracy of beaming could be much improved with the aid of the Global Positioning System (GPS), which is also satellite-based. Any realistic assessment of the dangers of power satellites must be balanced against the pollution from fossil fuels, and the waste from nuclear reactors.

The SPS concept may resemble "Star Wars" and frontier-of-science type of technology, but successful and promising experiments have been conducted in the past that validated the feasibility of such an idea. Using its Global Positioning System (GPS), each individual FCS could identify its definite location so that it could receive the transmission with high accuracy and, better yet, while on the move. Once the transmitted energy has been absorbed by the FCS, it will be converted into electrical energy and stored in high-density storage devices for future consumption. An energy management and control system will allocate energy to the various "consumers" (EM gun, fire control system, laser gun, prime-mover, etc.). The FCS could also receive electrical energy from a dedicated "refueling" vehicle (generator) and by physical connection to another FCS that could share some of its own electrical energy.

Admittedly, there is a vast array of problems yet to be solved in order to harness this type of energy source for automotive applications. To mention just a few:

- The *rectennas* on the FCS must be small to accommodate its limited size, and still be efficient.

- The safety hazard of exposure to microwave radiation must be eliminated or reduced to controllable and acceptable levels.

- Radio noise disruption over a wide range of frequencies, and detrimental ionospheric and atmospheric effects, must be mitigated.

- The beaming process must be sufficiently accurate to hit a single FCS, or a group of them, in a pre-planned rendezvous location, and recharge them within a reasonable duration. The high efficiency of microwave power transmission and reception is crucial to the economics of placing the SPS in space for practical military applications.

In conclusion, the authors realize that one may challenge the feasibility and practicality of such an approach to the refueling problem. It stands to reason that, if we are to be independent from conventional fossil fuels, we *must* use a different source of energy. Just another, even more potent, "synthetic" fuel is not going to provide the desired level of independence from the burden of the logistical "umbilical cord." Compact, reliable, and economical diesel engines[5] have probably reached their peak performance. Turbocharging, recuperation, intercooling, high-temperature resistant materials (e.g. ceramics) and combustion control, have all contributed to their performance with limited progressive improvements yet to be expected. One way or another, this particular problem must be addressed sometime in the course of the next century, when fossil fuel reserves become scarce.

High-Density and High-Energy Storage Systems

The utilization of tactical, electrically energized EM/ETC guns, high energy laser and charged particle weapons, and other subsystems will aggressively drive energy densities (Wh/kg) far beyond those presently deemed acceptable. It will require capacitors and batteries to provide highly-mobile sources of stored energy for producing electrical pulses at the MegaJoules (MJ) level.

Development of electronic components that can handle megawatts of power will lead to solid-state, optical and gaseous switches, high-density batteries and capacitors, advanced magnetics, high-power microwave devices, electrical actuators, and superconducting energy storage.[6] The U.S. Army Research Laboratory's Electronics and Power Sources Directorate, in collaboration with the Tank Automotive Command, are engaged in a study to identify future components such as electric drives, weapons, active protection, and countermeasures.

The most common type of storage device is the conventional lead-acid battery (accumulator). Typical batteries for automotive military applications require a 10-hour charge-up period. When discharged, about 90% of the actual storing capacity (current times time) is recovered. However, when the discharge voltage is lower than the corresponding charging voltage, the actual energy recovered is only 75% of that used previously to charge the battery.

There have been great efforts to reduce battery weight and volume for a given output. This has been accomplished with the development of alkali batteries, which have nickel and cadmium, or nickel and iron plates immersed in a potassium hydroxide solution. These batteries are very robust mechanically and electrically, and have found considerable applications with electric vehicle drives, but they are not adequate yet for utilization in an all-electric military vehicle. Current recovery is 75-80%, but the ultimate energy return is only 60-65%.

High-power/high-densities and cycle-enhanced efficiencies could be obtained from *high-temperature* batteries such as lithium alloy-iron sulfide, and sodium-sulfur batteries. For example, the sodium-sulfur design has a working temperature of over 300° C and has sodium and sulfur electrodes, which are maintained in a liquid state at the working temperature, and an alumina electrolyte, which is in solid state. The output per unit weight (140 Watt x hr per kg) is currently more than five times that of the common lead-acid battery. Promising research is conducted by the Electronics Technology and Devices Laboratory (ETDL) aimed at a *second* and *third* generations of lithium thionyl chloride batteries with energy-density up to 300 Wh/kg and beyond! Current aluminum-air batteries are comprised of an aluminum-alloy anode sandwiched between air-breathing cathode sheets while electrolyte is pumped through the system. They are about twice the volume of a lead-acid cell, though with 15 times the power output. Much research is still required to improve storage capacity and increased recovery levels. Nonetheless, further developments will yield new technologies for developing super high-density storage for extended operations. Computerized integrated power-energy management systems will be introduced to optimize performance, reduce maintenance costs, and improve reliability. Undoubtedly, the logisticians' desire to reduce the vast number of batteries replaced each year in military service, and the emerging electric car market, will substantially contribute to developing technologies for super high-density, maintenance-free, long-life electrical energy storage devices.

Enhanced Mobility

The FCS will be equipped with a highly-efficient, all-electric power train which consumes substantially less energy than conventional prime-movers to produce equivalent output. It could increase the operating range by up to 50% compared to the fuel-guzzling gas turbine engine. It has a much higher power density (HP/ft^3) and is much smaller in comparison to conventional diesel or gas turbine prime-movers (up to 50% increased volumetric efficiency). Power electronics could be increased by 100%, which ultimately implies a smaller envelope of the tank. Other improvements will be in utilizing a composite 'band' track to reduce noise signature (30-50%) and increased life such that no maintenance is required during operational activity.

Tracked suspension is by far the best system ever devised for ground automotive applications in terms of mobility, reliability, and durability. There is no emerging evidence of any other system that could match or outperform it, currently or in the foreseeable future. Tracked suspension will remain the best and only choice for tanks as long as they will ride on the random surface texture of the earth. Future improvements will include extended durability, maintenance-free operation, and substantial weight reduction. The FCS will be equipped with a Hydropneumatic Active Suspension (HAS).[7] HAS is a hydropneumatic tracked system that provides a high degree of tactical mobility. Variable suspension height is dynamically computer controlled and allows operation over all terrain types and in all weather conditions, while improving accuracy of firing on-the-move. HAS can save over a ton of weight compared to conventional torsion bar suspension systems and will significantly contribute to the paramount overall goal of weight reduction.

Composite Armored Vehicle For Reduced Weight

To allow rapid deployability and facilitate transportability, weight reduction is one of the dominant and mandatory prerequisites imposed on the FCS. To achieve meaningful weight savings, the crew must be repositioned in the hull (see FMBT) such that the overall protected envelope could be dramatically reduced. A possible way of complying with this requirement is to manufacture the hull and possibly the 'turret' out of composites with reinforcement of titanium or other light but strong metallic components to serve as a 'skeleton' for maintaining structure integrity. In essence, the issue is to achieve large scale economical production while establishing the level of confidence in ability of composites to be successfully applied in armor structural applications. To gain additional weight reduction, the tracks and road wheels must be made of composites, though they may also contain metallic components for reinforcement. Hughes is currently developing a composite material known as Silicon Carbide (SiC) Whisker Reinforced Squeeze Casted Aluminum Metal Matrix Composites[8] (MMC). This affordable MMC technology could be demonstrated as a cost-effective alternative approach to manufacturing military components. Applications may include road wheels, suspension components, and track shoes, leading to significant weight reductions and increased durability. Composite materials, like those utilized in the construction of the B2 Bomber structural elements, are lighter than steel and can improve a vehicle's fuel consumption, cross-country speed, operational range, and endurance.

A four-year contract to develop a lighter, more transportable composite armor vehicle was awarded to United Defense L.P. in 1994. The program is aimed at exploring the use of composite materials in structural applications to reduce weight, enhance vehicle survivability, and improve deployability.[9] In order to reach a practical stage of applicability, there are still many problems associated with ballistic and structural integrity, non-destructive testing, signature reduction, producibility, and field repairability that must be resolved. Although the program focused on developing a medium-size chassis (17-22 ton) for typical applications such as Bradley and the Future Scout Vehicle (FSV), similar principles and production techniques could be successfully applied to a heavier chassis, such as that of the FCS (40-45 ton). It is expected that as much as 50%(!) weight savings could be achieved in the future compared to a conventional steel structure. Composite materials technology[10] will bring about substantial reduction in size and weight of high performance future tanks without sacrificing operational capabilities. Indisputably, lighter tanks offer many advantages in the form of strategic deployability, tactical mobility, and sustainability. The lighter FCS will play a key role attaining the new logistic goals and restoring the rapid maneuvering essential to full exploitation of armor.

The FCS Scenario - A Major Digitized Battlefield Contributor

Operational requirements dictate that the FCS should operate as a 'combat system' while functioning and communicating beyond the conventional rather *narrow* tactical level. The FCS will be an *active* node on the battlefield digitized network. This is, in essence, a dramatic departure from the conventional way tanks have been operated and deployed since their inception. The FCS will carry Reconnaissance Missiles (RM) that will be the natural evolution of today's Unmanned Aerial Vehicles (UAV). The RMs will be fired to assist the local commander and crews in obtaining real-time digitized information on the close-area battlefield. This information will be used by the local forces, but also will be conveyed to the Greater Area War Management Center. Information on enemy targets obtained from the RMs will be fed back to the FCSs, prioritized, and used to automatically direct, aim, and fire the EM and high-power laser guns and anti-armor/air missiles at their potential targets.

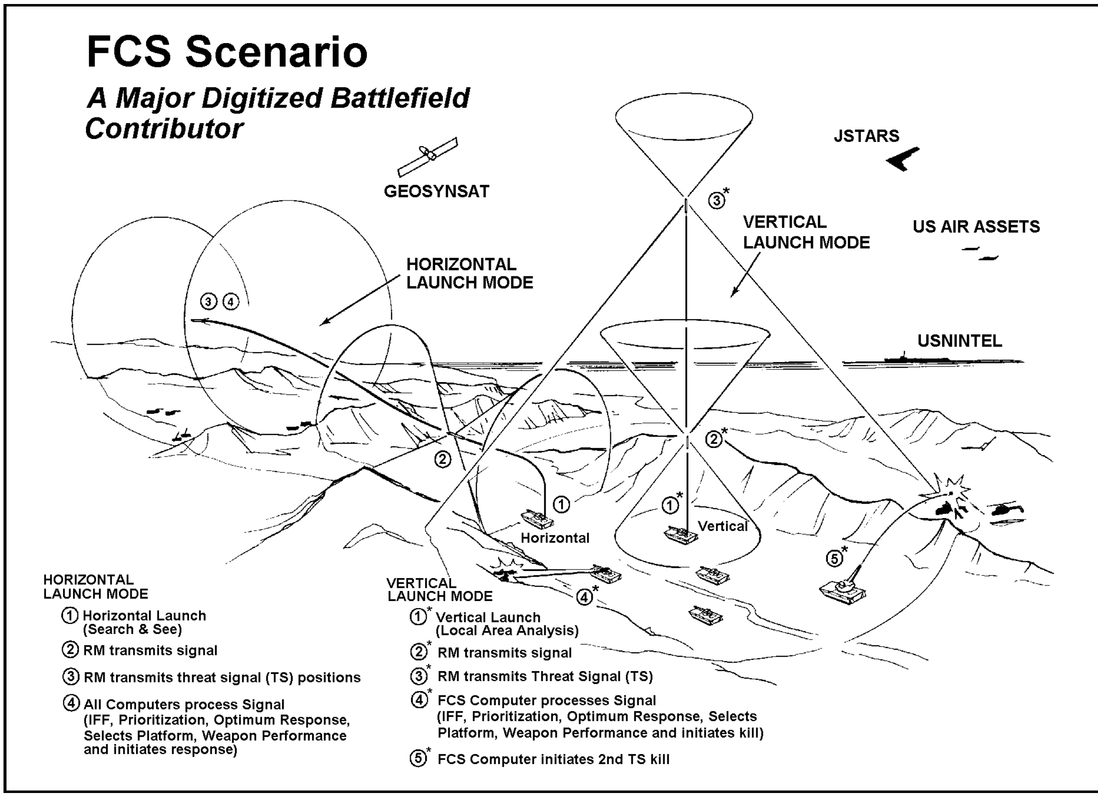
The FCS will be an integral part of the digitized (computerized) battlefield network system and will serve as its "eyes" and "ears." Much has been recently written about the essence of battlefield digitization, so that it will not be elaborated any further here. The FCS will be equipped with a *second* generation vetronics[11] system that will further advance digitized data control and distribution, electrical power generation and management, computer resources, and crew control and display processes. The vetronics system will be capable of accepting a variety of inputs and delivering outputs related to power system control, communications, countermeasures, weapon control, sensor control, artificial intelligence, training, maintenance, diagnostics and prognostics. This architecture will provide the required interface between the various functional modules, computer, and power resources.

Concluding Remarks

The futuristic FCS is indeed an *extraordinary* but visionary combat weapon system which, with its extended capabilities, pushes the boundaries of technology well beyond what is achievable today. It is virtually an all-electric platform that uses electricity as a *sole* energy source. Electricity is used to power its EM (or ETC) and laser guns, main power train, and all other self-defense suites, communications, fire control systems and auxiliaries. It is designed to be highly reliable by virtue of advanced technologies, requiring only low-level or virtually no maintenance during operation. In essence, it is the logistician's ultimate 'dream war machine.' The FCS may be the first tank that could veritably transform armor warfare. Armor maneuver forces that never seem to halt while on the offensive could rarely be defeated or held back (remember German 'Blitz' armor attacks across Europe, and General Patton's fast advance in Italy during WWII). The underlying philosophy here is that the only imposed limitation on armor deployment should be human resilience, rather than a shortage of consumables, or low reliability of equipment. *In terms of freedom from logistic constraint, one could argue that, in principle, the FCS will do to tank warfare what the nuclear powered submarine did to the deployment of conventionally driven diesel submarines.*

The proposed particular configuration of the FCS is not as important as the core idea behind its conception. Revolutionary main armament, extraordinary survivability and deployability, and substantial reduction in logistic reliance are the key to the FCS. From its inception to its fielding, it took the M1 tank development program more than 20 years. Considering the time that was necessary for maturation of new technologies that were incorporated in the M1, such as the gas turbine engine and the British-developed *Chobham* armor, the FCS represents a much higher and riskier performance step than the M1 was at the time, in comparison to the M60-series Patton tank.

In the author's personal opinion, the opportunity for fielding an FMBT type fleet has already been missed. Nonetheless, FMBT prototypes could still be



built to serve as 'technology-carriers' and 'test-bed' demonstrators for test, evaluation, and maturation of emerging technologies that, if successful, will be implemented in the FCS in the 2020-2030 time frame.

The FCS, as formidable a concept as it appears to be, must compete on availability of funds for R&D like any other major development program. The fully justified requirement to support the existing M1 series tank fleet and preserve the industrial base for tank design and production, will naturally limit the allocation of funds set aside for the FCS. To optimize allocation of funds for development, test, and evaluation, the U.S. Army *must* determine whether emerging technologies are best fielded in a new tank design (technology carrier) or better implemented as a part of the existing M1 Abrams series fleet upgrade program. This unavoidable situation will further stress the practicality of the FCS's proposed fielding time frame — 2020-2030. The FCS's ultimate destiny, among other major development programs, will be determined in the forthcoming Army's Quadrennial Defense Review (QDR) that will dictate the Army's shape for the next 20-30 years.

The proposed FCS, with its extremely powerful main armaments, alternative unique energy source to operate *all* systems, enhanced self-defense capabilities, digitized communications, computer networking ability, precision navigation, and advanced aerial sensors, will be a paramount member of Army XXI and beyond. It will be able to maneuver, occupying and retaining territory, and collapsing the enemy's resistance by attacking rapidly and deeply into its center of gravity, thus ending the war more expeditiously and with much fewer casualties. Undoubtedly, if the FCS will come to pass, it will dominate the maneuver battlefields of the future with virtually no or little competition.

Note*: All information contained in this article was derived from open-sources and the analysis of the authors.*

Notes

[1] *Defense Daily,* 12/11/96, p. 398.

[2] The New Illustrated *Science And Invention* Encyclopedia, H.S. Stuttman Inc. Publishers, *"Nuclear Reactor,"* Volume 13, p. 1727.

[3] Meadows, S.I., "Army, Navy, Air Force Vow New Weapon Systems Will Not Pollute," *National Defense,* October 1996, p. 26.

[4] The New Illustrated Science And Invention Encyclopedia, H.S. Stuttman Inc. Publishers, *"Frontiers of Science, Power Plants In Space,"* Volume 7, p. 884.

[5] Ogorkiewicz, R.M., "MTU Tank Diesels - New Developments," *International Defense Review*, 1/1988, p. 57.

[6] Hewish, M. and Hammick, M., "Battlefield Power At The Technical Limit," *International Defense Review*, 11/1992, p. 1083.

[7] Editorial, "We Have a Winner!," *ARMOR*, July-August 1993, p. 6.

[8] Proceedings, 1996 Combat Vehicles Conference, American Defense Preparedness Association (ADPA), September 24-26, 1996, U.S. Army Armor Center, Fort Knox, Kentucky.

[9] Grimes, V.P., "Next Generation Tank - Looming Lethal Leviathans Demand Development $$$," *National Defense,* September 1996, p. 26.

[10] Dr. Hoffman, P.R., "The Latest Developments In Specialty Aerospace Materials," Textron Specialty Materials, p. 197.

[11] Brig. Gen. (USA Ret.) Bolté, P.L., "Vetronics: what it's all about," *ARMOUR 1987 supplement, IDR* 7/1987, p. 13.

Western Design HOWDEN (WDH) is a small defense company in Irvine, California, which specializes in the design, development and production of ammunition and material handling systems for the U.S. and International military markets. WDH's track record includes a variety of air, land and seaborne weapon systems which require automated feed, resupply and optimized ammunition packaging. WDH has been involved among others in the Tank Test Bed, AC-130U Gunship, AH-64 Apache and Tank Compact Autoloader Programs.

Mr. Lawrence D. Bacon is the Director of Graphic Arts at WDH where, for the past 18 years, he has been responsible for creating numerous concepts for automatic ammunition handling, loading and storage systems.

Dr. Asher H. Sharoni is the Director of Engineering at WDH. He holds a Sc.D. in Mechanical Engineering from MIT and a M.Sc. & B.Sc. in Mechanical and Industrial Engineering from the Technion, Israel Institute of Technology. Dr. Sharoni is a former Colonel in the Israeli Defense Forces in which he was involved in various major armored weapons developments. Dr. Sharoni has accumulated more than 30 years of experience in armor design and production.