"MAKING MARS A HOME AWAY FROM HOME"

Interview with 4Frontiers Vice President, Joe Palaia

(Revised for clarity)

Exploration, settlement and development have in the past presented themselves as alternatives to war, providing a means for human societies to expand their horizon. These pursuits have in turn led to innovation in acquiring the resources which society needs to fuel its endeavors. While the major space faring nations continue to exhibit legislative indecision regarding the funding of serious human space exploration and commerce, there are those who see vast potential within the inner solar system to expand the resources available to humanity. Government and industry need to "fish or cut bait" with regard to much of the preparatory work required for human exploitation of space domains. In the case of Mars, they need to do much more than just drive rovers across its surface. Some private companies are now beginning to undertake the required preparatory work, having realized the potential, which Mars in particular offers.

In March of 2007, I had a chance to speak with an officer of one such company: 4Frontiers Corporation's Joseph Palaia.

Bruce: I'd like to begin by expressing my admiration for members of the 4Frontiers team and the work that they are doing. It's uncommon to see a group of technical people come together to pursue an endeavor that promotes space development, settlement and which often leads to prosperity for humanity. I don't think the general public fully understands the potential our solar system holds. I doubt that many think about any celestial body in our solar system beyond perhaps lovers contemplating stars in the night sky.

Could you briefly describe 4Frontiers and its mission to our readers?

Joe: Thank you, Bruce, for your kind words. In essence, the 4Frontiers Corporation is a company that's looking at what's going to happen in this new space domain that really is going to be opening up to humanity in the next couple decades. There's going to be a whole new economy that's going to emerge, we call it, "The Inner Solar System Economy". There's going to be people and companies going out and doing activities in the inner solar system. That's where 4Frontiers gets its name, from the four frontiers of Earth orbital space, the moon, the Mars system, and the asteroids. We have quite a bit of focus right now on Mars in particular, although we're looking for other opportunities as they emerge to have activities in some of these other space domains. The real reason that we are looking at Mars in particular is because it's the most attractive target in terms of sustainability. It has all of those elements and resources that you need to support industrialized society – agriculture and industry, and all in one location, whereas, a lot of the other locations in the inner solar system do not. So that's why we have a real focus on Mars. In the short term, what we're trying to do is, of course we're a 'for profit' company. We can't be so focused on the long term objectives that we starve in the short term, and so we've got three business segments that we're pursuing: an informative entertainment business segment, a research and development business segment, and a consultancy. There are a number of projects we're pursuing in all three of those areas. The Gen II study, the Mars settlement technical study is on the research side. We expect there will be a number of items, intellectual property that come out of that, things we can patent, perhaps spin-off technologies that we can license and develop. We're also looking to try to get a couple of small contracts in place at this point. We have a number of potential consulting jobs lined up. We did have one in 2006 that we did. Then on the informative entertainment side, we're looking at a number of projects. We have a series of short stories that are up on our kid's website right now. We're going to be looking to publish a short story book. We also have a big project coming up that I can't really tell you much about right now because it's in the formation stages. And the big project in the mid-term is to build an entertainment center, a place where the public can come and see what a Mars settlement will be like first hand. And that would generate revenue to support the other business segments.

In a nutshell that's what 4Frontiers is trying to accomplish, at least in the short term.

Bruce: I wanted to comment on the imperative that in order to realize these projects it would call for the use of nuclear energy in space within our solar system especially in light of the limited options from other power densities and the longevity that nuclear power can bring. There is also the possibility with nuclear energy of terraforming Mars and to aid in reducing the release of GHG (Green House Gases) in the Earth's atmosphere (contributing factor to Earth warming).

My first question is a debating point with regard to the myriad of human missions to Mars studies: Von Braun 1952; Stuhlinger 1966; Boeing 1968; Von Braun 1969; Jenkins 1971; NASA 90-day study; Soviet all-solar 1989; Mars Direct-chemical 1990; Mars Direct-nuclear 1990; NASA ref. version 1. 1993, NASA ref. version 4. 1999; VASIMR 2000.

Here's an example; let me first point to another well-known author, referencing his version of a Mars Mission, "...In fact in 1998 I had done studies showing the out-bound leg of the mission, a single booster in the class of the Apollo-era Saturn V could launch an entire human Mars mission with a single booster, the whole system could be integrated on the ground at Cape Canaveral and the issue of in-orbit assembly of interplanetary spacecraft would be moot." *Robert Zubrin, The Case for Mars.*

I believe 4Frontiers advocates the VASIMR plasma rocket engine 10,000-300,000 m/s (1,000-30,000 seconds), which is so far known as a hypothetical concept. VASIMR drives require a great deal of heavy machinery to confine even for relatively diffuse plasmas, it would be unusable naturally, for very-high-thrust applications such as launch from planetary surfaces. Unless research has changed of late the thrust of this system is unsustainable. Fusion and antimatter remain potentially as ideally suited for deep space travel, but have not matured enough to become indexed into near-term missions. You advocate the use of a liquid metal molten sodium type reactor that as designs of choice at the moment has not mentioned this type reactor for in-space flight configuration because it may require added mass to operate efficiently in space. 4Frontier requires 3 (4MW/each) separate LMR's.

The system that has legacy data is the NTR (Nuclear Thermal Rocket) and it's reusable. NASA-Glenn Research Center's Bi-Modal NTR flight system using a cermet-tungsten elemental U-W fuel is currently the system of choice. Both for safety, redundancy and quick quality thrust of between 66KN -1112KN using propellant fuel of H2 and LOX for added thrust for Earth escape velocity. This would be accomplished without adding mass to accommodate energy transfer from N-reactor. The JIMO mission to Jupiter's moon Europa was canceled by NASA in 2003 because, in effect it was configured to use a NEP (Nuclear Electrical Propulsion) feature which removed the N-reactor from its main thrust propulsion system; besides the system depended on an extreme amount of cooling mass area to provide heat sink to reactor operations further adding unnecessary mass. The Bi-Modal NTR also uses this strategy as acceptable, but only providing low thrust, low mass EP thrusters for mid-course corrections to trajectory to power and maintain NTR momentum thrust to power and quickly achieve transit with destination Mars and provide electrical power for angular rotation (artificial gravity) and crew flight systems. You raised the point that the exhaust plume from the NTR would not be palatable to the public because of increases in radiation levels.

What if it could be demonstrated that no significant background space radiation would be adversely effected? Would you accept a study that pointed to this result? Can you explain 4Frontier's launch to Mars strategy?

Joe: There quite a few things I'd like to say about what you said here. Number one, before 4Frontiers was established, I took part in a nuclear design study at MIT that looked at reactor concepts both for supporting the Earth-Mars journey and also for operations on the Martian surface. In that paper I did advocate a VASMIR engine. I still think it's a tremendously interesting idea. I wish Chang-Diaz and his group all the luck with it. However, I think I need to clarify. Presently, 4Frontiers is going through this design study for the Mars settlement and we are not making any call on what launch systems and transport systems are going to get the cargo from Earth to Mars. We have a group of people working with us now that are doing a mission planning element, taking a look at what types of boosters could we use to launch the payloads to earth orbit, what could we use to shoot them off to Mars. They are going to make a recommendation to us regarding what they think the best strategy is. But, I think I need to be very clear that 4Frontiers is not in the business of making rocket systems or propulsion systems. We're very much looking to be a customer of some of these groups out there that are developing new launch systems, and we're hoping that they reach their price-per-kilogram target. We are not developing any particular system, and I would say we're really not advocating any particular system over any other.

Bruce: Oh I see...

Joe: We've always taken the attitude that we need to be planning on using near-term or present technologies and not depending upon technologies, which are, you might say, far distant in the future; or at some undefined time frame when they become available. So we are designing our systems and our strategies so that we can make use of what is available. And if something better comes along say, a VASMIR engine is developed and is flight ready, then we would certainly consider making use of it, but that's not to say we're advocating it. Also I do want to say that we are looking at, as you said, three reactors to support the initial settlement of 12 people. The design of these reactors is still to be decided. The initial design you quoted, a liquid metal concept, was for a space reactor to be employed with the VASMIR system. For the surface reactor we are looking at a variety of reactor concepts.

Bruce: Would that be the epithermal reactor? I think the nickname for similar variable slow neutronics in a reactor is a "Slowpoke".

Joe: Well... there's a number of reasons why you might want to go with an epithermal reactor. I would point you at our website to read the in depth trade analysis done on that. Primarily it was the need to have slow transients, so that if you start-up the reactor remotely, by the time you have your feedback signal and can respond with a control signal to do something about whatever is happening at the reactor. You don't want things to have changed so quickly that some damage might have occurred. Another idea we're looking at was using CO2 coolant. So the reactor would be insensitive to the ingress of CO2. Also in the case of a leak, if you need more coolant, you just suck CO2 in from the Martian atmosphere.

Regarding the NTR, I'm familiar with the work of...

Bruce: Would that be Dr. Stan Borowski?
The Pratt & Whitney Company has been active in supporting scientist and engineers advocating [propulsion system] the rocket engine. They're on record as throwing their hat in the ring if only DOE and NASA were to wholly support the funding required to test the NTR system out properly. There has been some work toward NTR, but it falls way short of what's needed to answer the question: Does the exhaust plume from an NTR rocket engine contain harmful radiation irretrievably affecting the space environment and crew?

Joe: It's a technology that bares more investigation. I'm certainly not in a position to make the call whether funding should be allocated to it or not over other research. I would love though for more research to be done there. Again, it's just another potential system, which can improve our capability to get cargo to Mars, and if it's developed and available when the other elements are in place for us to move forward with the real Mars settlement then we will consider it. We're trying to eliminate as many barriers as possible. So if there's some technology that we make 'critical path' that didn't necessarily need to be 'critical path'. Well, that just slows the program down and presents another stumbling block for us. This applies even to the degree where if we had to rely on the development of a Saturn V class rocket. That represents a significant effort to put together. We don't have that capability anymore, and so we're not going to depend upon that. Our baseline concept is going to call for launching all the elements that we need to put the Mars settlement in place on EELV class boosters, because that's what's available, that's what we have right now. Again, if something better comes along, if a heavy lift booster is developed, then we can adjust our plans accordingly.

Bruce: 4Frontiers mentions a VASMIR fast transfer and Mars Overshoot Technique. Described, the VASMIR engines would continue to thrust for almost the entire trip resulting in a 90-day crew transfer. Near Mars the crew would board a capsule that would aerocapture and land while their transfer propulsion system and habitat would overshoot Mars and re-encounter it several months later. The VASMIR craft would remain in Mars orbit until the crew is ready to return to Earth. What sort of propulsion system would be used for transfer? It's an interesting concept to allow an overshoot to Mars.

Joe: Yes, you're referring again to an early paper before 4Frontiers was founded, that the MIT class had done. I

believe that's a rather baseline concept, it's not something new or that we developed. It's something I believe the VASMIR group had developed as a strategy to essentially accelerate your craft, but not decelerate it all the way to the point where it can capture into Mars orbit right away. So have it essentially fly past Mars. So you get your crew there more quickly and they are going to go on say, a direct entry and land while the main spacecraft flies past Mars and continues to thrust over time and then re-encounters Mars.

Bruce: Another facet of the 4Frontiers Mars proposal is the establishment of telecommunications. I would think that would be a great testing ground for either propulsion concept, for the company to install a Mars orbiting telecom satellite to begin to process high bandwidth, high throughput, communications.

Joe: Again, you're referring to the initial MIT paper, where we were looking at putting a telecom satellite in Mars orbit to support all of these high bandwidth applications. If you have a settlement there, if you have multiple pieces of infrastructure, you have a lot of data you would like to get back. You would like to have the capability for high bandwidth transmission. In this case, in the case of the paper, we were looking at a development strategy whereby we could use a scaled down, in size and/or power, version of our space reactor and actually power the telecom satellite with that space reactor. So it was looked at as an incremental step, since we said we would need the telecom capability anyway, let's make use of the reactor for that purpose. I don't know if we really need a nuclear powered telecom satellite, but we will certainly need some communication satellites in orbit to support our activities on the surface. 4Fontiers is looking in the long-term plan of sending at least one precursor mission to Mars to obtain some ground truth data at whatever location we ultimately select for the settlement. I think that is very important in terms of the industrial processes that we really understand the constituency of the local soil and the local minerals and also perhaps that we would have a small, portable, automated drilling rig that would land there and drill down and see if we could tap the subsurface aquifers, assuming that they are there. So I think there are going to be these precursor missions that we're going to want to send; but whether they will be nuclear powered or not would depend upon the power requirements of what we're trying to accomplish.

Bruce: Does RPS (Radioisotope Power Systems) techniques figure in any of the 4Frontiers plans for Mars?

Joe: I'm sure that we would want to make use of them, just as NASA is looking at sending them on the Mars Science Lab (MSL) rover. They have a call for higher power over a longer duration. It would be one option for powering whatever systems we send. We are also looking at having it as a back-up capability. At the actual settlement, should all of your other systems fail, you could always go back and rely on your RTG's to generate at least enough power to maintain living quarters and breathable atmosphere.

Bruce: The 'hard boiled' hyper capital industrialist would ask, "Once a Generation II thriving Mars settlement is established what sort of export product to Earth would we expect other than settlement 'destination', and the odd rock/soil trinkets"?

Joe: It's an interesting question. It really drives to a more fundamental question, which is what is the economic justification of the settlement? Can the settlement pay for itself and generate value? We've tackled this issue within 4Frontiers, and have come up with a number of things and I'm sure we will come up with more over time. First of all, if you're looking for a physical export, there may not be a case for bringing physical material all the way back to say Earth. Now that's not to say that it may not make sense to send some physical product somewhere else in the inner solar system - remember we are looking at more than just Mars here, we are looking at the bigger picture. For instance, I will give you an example; we are looking at having all these payload delivery systems, such as decent and landing systems, which are going to deliver our cargo to the Martian surface. Well, what happens to these systems after you have unloaded the cargo from them? They still are viable systems, with control systems, the rocket engines are there, they have propellant tanks, etc. You can potentially 'retro-fit' this equipment, fill the tanks up with Martian derived propellant, and load them up with lets say water, or raw building materials perhaps from our steel foundry and other goods and materials. You can fire them off and send them say to the lunar surface. So it begs the question, what is the value of however many tons of let's say, water on the lunar surface?
There are also other ways to look at this picture. You don't have to necessarily export something from Mars all the way back to Earth to get an economic justification. What we really like to export all the way back to Earth is data because data will be relatively cheap to transfer. So it's data, know how and experience. I also see the

serving of a Mars market. In essence as more people come to Mars, whether they are scientists, geologists that want to do various science experiments, research and exploration; the settlement can serve a supporting role for those people that can generate a revenue stream. I can see eventually tourism playing a major role. I think after the initial settlement is established, that will be the proof of concept. People will see this can be done. Mars is a destination, that there are interesting things to do there, that it really is a new world. I think that many people will want to come and setup shop there, and so now you have another whole market that has emerged. You have this industrial base in place on Mars including mining, refining, manufacturing, agriculture, habitable space, and you can support and outfit others who wish to establish facilities there on the Martian surface. So there are a number of different ways that this settlement can generate revenue to support itself.

Bruce: Mars is sort of a frozen desert. Akin to maybe a research station on Antarctica just short of an astronomical unit in distance removed from Earth with water ice locked up under its surface.

Joe: I would disagree with you. I view Mars more as an empty continent awaiting exploration and development. All of the resources we need, again to support agriculture and industry are there. I would argue that we are far better prepared to settle Mars than those who came over to settle North America were.

Bruce: If I may play devil's advocate here with regard to my description of Mars as a desert. Just like deserts here on Earth, societies that have lived in these geographical regions have had to adapt and build societies around the availability of water. The first thing that a human being has to do is process water and insure its availability, whether it's locked up as ice, free flowing underneath the ground, or flowing from melted snows from mountains. Processing Martian water sources will require filtration and treatment of sanitary potable water for human consumption. Case in point, in arid regions humans have been able to survive, prosper and build societies in and around arid land in part by digging wells. Mars is not barren. The first impression one gets looking out across the Sahara desert or on arid regions of the Middle East for example, before the beginning of the last century no one then could have imagined these totally barren wastelands would yield a giant petrochemical industry. It provides a great part of the worlds energy needs currently. The imperative to provide potable water on Mars would seem to be the very first step in establishing a successful settlement for the first humans to arrive on Mars. How difficult would it be to process drinking water?

Joe: Actually, it would be a relatively straight forward procedure. One of the technical concepts that are being developed in our latest round of studies is exactly that, a water processing system using off-the-shelf water processing systems and technologies that are used in industry right now. In fact in many regards it's actually easier to process the Martian water, assuming you can get at it by extraction from the soil or tap into subsurface aquifers. Assuming that you can get to the water, it's much easier to process it because we are assuming it has zero percent bio matter in it. So there are no germs, there are no pathogens, there's nothing living in it that we would need to worry about and strain out. It will probably be very salty and briny, but that's a relatively straight forward process to extract the salts. In terms of where we get the water from... we're watching very closely the information coming back from the two radar experiments that are in orbit around Mars right now.

Bruce: Didn't Global Surveyor spacecraft take photos of something akin to water oozing from a ravine on the Martian surface?

Joe: Yes, it did. But, I was referring to a different experiment. On the Odyssey spacecraft and the Mars Express the European Space Agency (ESA) spacecraft. They are all equipped with subsurface radar.

Bruce: Ground penetrating radar...

Joe: We are very interested in getting that information and seeing where exactly are these subsurface aquifers. Are they within drilling distance of the surface and located lets say near the equator, which is where some of our prime locations for putting the settlement are? However, it's entirely possible that we won't find a suitable aquifer to drill down and tap. So we are also looking at alternative strategies. We're looking at taking hydrated minerals that we know the locations of from orbital hydrogen signature data, and basically "baking" the water off of them. We are planning on having both capabilities; the drilling capability and the ability to extract water from hydrated minerals. That's another reason why we need a precursor mission to see some ground truth data, so that we can

down select and decide if we need to bring a drilling rig or would we not? Let me add also, that if you look at the history of settlement and the expansion of humanity on this planet; people have followed the water. Where there was a readily available source of water, people have settled and made a new life for themselves. Where there was not water available, they have not settled. I think that the same thing will happen as we go out into space. We will look for places where we can find readily accessible sources of water.

Bruce: Last question...Other than fish and substitute animal protein, couldn't frozen embryos be raised to provide livestock, such as chickens or pygmy pigs or cattle etc.?

Joe: Certainly you could look into scenarios like that. We have as part of the GEN II effort on staff a commercial fish farmer from Mexico, Pablo Rivera Jimenez who is working with us. We also have Nathen Owen-Going who is working on the agricultural concepts for us. We are looking at a combination of agricultural produce and fish, Tilapia, to provide the dietary requirement of the settlers. Really, when you look at some of the other choices for livestock, you have to look at how efficient are they at converting biomatter (plant matter) into meat, something that can be consumed by people. Chickens for instance are not all that terribly efficient at doing that, and another thing is that chickens eat things that we could eat. A better choice would be say pigs and goats, creatures that eat what we consider to be the inedible portions of plants. In essence you are taking this inedible biomatter that you are going to be generating anyway and instead of composting it, which you're going to do, your going to be doing quite a bit of composting, but instead of composting your going to feed it to these animals that are then going to produce material that you can eat.

Bruce: In that regard the Biosphere II project and the Mars Society, Devon Island experiments... how do these efforts tie in with the 4Frontiers plan for Mars settlement? Do you liaison with these groups for information and resources?

Joe: They're both tremendous experiments. They have provided a wealth of data, both of them. We actually have on our board of advisors one of the Biospherians, Jane Poynter, and she's working with our agriculture and aquaculture experts. We have taken quite a bit of information that they obtained in Biosphere II and applied that operational experience to our concept. Regarding the Mars Society's efforts, and I think they're doing some terrific work in terms of finding out what it's really going to take for us to live and work in an environment like Mars. For instance, how much water does a typical crew person going out on a Martian EVA use? I think that's a number that Johnston Space Center and some of the folks at NASA did not accurately estimate. I think it's absolutely imperative that the type of research that the Mars Society is doing is done so that we can really get some more accurate numbers. So we support that type of research wholeheartedly, in fact many of the members of my team are members of the Mars Society and we think that they are doing some good work.

Bruce: Thank you for your participation.