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SPACE TOURISM – ESSENTIAL STEP IN HUMAN SETTLEMENT OF SPACE

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This paper draws attention to the essential role of space tourism, as a commercial enabler, in the development of a sustainable long term strategy for exploration and settlement of solar system objects. Since governments will not be able to obtain all of the necessary funding and public support over the long duration necessary (multiple election cycles in democracies) in order to unilaterally, or even in collaboration, conduct missions to explore and colonize the Moon, Mars or other solar system objects, other alternative sources for such funding are explored. These sources would provide an economic development basis for such a venture, and simultaneously engage the general public through direct involvement to eventually make such a venture possible. The analysis determines that space tourism is the one near-term commercial space market sector whose development can lead to the desired long term results. A major consequence of a successful space tourism industry, in addition to creating an involved public, will be regular, safe and relatively low cost journeys to and from low earth orbit. This in turn will provide a new starting point, or platform, for the long term exploration and settlement of the solar system through further economic development stages. A basic architecture is described for a sustainable approach to the exploration and colonization of solar system objects, which relies as a key factor on the successful development of a viable space tourism industry.

I. INTRODUCTION

How do we get there from here? We start by underlining the need for humanity to eventually settle other parts of the solar system. While recognizing the technological challenges to achieving this long term aim, the paper focuses on the political challenges. In order to do this, there is a need for a commitment from politicians and the general public that has proven impossible to achieve thus far. The paper explores why this has been the case and suggests that the political dimension requires a delicate balance of timing, funds and honest rhetoric for sustainable progress. The key, it emerges, is planning a backwards schedule so that short-term funding decisions are seen in a long-term context which is not in itself politically contentious. This, in turn, leads through judicious focused R&D spending in the near term, to the gradual development of an evolving space infrastructure which will ultimately provide the means for the exploration and settlement objective in the long term. Building this infrastructure, which must be economically beneficial and revenue generating in its own right, relies upon a mixture of governmental and private entrepreneurial investment which must initially be built upon a platform made possible only by the development of a successful space tourism industry.

II. SETTLEMENT

Let's start with a set of agreed non-political reasons for human settlement beyond the Earth, possibly in multiple places within the solar system. The well-known physicist and cosmologist Stephen Hawking said in 2001 "I don't think the human race will survive the next thousand years, unless we spread into space". Settlement or colonization of space is not of course a new idea. Perhaps one of the most persuasive cases was made by Gerald O'Neil in 1977 (Reference 1). But even going as far back as Tsiolkovsky in 1912, the rationale was understood. He said "The better part of humanity will never perish but will move from sun to sun as each one dies out in succession". Both of these quotations provide an indication of the very long term timeframe that is involved. Tsiolkovsky is worried about the eventual fate of the Earth when our sun begins to turn into a red giant, something that is not expected to happen very soon. Hawking is considering events that may well happen in a less-distant timeframe. Events such as asteroid or comet bombardment, cosmic radiation during a magnetic pole reversal, gamma-ray bursts from elsewhere in the galaxy, and impacts due to humans themselves (such as nuclear war, biological warfare, out-of-control human-induced climate change, etc.). Clearly it is not a matter of "if" but "when" it will become necessary for a human "insurance policy" through settlement to be instituted.

I have underlined the very long timescales (from hundreds to thousands or even millions of years) because I do not think there is anything very time-critical in our efforts right now. Just so long as we are headed in the right general direction. We should not pretend otherwise, or there will be no credibility to our plans. The human race has made the crucial first steps into space during our lifetime, so that we now at least

(and at last) have the opportunity, and one could say the responsibility, to work on the next stages, even though the timeframe is not urgent in any realistic sense. The early dreamers, engineers and astronauts have done their part, and in some cases even given their lives, to give us this opportunity to figure out a survival strategy for the human species (and in fact for all other life of which we are aware). Therefore, developments should proceed against a background of understanding the very long term existential threats, while proceeding at a pace that nevertheless makes sense in the short term from the point of view of budgets and alternative priorities.

Besides the survival imperative, there are other reasons for exploring outwards into the solar system, such as to enhance prosperity by making use of the abundant resources from space. And there is the more spiritual reason, summed up by the phrase "because we must explore". In the American context, pioneering the frontier was an essential part of the country's risk-taking character. Former Space Shuttle manager Wayne Hale, however, wondered aloud whether things had changed. In 2005 he said "It is not certain that the US today, living as it is in the luxury of the legacy of its pioneers, still has the capability to weigh risk, reward, hardship, hope, difficulty and opportunity as they formerly did". Let us hope that the national character is still capable of rising to a challenge.

There are other reasons, too, for space exploration and settlement, including a search for knowledge, and new sources of energy and minerals in scarce supply on Earth (References 2, 3, 4, 5, 6 and 7). Probably the best overall rationale in recent times was articulated by President W Bush's Director of the White House Office of Science and Technology Policy, John Marburger. He said in 2006 (Reference 2) "Phenomena in the solar system…can reasonably be described as falling within humanity's economic sphere of influence…questions about the vision boil down to whether we want to incorporate the solar system in our economic sphere, or not. The ultimate goal is not to impress others, or merely to explore our planetary system, but to use accessible space for the benefit of humankind. It is a goal that is not confined to a decade or a century. Nor is it confined to a single nearby destination, or to a fleeting dash to plant a flag. The idea is to begin preparing now for a future in which the material trapped in the sun's vicinity is available for incorporation into our way of life". For many people, including many politicians and leaders of government, the lack of immediacy and the long-term nature of the endeavour make it hard to formulate the necessary policy statements. The space entrepreneur Jeff Greason declared in 2011 (Reference 3) "It is actually the national policy of the United States that we should settle space, but everyone's kind of afraid to say so". There are, however, many supporting organizations (eg The Space Frontier Foundation, Space Renaissance International, the various Interplanetary Societies, etc.) which embrace the notion of opening up the space frontier to human settlement through economic development. We should not press for unrealistic timescales for the grand endeavour. There is no need. As said (Reference 8) "It does not really matter how long it takes, as long as the vision is maintained to establish one or more self-sustaining space colonies".

The best aspect of this very long term vision is that, when described properly, it is capable of appealing to multiple constituencies simultaneously. They can be national and international. This kind of very long term aim is not inherently Republican or Democrat. It is not specifically Labor or Conservative. Even religious leaders would get behind the idea that we have a responsibility, ultimately, to provide an Ark to ensure that life survives an approaching catastrophe. To do this will require the best of human ingenuity, for generations to come, and it will challenge all of us, and our descendants, if we are to succeed.

III. RIGHT TIME, RIGHT MONEY

So, if there is no disagreement about the ultimate need, what has been the problem with regards to working towards fulfilling that need? The answer involves technology (quite simply we don't know how to do all of it yet), but is more firmly rooted in matters of budget, resource and timing. At least in democracies there is an annual budget process to determine priorities for allocating the funds raised by the government via taxes on the population. The very long term exploration and settlement option just does not easily fit into such a short term prospect, especially when overlaid by an only slightly longer election cycle of four or five years.

There was one exception to this rule, in the case of John F Kennedy's call for the race to the Moon. And in some ways the success of Apollo has resulted in decades of frustration when nothing equally audacious has been possible since 1970. However, we must recall that there was a Cold War mentality which made it possible to levy a 5% of GDP tax burden on the American people throughout the sixties to achieve the Moon landings. Nowadays, in the US, NASA has an annual budget, which while large in global terms at $17 billion, is nevertheless only a tenth of those Apollo-era figures.

Furthermore, there is probably a miss-match, which needs to be corrected, in the minds of the general public

between what is wanted and what is achievable in a given period at these reduced budget levels. Almost certainly too much has been promised, and the public believed that what they saw in the simulations and videos already really did exist. This is partly due to the audacity of Apollo itself (and folks forget how much it cost) and partly due to the Hollywood and TV versions of the fantasy of interplanetary, and even intergalactic, travel, with "warp-drive", etc.

There has been no shortage of attempts to raise the support for new space visions. There have been examples under the leadership of each of the two Bush presidencies, but in neither case would the Congress (representing the public) fund the initiatives. Does this perhaps mean that it is impossible in a democracy, outside of a war situation, to levy the funds to make human settlement of space a reality? Such a conclusion would be unduly pessimistic. What is needed is a situation where the public understands the overall direction, and a realistic assessment of the long time horizons, while meanwhile deriving interim benefits on an ongoing basis from the space exploration activities. It's about balancing the timing, rhetoric and funding.

In the current administration, President Obama himself said "Our goal is the capacity for people to work … and live safely beyond Earth for extended periods of time, ultimately in ways that are more sustainable and even indefinite." The official US space policy language is provided in Reference 9. The advisory body which was most influential in defining current US space strategy was known as the Augustine Commission (Reference 10), and they recommended a "Flexible Path" concept as the most likely to be sustainable. In their report we read "There was a strong consensus within the Committee that human exploration should advance us as a civilization towards our ultimate goal: charting a path for human expansion into the solar system."

This broad policy is interpreted by NASA's leading management in ways which emphasize the need for sustainability (Reference 11, 12): "NASA will accelerate and enhance its support for the commercial spaceflight industry to make travel to low Earth orbit and beyond more accessible and more affordable. Imagine enabling hundreds, even thousands of people to visit or live in low Earth orbit, while NASA firmly focuses its gaze on the cosmic horizon beyond Earth.", and "We must invest in innovations for space technology and new ways of doing business, if we are to develop a space exploration and development program that is truly sustainable over the long term.", and more specifically "When we go beyond the Earth-Moon system, we must do it in a cost-effective manner. In order to do that, we need the capability to refuel transfer stages, the ability to live off in-situ resources, and the ability to take advantage of breakthroughs in on-orbit space propulsion". The US National Research Council added (Reference 13) "Emphasis should be placed on aligning space program capabilities with current high-priority national imperatives." We can find plenty of other advice in References 14, 15, 16, 17, 18, and 19.

So what, if anything, is missing from all these statements? The taxpaying public needs to be told what they can expect to obtain for their tax dollars both in the near term (for themselves) and in the long term (for their children and grandchildren), and its relevance to current national needs. In Reference 16 we are reminded "Space programs in order to be sustainable need to maintain a healthy balance between the immediately useful and the exciting". We shall attempt, in the next section, to provide the raw materials from which this new "*Peoples' Vision for Space"* may be formulated, and which will indeed strive to maintain that critical balance.

IV. THE BACKWARDS SCHEDULE

We begin at the end, the Very Long Term (VLT). Where do we want to be, maybe centuries from now? Consider the gravity wells in the solar system. The toughest part will be getting out of Earth's gravity well in the first place – at least as far as the geostationary orbit (or arguably to the L1 Lagrangian point in the Earth Moon system). Once we are there we have almost enough energy to get to the Moon, near Earth asteroids, or the Martian Moons, and points beyond. So, a good platform for the long term exploration and settlement of the solar system would be a "Spaceport Earth" complex in geostationary orbit. And of course the regular taxi service to take humans and materials there. We want to be able ultimately to enable large quantities of humans and other living things to travel the solar system across the vast distances of the interplanetary gravity well plateau, and then to be able to land and set up self-sustaining outposts there. It has been about a hundred years since we learned to fly, so maybe a century from now would be a reasonable time frame to consider for at least the beginning of the VLT, the colonization phase, but we do not really need to put a date on it.

Let's now move somewhat closer to the present, and explore the Medium Term (MT). During this phase we need to master the skills of transferring relatively small payloads of cargo and people (when compared with the VLT) across the near solar system. In this phase space activities need to be becoming economically self-sustaining, so we shall use some space objects, such as asteroids and the Moon, to provide fuel and other

precious resources, such as oxygen, water, the platinum metals and rare earths (currently only available from China). Some of these products will be used for supplies for further outward travel, and for in-space assembly; some will be used for trading back to Earth to generate funding. References 20, 21, 22 provide insight into the potential values of materials mined from the Moon or asteroids. Reference 21 in particular provides a detailed account of the economics of He3 extraction from the Moon, and its potential as a key to long term energy needs of planet Earth. Also, in this time frame, we can organize to be able to protect the Earth from future potential asteroid impacts. Thus, while helping solve some of Earth's resource and security issues, we shall have alternative revenue sources for the ongoing space program by building an economic development base for the venture. What, precisely, do we mean by the MT? Again, it will not be helpful to attempt to put a date on it. The whole idea of this approach is to conduct each phase within the available resources, for as long as it takes, while simultaneously offering something to the Earth-bound tax-payers who are paying at least part of the initial funding. This phase, the economic resources phase, might take, say, 50 years – but we cannot know when it would start.

Finally, in this reverse schedule, we do reach the Short Term (ST). This is the platform-building phase. It starts now, and proceeds for maybe five to fifteen years, which is about as long as can be politically managed in a democracy. I use the word "platform" merely to mean the ability to regularly go and come from GEO with humans and cargo. Particularly in an election year, we must address the main challenges that we are trying to solve here and now on Earth – jobs, clean energy reserves, economic stagnation, strategic material resource limitation, global climate change monitoring and mitigation, security, stewardship of the Earth's environment, etc. The space program which began in the sixties provided a great deal of technological momentum to carry us all to the present. By continuing, we shall derive future benefits, address our pressing needs, and be able to regularly keep the public engaged by pointing out the interim gains. We need to put together the rhetoric of *The Peoples' Vision for Space*, pointing out the costs and benefits and providing an honest perspective of the scale of the endeavour and the very extended timescales. Perhaps the true legacy of Apollo is the recognition that we live on a fragile world, and have developed the means to protect it from some threats and ultimately the means to leave it behind in the distant future when there is no alternative remaining. In addition to establishing GEO as a new destination for crewed spaceflight, we need to begin the R&D needed so that the problems and challenges of the MT can be met. Note that it is not necessary (or even possible) to have *all* the answers about how to do it before the grand adventure commences. We cannot even start the R&D for the VLT for maybe another 30 years until all the lessons from the ST and MT have been learned. How much will the public be prepared to pay for this? The US public, in opinion polls, has declared that the current level of expenditure ($17 billion proposed for NASA's 2013 budget) is "about right", at least in an era of austerity. For this, they expect space leadership and to obtain the benefits, in line with national objectives, of new leading edge technologies, inventions, medical discoveries, exploration, a search for life beyond Earth and new scientific breakthroughs to improve the quality of life on Earth. The public needs to view the space program as heading towards ultimately becoming a net generator of income to the economy, rather than a net source of expense. This very long term project will clearly be seen as an international endeavour, and so some funding can be expected from other countries. After all, "We came in peace, for *all* mankind"!

V. EVOLVING SPACE INFRASTRUCTURE

We can now, having seen the broad scope and duration of *The Peoples' Vision for Space*, reset the clock to proceed forwards from the present. So, we need to initially build a foothold in space near the plateau of the interplanetary gravity well. We need to first of all conduct the trade-offs to compare the possible locations at either the geostationary orbit, or at the Earth-Moon system Lagrangian Point L1. There are pros and cons for each location, and some might advocate for L1, but I opt for geostationary orbit at least in this paper as the best interplanetary launching platform. While it will require some coordination with the ITU, it nevertheless does have some advantages once we consider the role of space tourism in the next section. A human outpost in GEO, the Spaceport Earth complex, provided with the necessary transfer vehicles, could easily perform commercially valuable and revenue generating inspections, or refuelling, of satellites in that orbit.

We need to focus our R&D activities. Propellant depots are an important part of the future infrastructure, so we need to build the depots and the ways to replenish them and conduct space refuelling. Note that one firm (Reference 23) has already been formed to eventually provide "a gas station in the sky", so it will not always be necessary to seek Federal funding for all identified R&D, although of course it will be important initially. A new class of vehicle, the re-fuellable tug, will be needed as a transfer stage to shuttle back and forwards from LEO to GEO. Vehicles in the future going to and from distant solar system objects will begin and end their interplanetary journeys at the Spaceport Earth complex in GEO. As the geostationary base platform is

created, there will eventually be a large market demand for the tugs, so they may well be provided by more than one commercial provider. R&D is needed on solar sails, reusable thermal control systems, new lightweight materials, atmospheric re-entry systems, closed loop recycling ecosystems, long duration crew health and radiation protection, effective space robotics, space-based 3-D printing, new classes of rocket engine, ideally suited to the proposed missions, in-situ resource utilization (ISRU). Work has already begun on the VASIMR plasma nuclear propulsion engine, and at least two commercial operators (References 23, 24) have expressed their intention to eventually perform Lunar or asteroid mining and resource extraction. This list represents decades of research and development, and it is also the key to keeping the public engaged. Every time some progress is made, where possible a mission can be used to test out the results, and such missions can be designed to offer the public a succession of exciting space activities. Although it will not be possible to replicate the rapid pace of developments which occurred during the Mercury/Gemini/Apollo era, it should nevertheless be possible to replicate the idea of every mission testing out some new concept, which kept the public engaged throughout the sixties.

So these are the R&D technologies which will be the enablers for the short and medium term of the settlement task. Funding can come initially from NASA, then also from Energy Department and Defence budgets. Still other parts will be undertaken by private commercial entities seeking commercial gains. This is especially true of the contribution of the new space tourism commercial sector, described in the next section.

VI. SPACE TOURISM THE ENABLER

Space tourism will play a significant part in establishing the sustainable track towards human settlement of space. Deputy NASA Administrator Lori Garver (Reference 12) said "Space tourism is a catalyst that has sparked a whole new industry of passenger-carrying spacecraft. We plan to make use of commercial space providers to transport astronauts to the space station." The new taxi (or rental car) services, which NASA will be contracting with the new commercial providers like SpaceX, assume that either orbital space tourists, or experimenters, will be flying in the seats not occupied by (or paid for by) NASA. Space tourism represents one of the best ways to involve the general public; it brings the possibilities of space travel home to many.

We are about to see a transformation in access to space, which will in some ways mirror what took place in the early stages of aviation (Reference 25). Originally there were a few risk-taking aviators, then some government cargoes (usually air mail), then some primitive airliners carrying very rich passengers such as movie stars, and ultimately today's airline business with its high reliability, schedules and efficiency, where now almost anyone can fly. Space tourism already takes place using Russian Soyuz vehicles, and it is assumed that the SpaceX Dragon vehicle will also soon be able to provide orbital space tourism flights, but in much more comfort, and from US spaceports. Other possible commercial orbital space tourism vehicles include the Stratolaunch vehicle, the Orbital Cygnus and the Blue Origin and Sierra Nevada offerings. The sub-orbital space tourism business will soon begin with Virgin Galactic, XCOR and others such as Armadillo and Masten offering vehicles to provide the experience. All of these new space tourism craft have been designed to provide a reusable service into space, with the operator being able to perform rapid turnaround and airline-like operations.

The key to the success of space tourism is the potential market size. The forecasts (Reference 26) indicated that up to 15,000 passengers per year would be able and willing to pay $100,000 for a sub-orbital space tourism experience. The same forecast study found that far fewer tourists were anticipated for orbital spaceflight because of the high ticket price (of $20 million) when the survey was carried out. However, subsequent work using the same raw data from millionaire interviews (Reference 27) suggests that if ticket prices could be brought down to $1/2 million per seat, then since people are price sensitive payloads, there would also be a market of 15,000 a year for orbital tourists. The significance of these numbers, and the reason that they can frame space tourism as an enabling technology, is in comparison with the number of other payloads that have previously been sent into space. When we add up all global launches, including military, civil, commercial, everything, we find that the total number of payloads has remained at about 60 to 80 for decades. The difference between 60 and 15,000 payloads per year (if we call each tourist a "payload") is the kind of difference which allows us to experience the benefits of economies of scale. Furthermore, it is the *only* class of payload which can achieve this. In a major comprehensive study (Reference 28), NASA investigated 43 potential commercial and government markets (including communications, remote sensing, broadcasting, navigation, ISS missions, science, space rescue, asteroid detection, space advertising, space burial, crystal growth manufacturing, vacuum deposition manufacturing, hazardous waste disposal, space hospitals, solar power, etc) and determined that only space tourism had this ability to transform the

economics of the launch business within a twenty-year horizon. The new industry will also bring substantial economic and employment benefits around the new spaceports, where terrestrial tourists are expected to visit. Spaceport America in New Mexico, for example, is anticipating 200,000 visitors per year.

The space tourism industry as envisaged to date involves sub-orbital trips, LEO orbital vacations and even a circum-lunar flight. However, by providing a further destination at geostationary orbit with a suitable space hotel complex, this industry could further enhance its role as an enabler by opening up this "Spaceport Earth" complex to regular commercial flights from LEO to GEO. It would therefore help create the geostationary platform necessary for the eventual space settlement drive. Some more market research is needed to confirm the level of interest, and price level, for such a space tourism destination. There will also need to be some more detailed considerations of the use of GEO as a space tourist destination, eg provision of telescopes, the ability to use tugs to move a few miles above or below GEO to allow a drift phase to provide enhanced interest, etc. Remember the time frame we are discussing. We have time to allow the natural development of this new industry so that it assists in the creation of the evolving space infrastructure. So, the basic architecture begins with space tourism, then extends to the use of commercial LEO-GEO tugs to take tourists to and from geostationary orbit, which becomes the new platform from which human settlement architectures can commence in due course. The new long term initiatives then proceed as described above, once the fruits of the new focused R&D begin to emerge. And importantly, throughout all the stages from the ST thru MT to VLT, there will be a) involvement of the general public, b) solutions to the technological problems of the era, c) revenue generation opportunities via the commercial entrepreneurial providers and d) a sustainable relatively low Federal budget allocation, which however is focused on providing the focused R&D to enable the long term vision to succeed. Although for this paper we have used GEO for the new space tourism location, there is no reason why it could not equally be L1 which is used, or even both locations. Just so long as space tourists will be willing and able to pay to go there on regular trips.

A variety of objects in the solar system become easy targets for the space agencies such as NASA once we have established the Spaceport Earth launching pad in GEO. At this location, true space-faring interplanetary craft can be assembled, which do not need to cope with atmospheric drag or heating problems at either end. And it all becomes possible only because the space tourism business opens up the regular route into LEO and then onwards up to "Spaceport Earth" in GEO.

VII. CONCLUSION

We have described *"A Peoples' Vision for Space"*, which, built upon an initial foundation provided by the space tourism business, will provide for a sustainable multi-decadal and even multi-generational space program leading ultimately to human settlement in space. This approach and architecture will be sustainable because it is inherently non-partisan, it does not require an increase in NASA's current levels of funding, it addresses and offers solutions to many problems which we face today, and because it engages the public in a grand endeavour while providing ongoing evidence of progress.

The key elements of the strategy and architecture are a combination of government and commercial sources of funding, targeted R&D designed to make the next stages of development less formidable, and a successful space tourism business extending its presence to a geostationary orbit station, the "Spaceport Earth" complex, via use of a new class of vehicle, the reusable and re-fuellable LEO-GEO space tug, which may ideally be designed, manufactured and funded by private sector investment. This human occupation of a location in the geostationary orbit will represent a new platform from which to venture outward.

Imagine if NASA knew that there was a base at GEO and an assured way of getting there and back, how they would design and build the new craft for interplanetary travel. The vehicles for the eventual human settlement of space will be assembled there, and will depart from there. It will also represent "home base" for returning space travellers who have been to the Moon, Mars or other solar system objects. We can be sure that the new interplanetary craft would look very different from the space vehicles we have so far seen, which were designed to handle the launch and re-entry phases through Earth's atmosphere. And they would certainly be less massive and less costly.

The existing US space strategy needs very little change, and no more money, in order to bring this about. Apart from the new focus on the architecture of the GEO "Spaceport Earth" complex and its associated LEO-GEO space tug (which will require the active support of the space tourism sector) a propellant depot in LEO, and a focused R&D program, the main missing part of the strategy, which needs to be added to make the plan sustainable and immune to the vicissitudes of election politics, is a clear honest statement of the objectives, the very long time scales, and what

taxpayers will get in the meantime for their investment (with its clear relevance to solution of current issues). And an invitation to other countries to genuinely join in ,and share the costs and benefits, of humankind's next grand adventure.

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