II. LaRouche's Fourth Law

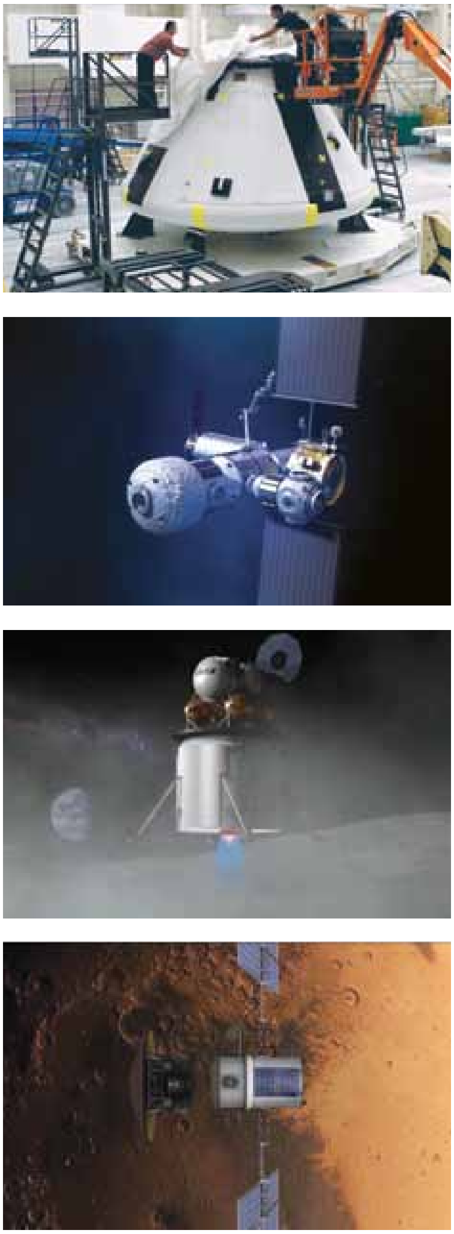
Revolutionary Space Propulsion Technologies Enable Mars Settlement

by Michael James Carr

June 1—Perhaps you did not hear about it, amid the daily din of fakery and foolery. President Trump has directed NASA to *reorganize humanity* around the mission of spreading civilization to the planet Mars and beyond. To make the point that this is not a rhetorical flourish, the President took the opportunity of the collapse of the Mueller coup plot, to announce that the first stage of this process will be accelerated to be accomplished by 2024: the landing of people on the Lunar surface. A permanent human presence on the Moon will be inaugurated by 2028. Human exploration of Mars will follow, based upon the technical capabilities developed in the process of Lunar development.

First, reorganization entails flipping NASA and America "right side up" after 50 years of imperial looting. For 50 years the rigged debate and accompanying physical economy policies have cycled back and forth between radical policies of contraction, austerity, financial takeover schemes, "inner space," financial bubbles and schemes, counterculture, etc. on the one side; and on the other side, attempts to maintain a status quo or "normalcy"—whatever that means.

In this situation, American science, technology, engineering and production was left in a miserable state. The quintessential American inclination to play at building and testing new ideas was suppressed. Factories were shut down wholesale. Children were told to study finance or law. Engineering and science schools were left to train millions of foreign students. The primary American voice of scientific and technological progress, Lyndon LaRouche (along with Krafft Ehricke, a primary designer and advocate of the Moon-Mars Mission) and his Fusion Energy Foundation, were jailed and shut down at imperial decree. We could go on, but that should be enough to give you the flavor.



NASA

To the Moon, Mars, and beyond. Scenes from NASA video "We Go Together."

To again fly "right side up" means not just giving a larger budget to NASA, but reorganizing NASA and the entire economy of the United States. The entire Four Laws of LaRouche must be implemented in order to bring the long-suppressed science and engineering talents out from their foxholes back into a dominant role in the economy and society. We quickly review those Four Laws here:

1. Return to Glass-Steagall separation of legitimate banking from speculation in order to stop the speculative looting of the productive powers of the nation.
2. Return to National Banking.
3. Establish a credit system which makes credit broadly available to designated national projects (such as the Moon-Mars program),

productive enterprises, agriculture and infrastructure.

4. Provide federal funding for the accelerated development of fusion power subsumed within the development of a Moon-Mars colonization program.

Secondly, spreading civilization to Mars entails integrating the scientific and engineering capabilities of the entire world into this project—emphatically including the participation of China, Russia, India, Japan, Europe, and many more emerging space programs—as well as private enterprises and universities. This project is not a project which can be accomplished with the existing technical know-how. It requires the revolutionary insights that pop up from unexpected people and places. The good thing about having over 7 billion people involved (a much-maligned number!) is that we have a rapidly growing pool of smart people! Remember, it is the spread of intelligence which has been the imperial target for destruction since long before Socrates was sentenced to death.

So far, President Trump and NASA Administrator Jim Bridenstine have done an excellent job of redirecting NASA and America towards this Moon-Mars development mission. But this is still a controversial project. The wailing and gnashing of teeth are heard everywhere! This mission will entail the participation of all smart people—including you—in the final destruction of the British Empire and the realization of the God-given destiny of our civilization.

Because of the magnitude of the transformation required, the President has set a five-year timeline for the accomplishment of the first step, putting people once again on the Lunar surface. Necessarily, this has forced a focus upon organizing the means for the immediate accomplishment of that objective. This means that all technologies, equipment, facilities required to meet that short-term goal are being put on the front burner. It means that a focus is being put upon the existing technologies which will be used to meet the 2024 goal.

However, those technologies do not include many of the cutting-edge technologies which will be required to actually turn a Lunar installation into a Lunar settlement—not to mention the even more stringent requirements for exploring and settling Mars.

NASA just granted the contract to build the first section of the Lunar Gateway orbiting transfer station to Maxar and signed up 6 companies to make proposals for the 3 major manned Lunar lander components. NASA has put forward a supplemental budget request for an additional $1.6 billion funding for the next fiscal year as this program ramps up.

NASA/JPL/Corby Waste

Chemical rocket propulsion and a months-long ballistic trajectory are acceptable for a robotic probe to Mars. Manned missions require continuously powered acceleration to reduce travel time to days, not months. Shown is an artist's concept of an unmanned Phoenix probe landing on Mars.

India plans to launch its first unmanned Lunar lander in July. (Remember that it was India's Chandrayaan-1 orbiter which discovered massive quantities of water ice on the Moon).

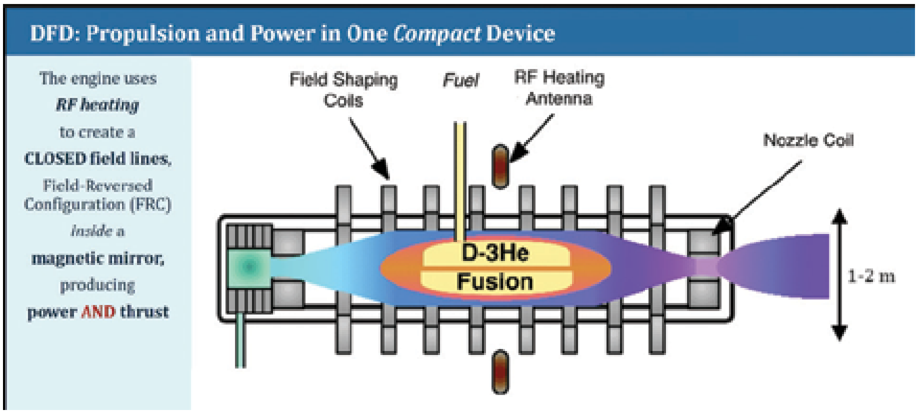
Meanwhile the NASA/Boeing Starliner is being prepared for its first unmanned test launch to the ISS this summer, while the scheduled abort test of the NASA/SpaceX Dragon II project is delayed, pending determination and rectification of the cause of a vehicle loss due to an explosion in between tests at the Kennedy Space Center.

With that in mind, we spend here some time discussing the *biggest technical problem* faced by the Moon-Mars program: transportation and propulsion.

We can probably get much of what we will need, such as food, water, fuel and some metals from work we perform upon the Lunar and later Martian regolith, but the equipment, buildings, power, infrastructure, will entail huge tonnages of imports from Earth.

Think of this as you would think about developing an area of virtually barren countryside on Earth. You will need earthmoving (lunar regolith moving) equipment, mining equipment, materials processing equipment, power installations, piping, cabling, etc. Even with super materials and super equipment, the requirements quickly move into the thousands and then millions of tons and beyond of equipment. What can we do?

We will probably always use chemical rockets for various aspects of activities in space; chemical rockets have some very impressive capabilities—such as the



Princeton Satellite Systems

See the Princeton Satellite Systems short video explaining how the Direct Fusion Drive works: https://youtu.be/hggqvB5I95I.

capability to quickly produce a very large impulse. However it is that precise capability which is also this technology's major failing. Chemical rockets quickly burn themselves out.

The problem reminds one of the case of the Hare and the Tortoise—or perhaps it might remind you of the habits of your cat. To send *robotic* probes through deep space with a chemical rocket jolt followed by a months-long ballistic trajectory is an acceptable plan. To send *people* into deep space in that manner is not acceptable. Secondarily, while much has been accomplished by miniaturization in satellites and robotic probes, we cannot miniaturize people and their life requirements. If we are to settle the Moon and Mars, we shall require revolutionary improvements in propulsion technologies.

In this article we begin not with the short hops from planet to orbit—but with the really-*long*-distance questions.

Instead of a heavy burst of thrust followed by months of "weightless" ballistic trajectory to Mars, we really need *continuously* powered acceleration followed by *continuously* powered deceleration. The ideal would be continuous acceleration at 1g (equivalent to Earth's gravity) followed by continuous deceleration at 1g. Such a capability would reduce travel time to Mars from months to days and allow passengers to live as if on Earth, without bone mass loss and other deleterious microgravity effects upon health. Also the increased speed helps to reduce damage to tissue caused by the extreme radiation environment of deep space.

Direct Fusion Drive

Fusion power, which has roughly a million times the energy output per reaction in comparison to chemical rocket reactions, has the potential to meet this ideal capability. An early model of a magnetic confinement/controlled fusion rocket is in development by the Princeton Plasma Physics Laboratory (PPPL) and Princeton Satellite Systems (PSS)—assisted with small-scale NASA grants. This first step towards the 1g continuous acceleration goal is a rocket engine called Direct Fusion Drive (DFD) and is based on Princeton's fifth-generation, field-reversed machine, the Princeton Field-Reversed Configuration (PFRC)-2 reactor. The reactor employs a unique "odd-parity" radio frequency (RF) heating method, producing a steady-state, closed-field configuration with a highly efficient current drive. The PFRC-2 experimental machine is currently in operation at PPPL.

The plan is for the PFRC-2 to demonstrate fusion by the end of 2020. An actual DFD rocket engine would provide about 10 megawatts of propulsion power (somewhere in the range of 50 to 100 newtons, or 10 to 20 pounds of continuous rocket thrust) via emission of fusion-produced ions from an electromagnetic rocket nozzle. Production of electricity is accomplished using a Brayton Cycle generator in the equipment coolant loop. A typical ion exiting the electromagnetic nozzle would exit at a speed of about 100 km/second, while an actual fusion product would leave at 25,000 km/second. Contrast that to chemical rocket combustion products leaving the engine at around 5 km/second.

Because this design burns deuterium (^{2}H) and helium-3 (^{3}He) as fuel—allowing all the reaction products to be magnetically directed out as thrust—this design does not suffer from troublesome stray neutrons which can induce secondary radioactive decay in adjacent machinery (as is the case in other fission or fusion systems). And while helium-3 is rare on Earth, it is abundant in the Lunar regolith—making it one of the Moon settlement's first high-value export products.

Besides propulsion, the DFD would also produce an abundant, continuous supply of electric power for powering the other systems on board the spacecraft. This is one of the unique features of this design.

Even though this project is probably the most promising fusion rocket concept/project in the world, it has only received some tiny NASA study grants, but would require on the order of $50 million to build the next re-

Princeton Satellite Systems

The Princeton Field Reversed Configuration-2 Reactor, showing a pulse generated during testing of the reactor core.

search machine and even more to build a prototype rocket engine. America is filled with people, universities and laboratories with great concepts, but no ability to bring concepts into reality. For example, the PFRC-2 was built using many recycled parts from earlier experimental devices.

America must reestablish a credit system and a real long-term research and development program. We cannot allow billionaires, fund managers and venture capitalists to decide which projects with the shortest pathways to fruition will be funded to development. The DFD would require a timeline of 7 to 15 years for full development. NASA needs sufficient funding to be able to fully fund development of this project, so that a working prototype could be running in about 7 years.

Ion Propulsion

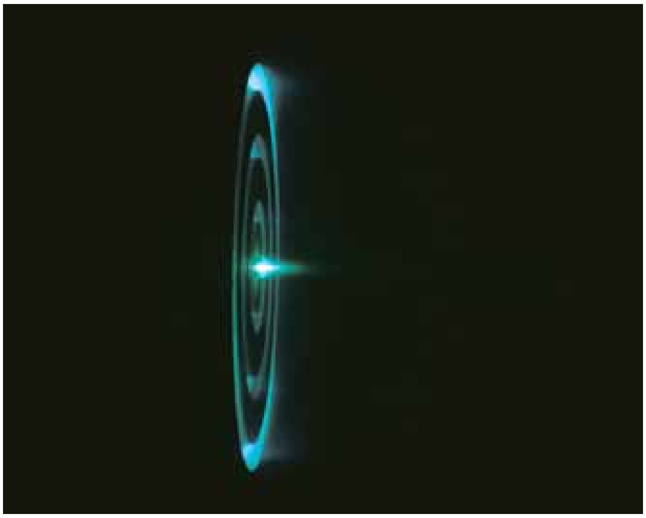
However, even without undergoing fusion, a plasma's unique electromagnetic properties allow it to be controlled and accelerated by magnetic fields. Disregarding for the moment the global self-organizing field characteristics of plasmas (such as is used in the Direct Fusion Drive rocket discussed above), for our immediate purposes we will be discussing a particular plasma situation in which a stream of atomic nuclei is ionized by removing at least one electron per typical nucleus in the stream. In this case, the positively charged ions (nuclei) can be accelerated towards a negatively charged grid, which sucks the stream through and expels it out the nozzle. (The stream of positively charged nuclei is then reattached to the previously detached electrons, so that the exhaust stream becomes neutralized and does not curve back along magnetic field lines to impinge upon the spacecraft.)

With such early systems of ion propulsion (or electric propulsion), a stream of ions can be expelled at roughly 20 times (or more) the typical exhaust velocity of chemical rocket exhaust. Such early systems have demonstrated Specific Impulse (the measure of thrust per unit of propellant) values of roughly 10 times those of chemical rockets.

However, these early designs have played the tortoise to the hare of chemical rockets. Early ion thrusters produced thrust equivalent to the pressure a piece of paper would exert upon your hand holding it up against the pull of Earth's gravity. But unlike chemical rockets which could burn for a few minutes, the ion thrusters could continue to accelerate continuously over months and years slowly reaching incredible speeds with tiny propellant expenditure.

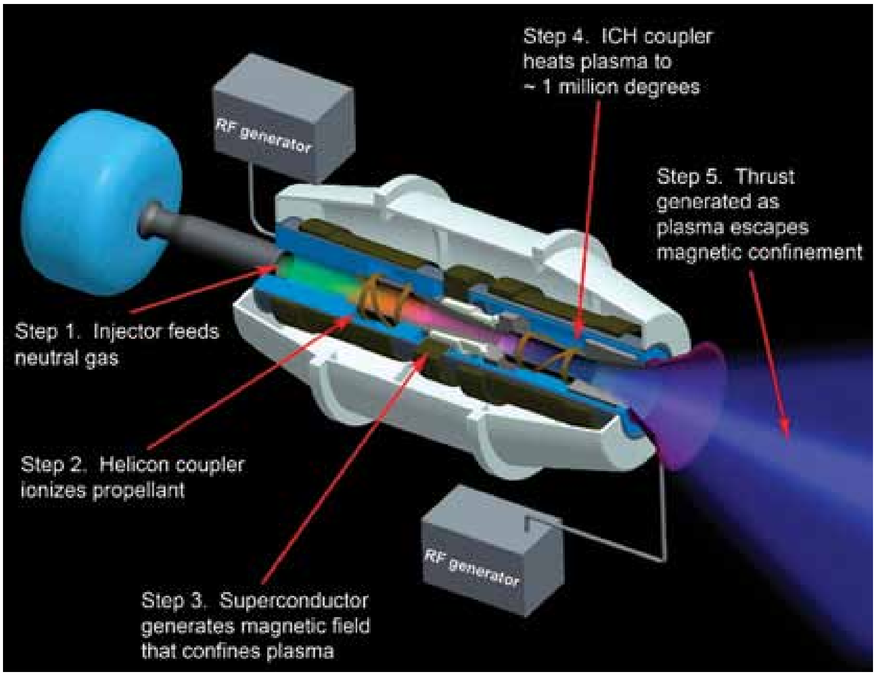
X3 Hall-Effect Thruster

Probably the most advanced electric propulsion system currently undergoing testing and development is the University of Michigan Plasmadynamics & Electric Propulsion Laboratory's X3 Hall-effect Thruster which has achieved a record thrust of 5.4 newtons (1.2 pounds) on 102 kilowatts of input. The first use of electric propulsion in human spaceflight operations will be for propulsion and Lunar orbital station-keeping of the Lunar Gateway. The Gateway will use Hall-effect thrusters developed by the NASA Glenn Center—powered by solar cells. The thrusters will allow the Gateway to change



U. Mich. Plasmadynamics & Electric Propulsion Laboratory

The X3 Hall-effect ion thruster in which xenon gas is accelerated by an electric field. Shown here are its 3 concentric emission channels running at a low 30 kilowatts of power.



Ad Astra Rocket Company

Cutaway schematic of the Variable Specific Impulse Magnetoplasma Rocket (VASIMR).

orbits in order to support Lunar surface missions at multiple points on the Lunar surface.

Variable Specific Impulse Magnetoplasma Rocket

Another advanced engine is the Variable Specific Impulse Magnetoplasma Rocket (VASIMR) engine developed by former NASA astronaut Franklin Chiang Diaz and his Ad Astra Rocket Company. It uses techniques developed in fusion magnetic confinement reactors, such as radio frequency plasma heating, to create an electric or plasma rocket with variable thrust regimes: either slow, super-efficient cruise, or more wasteful but more powerful bursts of thrust when necessary. It is sort of an ion engine with a metaphorical afterburner. Like the X3 discussed above, the VASIMR engine has demonstrated a thrust of 5.4 newtons at 100 kilowatts of power.

A projected test of the VASIMR engine on the International Space Station (ISS) was canceled due to budget constraints. A true crash program will provide for simultaneous development and testing of all of the most promising concepts—otherwise ultimate success is left to chance. A project as difficult as developing bases or settlements on the Moon and Mars demands that the best solutions to propulsion problems be found and utilized as soon as possible!

The most common use of electric (or ion) propulsion systems has been the efficient counteraction of drag effects upon hundreds of Earth satellites caused by occasional collisions with high-altitude molecules. This has always been a low-power process fed by electricity from solar panels. However, now with NASA preparing a mission to Mars, Administrator Bridenstine has made clear that we will be moving rapidly from solar electric to nuclear electric propulsion systems. It is becoming clearer and clearer to all researchers in this area that fission and fusion power sources, tied to one or another form of electric propulsion, are the key to crossing vast distances with speed and large tonnages on repeated round trips. Think in terms of regular daily departures from and arrivals at transfer stations in orbit around the Earth, Moon and Mars.

As is generally the case with transportation on Earth, transport of people and small, high-value items will be separated into faster systems as opposed to heavier freight, which will travel in slower systems. Once we are committed to high-power nuclear sources, work can continue on various pathways to ramp up the thrust levels of the electric propulsion systems from the levels of a few newtons (or pounds) to levels bringing us closer to the goal of 1g acceleration/deceleration.

A project of the European Space Agency and SITAEL of Italy turns the negative of occasional collisions with air molecules into a positive by sucking the colliding molecules into the ion thruster. In this engine, incoming air molecules are ionized instead of relying upon onboard supplies of inert gases such as xenon. This is a valuable capability both for low altitude satellites orbiting Earth and Mars.

Now we turn back to the question of improving access to our orbiting transfer station in Low Earth Orbit (LEO).

Freight from Earth to LEO

The American Space Shuttle program accomplished many things, but it did not succeed in lowering the cost of delivering payloads into Low Earth Orbit. There were many causes for this. I will list five.

First, the process of having to crew-rate every aspect of a mission meant additional costs imposed upon

ESA

Air-breathing ion thruster. Note the different coloring of ionized air exhaust here as compared to the ionized xenon gas in the X3 ion thruster (Figure 4)

"freight" delivery to orbit. Second, the Shuttle system was a cutting-edge system which required lots of maintenance and preparation between missions. Third, it was always a Research and Development project—always undergoing improvement and refinement—not a fixed production transportation system. Fourth, the attempt to build one machine to do everything inevitably means that its fitness to do particular tasks is compromised. Fifth, the continuous demands to "cut costs or terminate the program" led to continuous design downgrades which resulted in a less robust, more dangerous, and thus ultimately a more costly system—both in terms of time lost and lives lost. These factors precluded rapid turnaround, which would have been the key to lowering launch cost per flight and per kilogram.

Since the experience with the Shuttle, it has been generally acknowledged that it would be better to separate launching of freight from launching of people. People are irreplaceable. Food, water, satellites, etc., while precious, can be replaced. Hence we will be dividing this subject into two sections.

We start with freight. NASA has worked with a number of companies to take NASA's experience and develop simplified-production chemical rocket systems designed to achieve the lowest costs possible for delivering supplies, and soon crews, to the ISS. Advances on this front include fly-back soft landings of first stage rockets, and reusable spacecraft.

Yet these are incremental or evolutionary developments. NASA itself is concentrating upon building the largest, most powerful heavy-launch vehicle ever built—the Space Launch System (SLS). SLS is also derived from the Shuttle hardware/production system—using Space Shuttle main engines for example. We will have to use all of these systems in the immediate future.

However, none of these systems can put the tonnage of freight into orbit which will be required to support a permanent human presence on other heavenly bodies—not to mention space colonization. The more than 40 years of constricted budgets allocated to NASA has so far precluded the development of the really revolutionary heavy-lift systems necessary for building a base or village on the Moon, for starters.

NASA has done as well as it could, given the constrained resources available. But you must ask, "What would the best system look like if we started from a clean sheet of paper without regard to initial costs of development?" It should be noted here that the biggest payback to society always comes from the clean sheet of paper design (if the design is based upon a revolutionary technology). This is because the process of developing radically new technologies puts the new technologies into the hands of a broad spectrum of not just researchers, but the machine tool and manufacturing sectors. In other words the apparent cheapness of "off-the-shelf technology" is an illusion. The new technology (if it is really revolutionary) will pay for itself and thus actually be the cheaper choice (although there will be a time lag for the payback to become overwhelmingly apparent).

StarTram

Once freed from the necessity of using off-the-shelf technologies for budgetary constraint reasons, we can look at this problem in a new light. Dr. James Powell, who along with Dr. Gordon Danby, invented the superconducting magnetic levitation (maglev) rail system now being put into commercial operation by the Central Japan Railway Company, proposed to apply the same principles to launch payloads into Earth orbit.

His proposal is called StarTram, and, in principle, would use buried superconducting coils to store up electrical energy over a long period of time to be released in a short burst to accelerate a spacecraft with payload through a 100 km evacuated tube curving 5,000 meters up a mountainside. It would proceed through and exit from the atmosphere, where a small rocket burn can circularize an orbit. A first-generation system could launch a 40-ton spacecraft, the weight including its 35-ton payload, 12 times per day—for a capacity to put 150,000 tons of supplies into orbit per year.

This is the order of capability necessary to begin a permanent manned presence on the Moon or Mars. By comparison, the expendable SLS will initially have a 77-ton-to-orbit capacity, which will grow to a 143-ton-to-orbit capacity in the fully developed system. Even 1,000 launches per year of the fully developed Space Launch System could not match the capability of the StarTram system.

This is one task that requires significant outside intervention to bring to fruition. Remember that StarTram is completely different and has no pre-existing lobby. Yet it embodies the same technologies which shall be central to both the most advanced ground transportation and fusion plasma development and control—high temperature superconductors and superconducting magnets operating in near-vacuums or low-pressure chambers. The most advanced and fastest ground transportation system now operating is the Japanese repulsive superconducting maglev system. The most advanced ground transportation system currently conceivable would use similar technology—but inside evacuated tubes to allow velocities over 1,000 km/h and possibly up to several thousand km/h for very long distances.


NASA

Different technologies to catapult-launch a spacecraft have been tested by NASA, including this magnetic levitation (maglev) system evaluated at NASA's Marshall Space Flight Center.

As in the case of building a national maglev rail system, building the StarTram first-generation system will require an enormous initial construction cost—comparable to the cost of the Apollo program. But it is the only conceivable system that could lower the cost of massive provisioning to permanent settlement of other heavenly bodies to the point that cost per kilogram to LEO could be reduced to the range of $40-50 or so. On the other hand, these economies of scale apply only if the decision is made to develop extraterrestrial bases and settlements to actually use some high percentage of the StarTram capacity. Now that NASA is committed to settlement of the Moon and Mars, this technology must be developed.

This project is the answer to heavy-lift requirements of Lunar and Mars bases, villages and settlements. One of the main foci of our intervention will have to be to push this system. A first-generation system can be built in 6 to 10 years, once a decision is made to go forward with it.

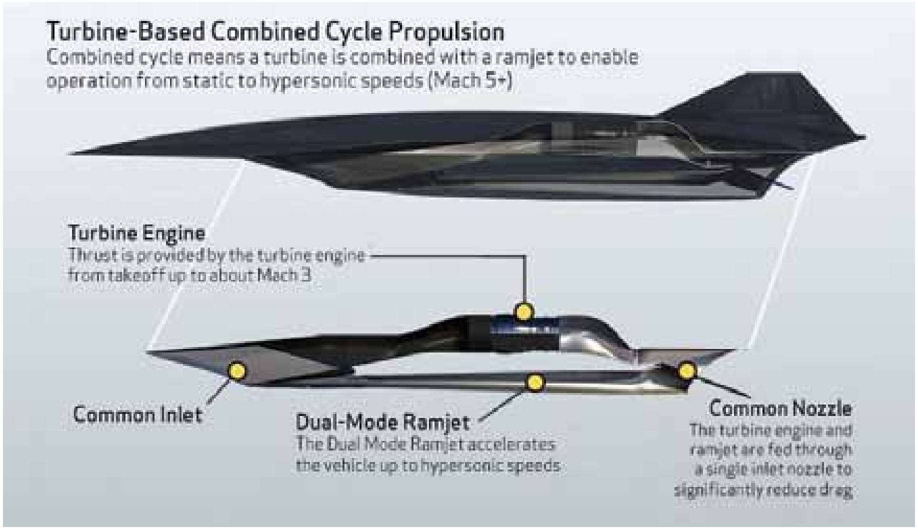
All of these new technologies about which we have so far written involve electromagnetic acceleration of ions or vehicles. These new technologies constitute a family of technologies that will play an ever-greater role in the advance of civilization over the next few decades. Heat-powered machinery will not be completely replaced, but development will take place increasingly inside the electromagnetic sphere of technologies. The same technologies are key to transforming the surface and subsurface transportation system inside the United States. And this area is one in which a great deal of international cooperation is called for. Japan, China and Germany have been the leaders in the physical production of magnetic levitation transportation systems. Any NASA efforts towards testing and development of the StarTram system would greatly benefit from cooperation with engineers and institutions from these nations.

The first-generation StarTram will not be able to launch people because of the 30 g force imposed upon the payload, and the bump of up to 6g's when the spacecraft comes out of the evacuated tube and hits the rarefied atmosphere. So how do we get people to orbit? In the near term, we will be using the chemical rocket systems that NASA, along with several private space access companies, has been developing. However, these systems are far from ideal.

Passengers to LEO

The liquid chemical rockets generally used around the world to orbit spacecraft burn fuels such as kerosene, hydrogen, or methane, which is combined with liquid oxygen to burn independently of the atmosphere. By mixing the oxygen with the fuel in the engine (and providing a spark to ignite it) the fuel will burn to create high pressure and thrust, regardless of whether or not it is surrounded by air. However, it is a little crazy to have to haul oxygen through the atmosphere that is roughly 21% oxygen. Imagine having to fill up your car with both gasoline and the oxygen it uses. That would be an unnecessary pain.

If we could do it, wouldn't it make more sense to get the oxygen we need from the atmosphere through which we must fly, rather than carrying aloft a separate (and very heavy) supply of liquid oxygen through the ambient oxygen in the air? That was the original concept of the ramjet.



DARPA

The American Defense Advanced Research Projects Agency (DARPA), as well as the Beijing Power Machinery Research Institute (and probably many more military/aerospace institutions) are working on building "combined cycle" or "full range" engines which incorporate a turbojet along with an integral ramjet/scramjet engine to allow full operation from a standstill to Mach 5+ hypersonic flight.

You can think of a ramjet as basically a tube with fuel injectors to mix fuel with air coming through the tube. With a spark, the mixture ignites and creates high pressure and thrust—in the same manner as a chemical rocket engine. However, a ramjet has no way to get air to begin to move through the tube unless we either attach it to a moving plane or rocket to force a stream of air into the tube, or attach a fan to suck in some air (as in a turbojet). Secondly, as a ramjet accelerates, shockwaves and other disturbances can disrupt the combustion process. Ramjets can be tricky. A long-term goal in the aerospace industry has been to develop efficient, high-speed ramjets that could operate with combustion taking place *inside the engine at supersonic speeds*—hence the term Supersonic Combustion Ramjet or Scramjet.

The Sänger Scramjet/Rocket

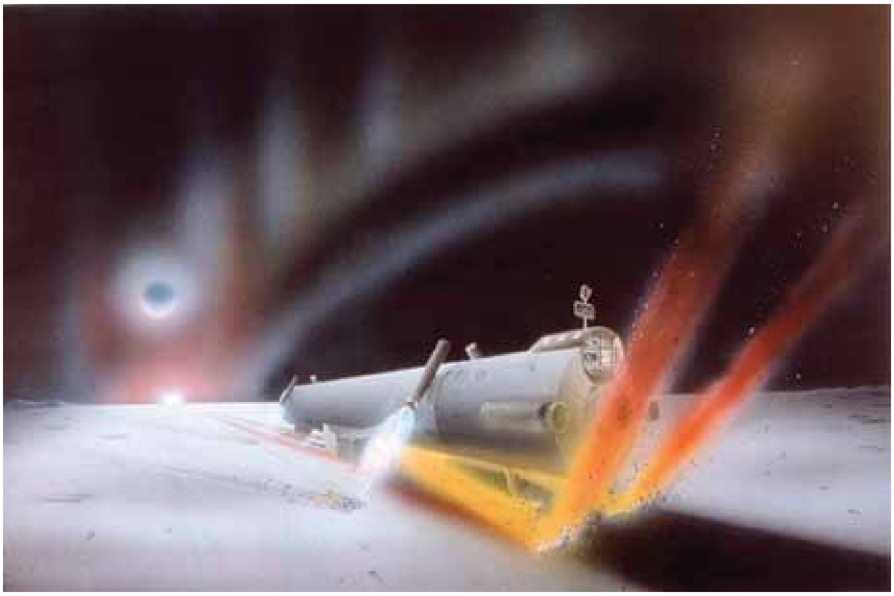
Since Lyndon LaRouche's 1984 promotion of the German Sänger two-stage scramjet/rocket launcher concept to reach orbit, scramjet engines have actually been built and used in powered flights. A short test flight achieved a sustained velocity of near Mach 10 (about 12,000 km/h), while another test flight demonstrated scramjet high Mach number propulsion for about 10 minutes. However, these test vehicles had to be air dropped and rocket assisted to reach speeds at which the scramjet could begin to function. Much work in this area is ongoing in America, China, Russia, India, and other countries; however, for military reasons, most of this work is being done in secrecy.

The Sänger idea is for a carrier scramjet-powered aircraft to accelerate from the ground to high altitude and high Mach number and then release a winged orbiter which would have a rocket motor to propel itself the final way for orbital insertion. The problem is that to ignite a scramjet, the scramjet must already be travelling at about Mach 4. The initial takeoff thrust could be provided by additional turbojet engines, rocket engines, combined-cycle engines (scramjet engines with moveable ductwork to redirect incoming airflow between integral turbojet and ramjet/scramjet sections) or maybe even an electromagnetic catapult on a much grander scale than the electromagnetic catapults recently installed on America's newest aircraft carrier, the U.S.S. Gerald R. Ford. NASA actually made such an electromagnetic launch assist proposal in 2010 and did some testing at the Marshall Spaceflight Center in Huntsville.

Synergistic Air Breathing Rocket Engine

While we encourage continued work on all of these technologies, the candidate most likely to succeed in making passenger access safe, gentle and relatively cheap to the LEO transfer station—to board the long-distance electric propulsion tugs—will be single-stage-to-orbit spaceplanes powered by SABREs (synergistic air breathing rocket engines). Our full report on this breakthrough is available in the June 8, 2018 issue of *EIR*.

In summary, the Reaction Engines Ltd. SABRE, when travelling at speeds up to around Mach 5, is able to rapidly cool the extremely hot incoming air, thus allowing the incoming air to replace liquid oxygen as oxidizer for its rocket engines. Beyond around Mach 5, the air inlets are closed, and on-board liquid oxygen is fed into the same rocket engines to allow the spaceplane to continue to orbit—never having to drop any



Painting by Chris Sloan

Krafft Ehricke invented the Lunar Slide Lander concept as a system to minimize propellant requirements during descent to the Lunar surface, taking advantage of the Moon's sandy and glassy soil to slow the vehicle. He created a new branch of spaceflight dynamics: harenodynamics, after the Latin word for sandy.

first stage or tankage.

The Defense Advanced Research Projects Agency (DARPA)-funded test program ongoing in Colorado, has recently successfully tested the cooler (key to the entire engine concept) up to Mach 3.5. Preparations are continuing, to perform testing of the system to its intended Mach 5 capability. There is great interest in this breakthrough technology throughout the aerospace world. We must insist upon full funding from NASA to speed the development and testing of the full SABRE (despite the fact that this is developed by a company based in the United Kingdom), and that NASA has the funding to start a competition for design of prototype space planes using the new engine.

Lunar and Martian Landers

Once our respective tugs for passengers and freight make it to Lunar or Martian orbital transfer stations, what happens? No real advances would affect the original designs of Krafft Ehricke for landers—except that now we know that the regolith of the Moon and Mars contains huge quantities of water ice. So as bases grow to settlements with advanced water-processing capabilities, surface water will be turned into liquid hydrogen and liquid oxygen for use as rocket fuel—both for powered ascent to orbiting transfer stations and as fuel resupplies to be used in the descent phases as well.

In the case of the Moon, Ehricke's Lunar Slide Lander could be used to conserve fuel burn on descent to the surface. For ascent, a much simpler version of StarTram can be used on the Moon and Mars. As Ehricke pointed out, on the Moon there would be no need for an evacuated tube since there is no atmosphere there, and since the force of gravity there is very weak (only 17% that of Earth), the track need not be that long.

In the case of Mars, the thin atmosphere may offer the possibility of winged Martian spaceplanes operating between orbit and surface—we will have to see.

In any case, for the first years, chemical rockets will maintain their position as the only means to land and take off from either body.

What You Can Do

Unless you happen to be a billionaire looking to use your wealth to start up a StarTram company to meet the massive demand for tonnage to orbit which we will soon face, the most important action you can take is to circulate this article as well as the "Moon-Mars Crash Program Under a Four-Powers Agreement" article in the October 16, 2018 issue of *EIR* and the "Breakthrough Heralds Dawn of the Age of Single-Stage-to-Orbit Spaceplanes" article in the June 8, 2018 issue of *EIR* to friends, acquaintances and to your Congressman. Tell your Congressman to stop wasting time on the investigation of the investigation of the investigation, and to think about the future.

If we are to have the future we need, we must implement LaRouche's full Four Laws. Credit and government contracts must flow into the areas identified in this series:

1. Full funding for the Artemis Program.
2. Full funding for a national program to rapidly develop fusion power—for electricity and rocketry, including the Direct Fusion Drive project.
3. Full funding for a national project to develop the StarTram technology into a freight-to-orbit railroad.
4. Full funding for rapid development of the SABRE.
5. Full funding for a competition to design, build and begin testing of an actual spaceplane using the SABRE.