The Potential for International Collaboration on Manned Space Transportation Systems to the Moon and Mars

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Abstract

Motivated by President G.W. Bush's new space vision to return to the Moon followed by a manned flight to Mars, many countries now consider and redesign their national goals in space for the long term. A main hurdle is a limited budget causing the wish and challenge to use this budget as effectively as possible.

In history, most rocket programs are national developments. Nowadays, the result is an over-supply of more or less similar national rockets. To pass this process again for the development of Moon or Mars Space Transportation Systems might not be wise. Instead, an international collaboration for only one Space Transportation System might be the alternative. Development costs can be shared between nations by only specializing and being responsible of one segment of the rocket.

This paper investigates on the pros and cons of an international Space Transportation System development and operation. Selected state-of-the-art Mars rocket concepts are presented and cultural business challenges of an international cooperation are discussed.

KEYWORDS: Business Culture, International Collaboration, Mars, Moon, Space Transportation System

1 Introduction

Figure 1: Manned Mars Mission (NASA)

G.W. Bush's speech about the plan for a manned mission to Moon and Mars as shown in Figure 1 is not the first one an American president has done. On July 20, 1989, President G. Bush announced his intention to support "*a sustained program of manned exploration of the solar system and the permanent settlement of Space*". In particular, G. Bush suggested establishing a permanent base on the Moon after the turn of the century and exploring Mars sometime later. The President's initiative follows through on a recommendation first made to President Nixon by the Space Task Group in 1969 (U.S. Congress, 1990, p.24).

Depending on the assumed scenario for a manned mission to Mars the estimation varies from $20 billion to $400 billion. For the best scenario case – costs around $20 billion – expenses are same as the $20 billion Apollo missions. Spent over 10 years, this amount would constitute an annual expenditure of about 20 percent of NASA's budget, or around 1 percent of the U.S. military's budget. It may be imaginable that USA could realize a national mission under these conditions. For all other scenario cases, costs are too high and an international cooperation may be the only one realistic alternative. Fundamentally, USA is interested in international cooperation over the time as stated by the U.S. congress (U.S. Congress, 1990, p.79):

"*If USA wishes to expand its activities in space, the costs of space endeavors would quickly reach the level where a much greater degree of international cooperation, including cooperation in space transportation, could be highly desirable.*"

In history, most rocket programs are national developments and only few are of international nature such as the Ariane family. The reason for this is that each country had the wish – due to political, military or economical reasons – to develop its own rocket program. Therefore, similar key technologies have been developed individually, each country with its own research budget but with similar objectives. Nowadays, the result is an oversupply of more or less similar national rockets on the one hand and a limited demand due to a stagnated satellite market on the other hand. Each country or company respectively is forced to reduce operation costs – painful by dismissing employees, reducing quality controls, etc. - to depreciate the big burden of development costs each nation has caused.

2 Benefit of Moon and Mars Missions

It is assumed that a manned Moon/Mars mission would be primarily financed by taxpayers over a long time horizon. Therefore, in this section some benefits for the public sector are given. Public-sector benefits include increased employment, the allocation of resources away from weapons to a space project, new technologies, scientific discoveries, and higher tax revenues (based on: Livingston, 2000):

- ***Increased employment:*** High-paying jobs and employment opportunities will result from a Moon/Mars program. For example, maintaining and flying the Space Shuttle involves five NASA centers and approximately 25 000 high-paying jobs. A manned Moon/Mars mission has equal or greater potential for similar employment opportunities within both the public and private sectors.
- ***Less military:*** A benefit would be the allocation of resources away from military and weapons programs to a Moon/Mars program. Resources and talents will be dedicated to designing and developing the Moon/Mars mission.
- ***New technologies:*** New technologies and scientific discoveries, including medical discoveries would certainly result from a Moon/Mars mission. Many of these benefits would flow into the commercial sector worldwide. With the private sector involved in this mission, there will be a high incentive to incorporate these developments into new products as soon as possible.
- ***Increased revenues:*** Creation of a positive government image as well as increased revenues and opportunities for corporate growth.

However, private-sector benefits are also questionable in terms of cost-benefit-ratio:

- ***Risky venture:*** Sending humans to Moon/Mars is not a priority for business people unless they can clearly see a way to benefit from their investment. A financial barrier for the private sector is the fact that there is no clear profit potential for a Moon/Mars mission. There is entertainment, media, sponsorship, and advertising potential for the trip to and from Moon/Mars as well as for the stay on Moon/Mars; however, the market and expected revenues from these activities is largely uncertain.

- ***Political unattractive:*** Sending humans to Moon/Mars is not a priority for politicians unless they can improve their image needed to be reelected in the next election.

3 Moon and Mars Rocket Concepts

It is sufficient to use a chemical-powered rocket for a manned Moon mission as the Apollo program has proven. However, for a manned Mars mission also other types of propulsion systems should be taken into consideration to reduce travel time. Selected Mars rocket concept studies are briefly introduced.

3.1 Fission-powered Rocket

The historical Orion Project is a nuclear-pulse rocket powered by nuclear fission as shown in Figure 2. Project Orion is originated at General Atomics in San Diego, USA in 1958. Orion was envisaged as a means of transporting large expeditions to the Moon, Mars and Saturn. It was suggested releasing atomic bombs behind a spacecraft, followed by disks made of solid propellant. The bombs would explode, vaporizing the material of the disks and converting it into hot plasma. As this plasma rushed out in all directions, some of it would catch up with the spacecraft, impinge upon a pusher plate, and so drive the vehicle forward. A shock absorbing system was devised so that the impulse energy delivered to the plate could be stored and then gradually released to the vehicle as a whole. The effective specific impulse could theoretically be as high as 10 000 seconds. One of the missions suggested for this so-called first-generation Orion was a 125 day round trip to Mars, involving eight astronauts and around 100 Mg of equipment and supplies. (Darling, 2004)

An advantage of the nuclear-pulse method is that it offers so much energy that high-speed, low-fuel travel become feasible. However, being based on fission fuel, the Orion concept is inherently "dirty" and no longer socially acceptable even if used only well away from planetary environments.

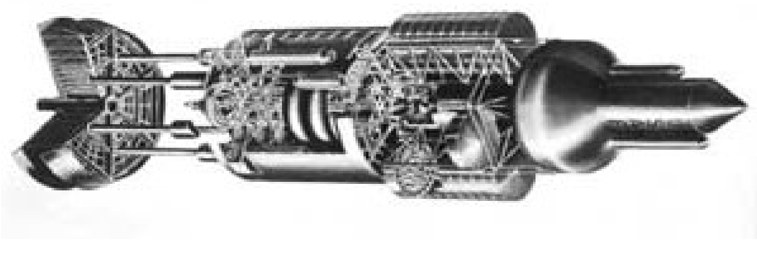

Figure 2: Project Orion (Holt)

3.2 Fusion-powered Rocket

Controlled fusion - joining two lightweight nuclei to get a slightly heavier nucleus and energy - has been challenging. In their quest to exceed Q = 1, the break-even point where the reaction is generating more energy than it takes to sustain it, scientists have moved from low energy yields of Q = 0,0000000000001 in the late 1950s to Q = 0,3 today (Dooling, 1999). A fusion rocket could have an estimated specific impulse of 130 000 seconds. Figure 3 shows a fusion-powered rocket concept proposed by NASA.

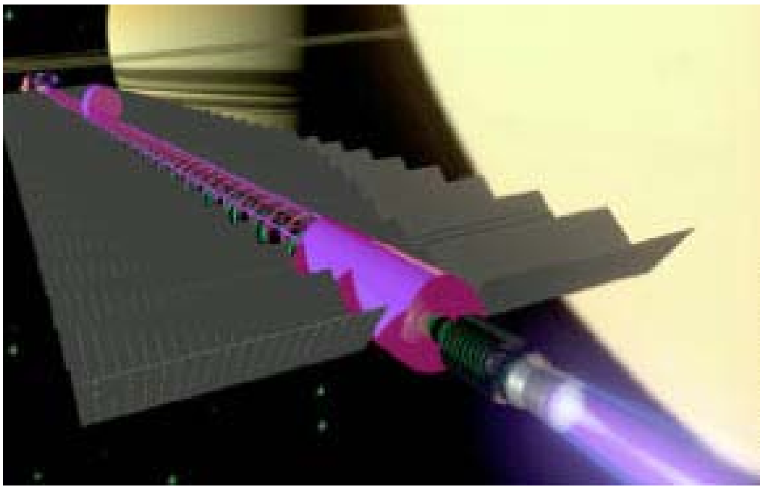

Figure 3: Fusion-powered Rocket (NASA)

3.3 Antimatter-powered Rocket

Figure 4 shows an antimatter-powered rocket investigated by Pennsylvania State University since 1990s. Where a chemical propulsion system, e.g. the Space Shuttle Main Engine, has a specific impulse of 455 seconds, matter/antimatter annihilation propulsion systems could reach up to 1 million seconds. Matter-antimatter annihilation - the complete conversion of matter into energy - releases the most energy per unit mass of any known reaction in physics. The gamma rays from a perfect reaction would escape immediately, unless the ship had thick shielding, and serve no purpose. But the charged debris from a proton/anti-proton annihilation can push a rocket. Anti-protons can be obtained in modest quantities from high-energy accelerators slamming particles into solid targets. The anti-protons are then collected and held in a magnetic bottle. Antimatter is the most expensive substance on Earth, about $63 trillion per gram. (Dooling, 1999)

While true antimatter and true fusion propulsion will remain the "rockets of the future" for some time, a hybrid of the two – called antimatter-catalyzed fusion - might work in the near term. In this approach, a small quantity of antiprotons is beamed into a fusion target. The resulting matter-antimatter annihilation heats a target enough to cause thermonuclear fusion.

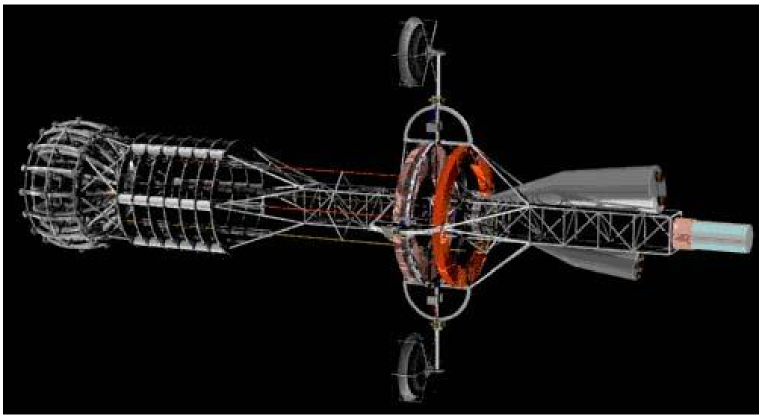

Figure 4: Antimatter-powered Rocket (PSU)

3.4 Laser-powered Rocket

Laser power stations might one day propel spacecraft throughout the solar system as shown in Figure 5. U.S. scientists have begun testing a rocket powered by a laser beam which they hope could revolutionize space travel.

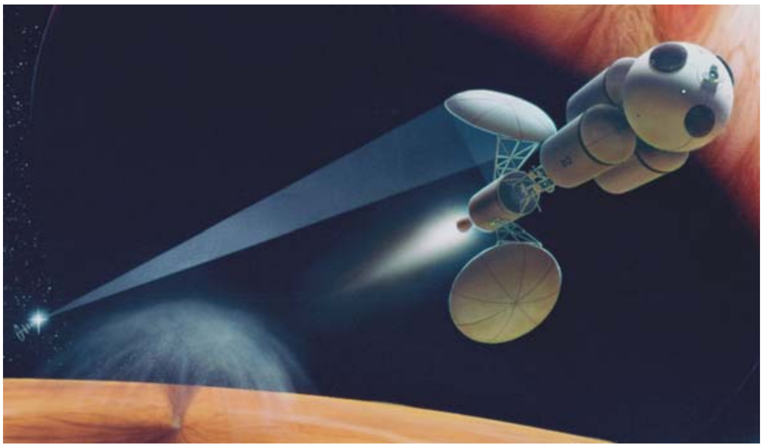

Figure 5: Laser-powered Rocket (Rawlings)

4 International Cooperation

In this section Arianespace is briefly introduced representing a typical international space organization. The main advantages, disadvantages and cultural business challenges caused by an international cooperation are pointed out.

4.1 Example: Arianespace

Commercial competition subsidized by governments has become an important part of space transportation competition. Europe, Russia, USA, China, Japan, India, etc. compete for the international space launch market. Each government has developed its own mechanisms for assisting its launch fins. For example, Arianespace is owned by 35 companies, 13 banks and the French space agency CNES (Arianespace, 2005). The percentage distribution of Arianespace's shareholders in each country is shown in Figure 6. Although it operates as a private firm, Arianespace receives considerable indirect support from the European Space Agency, which has developed the various Ariane launchers, built the launch complexes, and purchases launch services.

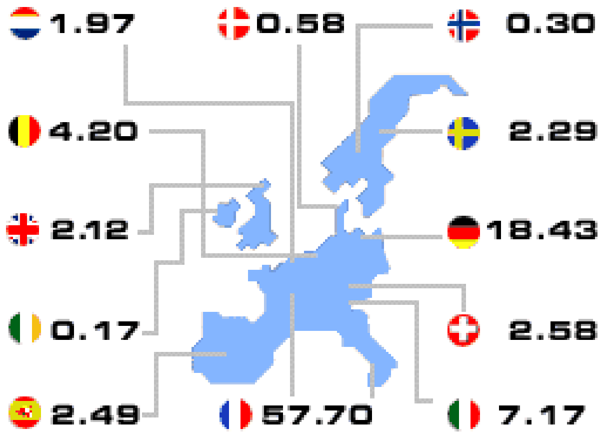

Figure 6: Arianespace's Shareholder Distribution in % (Arianespace)

4.2 Advantages

- ***Synergy effect:*** To achieve much more in a space program than a country can afford to attempt on its own for a given budget. It includes man power (experts from different countries), know-how (high technology) and use of existing infrastructures (spaceport, production facilities, etc.).

- ***Social benefit:*** In terms that it does broaden the mind and give people a planetary conscience (humankind is sitting in the same boat if e.g. a killer asteroid hits Earth).

- ***Realization:*** Because this might be the only way in near-term to put the vision into action.

4.3 Disadvantages

- ***Share pride with other nations:*** Because development of space transportation systems is a national achievement that signals a nation's status as a space power, able to develop and use advanced technology, which is best reflected by an U.S. statement (Longsdon, 1989): "*The space program is a visible symbol of U.S. world leadership; its challenges and accomplishments motivate scientific and technical excellence among U.S. students; and it provides for a diverse American population a sense of common national accomplishment and shared pride in American achievement.*"

- ***Share technology leadership:*** Is problematic because most launch technology has direct military applications and much of the technology has been classified or is sensitive.

- ***Tendency of parallel contractors:*** For an international cooperation, as well as for any other national program, it is necessary to have a clear-cut prime contractor / subcontractor relationship with well defined responsibilities. The lack of a strong prime contractor increase cost and probability for program failure. Cost growth is caused by more manpower, more interfaces, planned and unplanned parallel activities, schedule delays, etc. For example cost increase by 15 % if there are two parallel contractors instead of one, by 25 % for three parallel contractors, by 32 % for four parallel contractors, by 38 % for five parallel contractors and so on (Koelle, D.E., 2003). Due to political or prestige reason, this cost penalty is often accepted.

4.4 Cultural Business Challenges

In particular for an international cooperation there is a cultural business challenge beside the technical one. Management practices and effectiveness depend on cultural variables such as attitudes, beliefs, value systems, need hierarchies, etc, which are the result of different environmental factors in different countries. In the following are given some examples for behavior based on different environmental factors. The challenge (which may also be transformed to a positive synergy) for managers and workers arises when these different environmental factors collide. North American, European and Asian business cultures are only observed because this includes the leading countries in space technology and political power.

- ***Management:*** Employees in high power distance cultures like Japan and China expect managers to lead and are less comfortable with the delegation of discretionary decisions than those from low power distance cultures such as USA. In addition, American or European managers take personal responsibility for their decisions (Ireland, 1991).

- ***Decision-making:*** Western companies' decision-making is an individual process, while in Japanese companies it is a group process. Since many people are involved in the process and various meetings are held, there is a greater participation resulting in an easier and more efficient implementation. However, often too many meetings are held with many unnecessary questions and suggestions raised. These may significantly delay business decisions, which often require a swift response.

- ***Family business:*** In the Chinese family business system, subordinates are supposed to think what the boss is thinking and tailor their ideas accordingly. Dissenting opinions and proposals are conveyed to the boss through personal channels with a duly respectful tone (Chen, 2004). But also in Western companies, this process for decision-making is often the case instead of objective assessment of cost and benefits for the company.

- ***Success:*** While Americans see success as contingent upon their own individual efforts, a promotion in Japan as a reward for hard work may be detrimental to the employee's performance, as the highly cherished harmony between the promoted person and colleagues may be disturbed. Summarized, to be successful can be assumed to have the same meaning for the Asian and Western world but different for individuals of these two regions: While in the Western world success is mostly projected to the person itself, success within Asia is more related to the organization of the individual.

- ***Alternatives:*** As for constructing alternatives, future-orientated cultures (typically Western cultures) tend to create more new options, whereas past-oriented cultures (typically Asian cultures) often search for a historical precedent.

- ***Guanxi:*** Representatives of other countries need acquire a basic understanding of guanxi dynamics for a successful cooperation with China, Japan and some other Asian countries. Guanxi seems to be the most important to understand business dealings in Asia. It can be best translated as friendship with implications of a continual exchange of favors. It is important to understand the difference between "guanxi network" in Asian countries and "protectionism" in western countries, which at first sight looks similar. In Asia, for thousands of years, it has been drummed into people that relationships, especially those within the family, are very important and the individual is less important. Children should learn to restrain themselves, to overcome their individuality so as to maintain harmony in the family. Therefore, guanxi network starts from the birth. Contrary, in western countries, the baby is born already with a strong ego, which is supported by the family with a result of an individual person with weak relationship to the family. Only launch government satellites with national launchers due to security and economic reasons is a typical example for protectionism. To sum it up it can be said that guanxi network is a tradition already there, while protectionism is a strategy gets through by government.

- ***Fast-in and fast-out:*** The Chinese mentality "fast-in and fast-out" means the tendency to trade a smaller margin for a shorter sleeping period leads to a fast turnover orientation. Due to political uncertainties in China, the sleeping period is the most dangerous, as cash may never awake from its deep slumber. If the business deal requires a long slumber period, the Chinese businessman would demand much higher rates of return to justify his risk (Chen, 2004). Space programs have typically a long break-even point. An international cooperation contract with Chinese industry would mean that it might be overpaid due to the higher rates demanded for the reason given above.

- ***Cost estimation:*** The cost from manufacturing to management in Japanese companies is already estimated at the stage of planning and design. The price that a customer is willing to pay for a product is first estimated and serves as the basis for calculating the prices of other component parts, ranging from designing to sale (Chen, 2004). In contrast, the typical method in USA and Europe is to design first, and then estimate cost based on a series of standard costs such as labor cost, material cost and manufacturing cost. Each item is calculated and is then put together by the accountant. If the cost is too high, the design will be modified and calculated again (Goehlich, 2003).

- ***Motivation:*** In terms of motivation, Japanese and Korean employees seem to put more emphasis on extrinsic factors such as job security, work conditions and wages than on intrinsic factors like creativity and achievement. Japanese and Koreans are good at informal communication, but tend to be reluctant in expressing their views openly on formal occasions, especially when their opinions conflict with those of their superiors or colleagues. They are reluctant to convey bad news in a direct manner and carefully avoid open interpersonal conflicts. In addition, they pay careful attention to develop informal channels for communication (Chen, 2004). For an international cooperation, this may cause conflicts, because in order to avoid openly disagreement, Japanese tend to avoid discussions with the result that schedule will be delayed.

Conclusion

If the total costs for a manned Moon and Mars space transportation system or mission exceed a certain amount, an international cooperation may be the only alternative. An international cooperation has the advantage of sharing the total program costs. In practice, total costs in the case for an international program is higher compared to total costs in the case for a national program. This is caused by more manpower, more interfaces, planned and unplanned parallel activities, schedule delays, etc.

One major reason for these negative factors are the different strategies in each country of doing successful business. It can be considered that strategy is developed to achieve a fit between the organization and its environments (Chandler, 1979). Environmental factors are traditions, religion (e.g. Christianity, Confucianism, Buddhism), political conditions (e.g. safety, parties, regulations, ethnic conflicts), economic conditions (e.g. growth, recession, stagnation, productivity, income distribution, levels of income, employment rates, inflation, changes in market structure), social conditions (e.g. consumer attitudes), market geographic location, technology, etc. This means, each country has unconscious developed optimal business strategies. A mixture of these country specific strategies results in conflicts and, therefore, a decrease in overall benefit.

In conclusion, even if an international Moon/Mars program is a challenging task, maybe this is the only way to put the vision of humans on Mars into action.

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