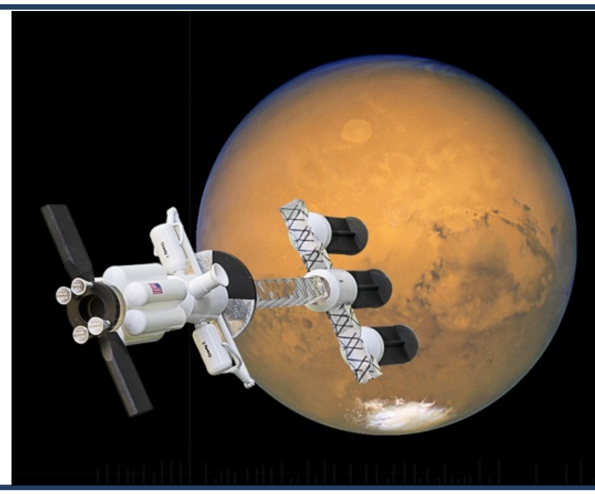
IMPROVE SPACE AND TERRESTRIAL POWER SYSTEMS

We are proposing to develop a small (5 to 20-MWe), utility power source (a Mini Modular Reactor (MMR)) and an integrated control and distribution system, appropriate for use in spacecraft and for terrestrial and Lunar/Mars surface applications. It uses a High Temperature Gas-(He) cooled Reactor (HTGR) with well proven TRISO fuel, a Nitrogen-Brayton Cycle power conversion system, and the associated controls. The following sections provide appropriate descriptions of this design, our qualifications, and show the major advantages. This system will replace diesel generators, at a significant savings, in remote sites around the world. A multi-billion dollar market.



OVERVIEW

The approach conceived by AGPower92 is based on a common reactor core concept that will be factory produced in large numbers and applied to a variety of markets as well as space:

a. Our primary energy source is mini nuclear reactor - 5 to 20 MWe High Temperature Gas (Helium) Cooled Reactor (HTGR) design that has been under development for 50+ years and operationally proven in the U.S., Japan, Germany and China. Two commercial power reactors operated in the U.S.; a new one is under construction in China. (TRL 9).
b. The selected fuel form, TRISO, is the well proven, it is U.S. licensed, and commercially available.This fuel form has been used worldwide in all HTGRs (TRL 9)
c. Power conversion is aNitrogen gas secondary loop driving a Brayton Cycle turbine generator which can be derived directly from current power and aviation combustion turbines since air is 78% nitrogen (TRL 9).
d. A variety of ultimate heat sinks may be used as dictated by the specific application. Three are outlined below:
    a. In space (zero-g) for nuclear electric propulsion and life support: Since the Helium coolant is pumped through the reactor, and there is no reliance on convection to move the Helium throughout the system. A combination of radiators (such as the "heat pipe" which has been developed at NASA Glenn, are feasible due to the high operational temperature of this approach (TRL 7) and heat exchangers pre-heating LH2 reaction mass
    b. Exo-Planet (Mars/Lunar) for life support and in-situ resource utilization: We may employ a combination of underground heat pipes(TRL 7) and surface radiators based on the circumstances of the deployment.
    c. For terrestrial (commercial electrical power): conventional wet or dry convection cooling towers (TRL9)

This approach allows a common reactor module to address without compromise Spacecraft, Exo-Planet, and Terrestrial surface power applications with a single technology integration effort of mature technologies, and with superior inherent safety characteristics. These systems will be factory built and tested (without nuclear fuel) and deployed to their application sites, which will require minimal commonly-specified preparation.

a. Dramatically reduces costs due to spreading Non Reoccurring Expense (NRE) across hundreds of systems instead of one and allows all applications to benefit from “Nth Item Costs” instead of the much more expensive “First of a Kind Costs”, which has been the historical norm for Space and gigawatt class terrestrial nuclear power plants. In addition factory production of identical systems on production tooling is orders of magnitude less expensive than the current one-of-a-kind, build-on-site process used today

b. Develops a manufacturing supply chain to support long term operation and ongoing development.

c. Develops an operations training syllabus and on-going verification practice as well as a broad base of career advancement throughout an enormous field of applications.

PERSONNEL

Arthur McMahon Chairman- Entrepreneur, Founder of Harvard Group International

Paul Halata – Vice Chairman, Former CEO & President of Mercedes Benz USA LLC, and a Canadian

Richard P Hora – CEO, Former industrial member of the DoEs International Thermonuclear Experimental Reactor Home Team, former member of DoE FEAC II, Vice President of Energy Progams, General Dynamics, Chairman of the Council of Superconductivity for American Competitiveness, CEO of SpaceHab Inc (Took SpaceHab public in 1995), Vice President of Strategic Planning General Dynamics, Space Systems Division, Vice President of Space & Missiles Advatech Pacific, Inc. Vice President of Strategic Planning and Business Development, Comptek Research, Inc.

Dr. Junaid Razvi (A.B., M.S.E, Ph.D.) - Junaid’s work from 1978 to 2018 at **General Atomics** included GEN-IV gas cooled reactors, TRIGA® research reactors, small nuclear reactors, nuclear fuel facilities, and management of used nuclear fuel.General Manager, Research Reactor Programs, Nuclear Fuel Operations, and Energy& Advanced Concepts.

Dr. Joe Holland _ B.S., M.S. & Ph.D. in Nuclear Engineer (Kansas State and Texas A&M), Sargent & Lundy Engineers, licensing of Fermi III, Zion; Byron/Bradwood nuclear power plants; Bechtel Power Construction, Arkansas Nuclear One, Unit 2, NSSS and Balance of Plant fabrication and construction;Battelle Northwest Laboratory in Richland, Wa., Hi-Level DoD waste encapsulation, FFTF instrumentation; TRW, hardness &survivability SME for MMIII, Peacekeeper, Patriot PacIV, THAAD, GBI, EEI, technical lead on the SMDC nuclear hardness handbook, At API, chief engineer/scientist for a magnetic bearing dynamics analysis for a 300 MWe vertical shaft direct cycle Helium turbo generator for the joint U.S./Russian Pu burner effort and the High Energy Density Propulsion project at AFRL Edwards.

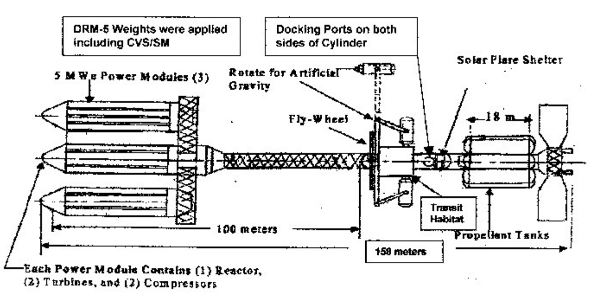
William C Strobl - Design Engineer on the Atlas ICBM Convair Astronautics, Vice President, Business Segment Manager of Advanced Launch Vehicles (ALS and NLS), manned interplanetary vehicles design (1961 to 1965) assigned toKrafft Ehricke. He developed all the vehicles for Venus and Mar missions that were published in our reports to NASA Marshall SFC and Dr. von Braun. Bill worked with the engineers developing the NERVA nuclear thermalengine for those missions. He has published 30 technical papers through the AIAA. Seven of these papers illustrate a concept for and discuss use and significant benefits of nuclear electricpropulsion for Manned Mars mission. Bill interfaced with Dr. Al Juhasz (NASA Glenn Research Center) for his details on nuclear electric propulsion,low weight/cost space radiators, and validation of our nuclear electric propulsion sizing tools.

James Mildice – CEO Earth Space Applications Inc, Expert in power management and distribution, member of the General Dynamics team awarded the first contract for space station power system design. Patent holder for the variable speed universal machine. Design engineer for NASAs National Launch System.

Donald Westergren – Chief of Design, Earth Space Applications Inc. Co patent holder for Variable Speed Universal Machine (VSUM) Mechanical Engineer on ALS and NLS for NASA and the Air Force.

SPACECRAFTSYSTEMS

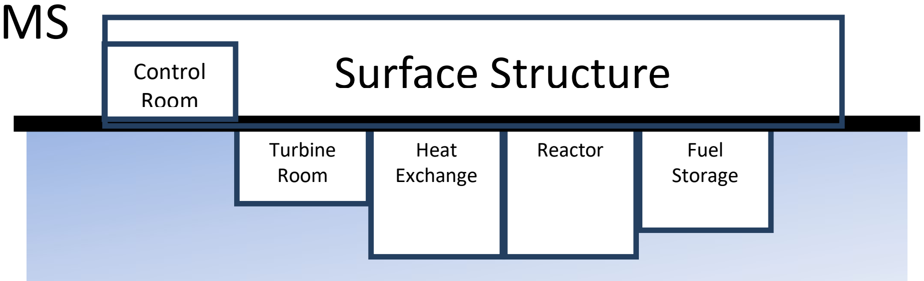
Astronaut Survivability/Safety Requirements: Shortest mission travel time, solar flare/space radiation protection,artificial gravity,expand engine radiation safe area,astronaut ability for In-flight repair,no fluid connections across docking interfaces,interchangeable multiple power modules,add reserve provisions,independent module maneuvering propulsion, andidentical power system for crew & cargo vehicle.We have published in 5 successive AIAA reports on Nuclear Electric Mars Transportation.



1. **It completes a round trip to Mars (from Earth's moon) in 200 days.**
2. **It thrusts continually there and back.**
3. **It can provide variable artificial gravity for the entire mission**
4. **The system is reusable not expendable. It can go again and again.**
5. **It stays in space, so it's not scarred with reentry protection.**
6. **It parks at and flies from lunar orbit, so there is no fear of radiation or unwanted materials falling to Earth.**
7. **It can dispose of itself by flying to the Sun.**
8. **It does not discard nuclear hardware in space**
9. **It is designed for a 5-year life without refueling the nuclear fuel.**
10. **It can expand travel to Mars into the"unfavorable years"**
11. **It provides Crew Solar Flare Radiation protection**

The Brayton Cycle power generation system contains the following elements: **1. A high temperature gas (He) cooled TRISO reactor –** 43% lighter than a Liquid Metal Cooled Reactor.**2. A two sided radiating carbon-carbon Heat Pipe Radiator** – NASA Glenn Research Center - tested prototype radiator design – 40% lighter than an armored standard radiator.**3. An AC electric system –** 40% lighter Alternator and PMAD.**4. Nitrogen secondary loop with combustion turbine driven generation**. **5**. **Electric Thrusters** – 4 Vasimir-type modeled thus far with data from Ad Astra.

SURFACE SYSTEMS



The basic surface power system is the same for terrestrial or planetary installations. The most significant difference would be in the cooling system, as previously described. Exterior security will be determined by the locality, however, is simple and straight forward. Such systems would be useful in Alaska, Puerto Rico, northern Canada and remote sites worldwide. These systems would provide ample power and valuable local employment

SAFETY

Small High Temperature Gas Cooled Reactors (HTGRs) are being developed by a number of organizations throughout the world as part of the global effort to further develop nuclear based power to help satisfy future energy requirements with less reliance on greenhouse gas emitting fuels. The growing international interest in the HTGR concept is the direct result of HTGR's features that are suitable for deployment at remote sites that are off-grid and currently rely on deliveries of diesel fuel to meet power needs.

(1) Inherent Safety. The HTGR does not require active safety systems to ensure public and worker safety. Reactor decay heat is removed by means of natural heat transfer mechanisms to maintain reactor fuel temperatures low for assurance of nuclear safety.
(2) High Temperature Capability. The HTGR is capable of safely producing temperatures of up to 950°C. This high-temperature capability translates into higher energy conversion efficiency for a variety of energy outputs, which can also include applications that require process heat.
(3) Competitive Economics. The higher-energy conversion efficiency of the HTGR, combined with the elimination of any need for active safety systems, results in a design that is more economically competitive than other non-passively safe reactor concepts.
(4) Flexible Fuel Cycles. The HTGR can operate efficiently and economically with several different fuel cycles. Since its inception, designs have been developed utilizing low-enriched (LEU) uranium fuels, high-enriched uranium (HEU) fuels, mixed uranium/thorium fuels, and surplus weapons-grade plutonium fuels. The thermal neutron spectrum of the HTGR, combined with the robust, ceramic-coated TRISO particle fuel, allow for very high burn up in a single pass through the reactor. This flexible fuel cycle capability, combined with its flexible energy output capability, result in a design concept that is very well suited for a wide variety of energy-growth scenarios.
(5) The helium coolant, graphite moderator and coated TRISO particle fuel are key HTGR characteristics that provide several important inherent safety features. More specifically
   - Helium is an inert gas, both chemical and nuclear, which remains in a single phase for all possible reactor conditions.
   - The TRISO fuel, graphite moderator and graphite structural components form an all-ceramic core that provides for very high temperature operating conditions that make consequences of loss of coolant accidents an insignificant event.

  - More specifically, the microsphere coated particle fuel plays an important role in assuring safety of all HTGR designs. The ceramic coatings retain fission products during both normal operation and accident conditions. The coating temperature limit is higher than can be achieved during even the most severe accident conditions. Therefore, no significant quantities of radioactive fission products can be released under any credible condition. These practically indestructible ceramic fuel coatings assure the safety of the public and prevent any releases of radioactivity to the environment at all times.
- HTGR safety is also enhanced by a combination of passive and inherent safety features:
  - Core decay heat removal during transients is achieved passively by natural conduction, radiation and convection to the environment.
  - A highly negative temperature coefficient of reactivity inherently terminates power excursions and shuts the reactor down in the event of operator error or failure of the normal control system, a key safety parameter in remote operations.
  - The inert helium coolant precludes the possibility of chemical reactions with the coolant. There are no high-pressure water sources that could inject water into the reactor system. No motive powered active safety features or operator action are required to ensure safety.

In addition, no motor powered active safety features or operator action are required to ensure safety.

ECONOMICS

The general economics of a SMR is governed by three significant components. The time, scale and scope of the project are significantly shorter and the development cost is amortized over multiple units. These should take the cost per kilowatt hour to less than half the cost of Diesel fuel generation. Operating costs would suffer by the same scale adjustment, however overall costs are expected to remain below a factor of 2 of the typical Diesel fueled system. In all we anticipate an extremely competitive cost picture, and will refine these estimates during the early development stages.

SUMMARY

The high temperature gas cooled small modular reactor using TRISO coated particle fuel is the only seriously-investigated concept that has the ability to successfully be applied to the three critical missions: terrestrial remote power, space propulsion power, and Mars and Lunar surface power. This commonality yields the opportunity for economy of scale no other system can offer.TRISO and high temperature gas cooled reactors were initially developed and deployed in the U.S. by General Atomics (GA). Both were developed on government programs, as has the further development of advanced TRISO fuels, thus the technology itself is public property. AGPower92 has unique access to the people, processes, and tools developed for TRISO fuel, HTGRs, and nuclear electric in-space propulsion;and represents the most capable and least risk solution to each of these power applications.

Contact: Richard P. Hora, rphora@aol.com, (858) 486-7527