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IMPACT OF HUMAN FACTORS ON THE GROWING RATE OF A MARTIAN POPULATION

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In a few decades, the problem of the permanent presence of humans on Mars will be addressed. With current space technology, it is not thinkable to send tons of resources every year from Earth to maintain the quality of life of the population during a long period of time. A sustainable development of the colony will therefore be possible only if the population grows and rapidly achieve a minimum number of persons in order to be able to develop and maintain industrial activities that will allow self sufficiency relatively to the Earth. The goal of our study is to examine possible impacts of human factors on the demographical evolution of the population during that development. It is assumed in this study that the settlement is technologically feasible and that the threshold for the minimum number of persons will be achieved thanks to demographical growing with a negligible number of immigrants per year. First of all, demographical data from several countries have been examined and the impact of human factors has been analysed. From these observations, we came to different options for a scenario of the Martian settlement and a simulator has been developed. The main conclusion of the proposed demographical analysis is that social factors such as religion, culture or public policy have a great impact on the growing rate. Simulations on the computer show that if appropriate options are chosen the population of the colony can easily reach 50000 people in less than 500 years. However, if the growing rate is too high, the development might not be sustainable any more. For instance, if the number of children is very high, their education would require the mobilization of too many human resources. A trade-off has therefore to be found.

I. INTRODUCTION

In a few decades, the difficult problem of the settlement of the red planet may be addressed. It is already mentioned in several reports from NASA and other Mars specialists as one of the key reasons to determine the best architecture for manned missions to Mars [1], [2], [4], [8]. However, the settlement is much more than just living one or two years in an extreme environment [5]. In order to achieve that goal, the autonomy of the colony has to be developed. As long as the Martian base is settled with less than a few dozens of people, it is possible to send consumables and tools from the Earth to support the colony. Such a support becomes impractical if the colony grows because the amount of goods grows in same proportions and the cost of sending them to Mars would rapidly becomes prohibitive. If we assume that there are no possible trades between Earth and Mars (at least in the early ages of the colony), the only way to perform a sustainable development is to minimize the goods that have to be imported from Earth and therefore to achieve full autonomy as soon as possible. In a modern society, millions of people are required to produce all the goods and services. However, only a fraction of them are essential. The autonomy can be achieved without planes, boats, trains, toys, robots, computers, oil, and so on. It is difficult to determine the shortest list of industries that have to be developed. But even if that list could be elaborated, two key questions arise. The first is how many settlers are needed to make these industries functional so that the minimum level of autonomy is achieved? And the second is how many years does it take to reach that number? A demographic simulator has been developed to help answering the second question. In section 2, the problem is addressed in more details and several hypotheses are discussed. In section 3, some results are presented and analyzed.

II. DEMOGRAPHIC SIMULATION

Simulations are often used to help understanding social problems [3]. Human factors play an important role on the growing rate of a population. The birth-rate especially depends on cultural variables, such as religion, customs, stress, security. It also depends on economical or political incentives and environmental constraints. The objectives of the colony are twofold. On the one hand, as many people as possible should work for the support and development of the colony. On the second hand, the population should grow as fast as possible to reach the population threshold (PT) from which the autonomy of the colony is possible. The problem is that the greater number of children, the

greater number of adults is mobilized to assist and educate them. A trade-off has therefore to be found. Several hypotheses have been made for the simulation:

- The initial number of settlers is 100. It is possible to send them in one or several vehicles, in several stages, eventually several years after the construction of the base. Although some recent works suggest that the landing vehicles and the crews will be very small [6], [7], it is beyond the scope of that study to determine the best way to start the settlement. From that number (100), it is assumed that the colony has to grow rapidly with the objective of total autonomy.
- The set of settlers can be divided in four subsets. The first is called "active persons". Active persons work for the survival and development of the colony. They control and maintain the life support, they produce food and tools, they maintain and repair objects, they participate to the management, they propose sportive and cultural activities etc. The second is the subset of "children". Babies and young children do not produce anything. Moreover, they need parents and educational support. Teenagers and young adults still need education but they can also provide some help to active people. The third is the subset of "assistants" who have to educate and take care of children and eventually old or handicapped persons. The last is the subset of elderly people who also need some assistance. Obviously, if the number of children and very old persons is high, there is a risk to have too few human resources in the first subset. The colony has to grow rapidly but not at the expense of the survival and minimum comfort of the settlers. An important parameter is therefore the minimum percentage of active persons (first subset) that allows a sustainable development of the colony.

III. VARIABLES

Initial population

The initial age structure diagram of the first 100 settlers may be very important. The distribution of the population can be random or very specific, for instance with all people older than 18 years. New colons may join later on but it is assumed that their number would be negligible. Different distributions will be examined.

Assistance to children

We propose to distinguish between 5 categories of children and their corresponding assistance level. See Table 1.

Age of children (years)	Number of persons mobilized, default value
0-3	0.5
4-5	0.3
6-9	0.2
10-14	0.1
15-22	0.05

Table 1: Children categories.

End of life

The age of death is randomly determined according to a Gaussian variable (A_d, σ_d). Some people live very old without assistance while others are handicapped very young. We propose to simplify the problem. It is assumed that only elderly people older than a specific age limit A_l require assistance for living and that 0.5 persons are mobilized for that task.

Births

It is assumed that a man and a woman have to form a couple before giving births to children. The number of children per woman is determined by several variables and formulas. The first variable is the percentage of persons who are not fertile %NF. The second and third variables are the age A_{min} from which a baby can be born and the age A_{max} after which it is not possible or strongly not recommended. Then there are 2 contradictory factors. The first one is incentive. Since the colony has to grow as rapidly as possible, provided that there are enough active people for a sustainable development, women are incited to give birth to a large number of babies with the constraint of 1 new child per year. On the other hand, religion, customs and other cultural variables play an important role on birth-rate. In current occidental civilizations, the number of babies per woman is quite low. If the settlers come from such countries it might be very difficult to convince them to give birth to 4, 5 or even more babies. For the simulation, the number of babies per woman is not a priori fixed. Each year, a new baby is decided according to the following algorithm. Let N_{adu} be the number of persons between 18 and A_l (adults). Among those persons, there are active persons N_{act} and assistants N_{ass} (introduced in Section 2). N_{ch} is the number of children and N_{old} is the number of persons older than A_l. The number of persons who need assistance is calculated first in order to determine the number of assistants N_{ass}.: N_{act} is equal to N_{adu} - N_{ass}. Three key parameters defined at the beginning of the simulation are then taken into account:

- $\%maxN_{ass}$ is the maximum number of adults who can be allocated to the "assistants" subset.
- %cult determines the strength of the culture for the decision of giving birth to a new child and
- N_{cult} is the average number of desired children according to cultural parameters.

A birth is thus decided for a given couple if the 3 constraints are satisfied (recalculated each year):

- The 2 persons of the couple are fertile and the age of the woman is less than A_{max}.
- $N_{ass} < \%maxN_{ass} \times N_{adu}$
- (random(100) > %cult) or the current number of children < N_{cult})

Note: Random(100) is a random function returning a random value between 0 and 100.

IV. RESULTS

Several tests have been performed. See figures 1-6. Simulations are stopped after 1000 years or as soon as the number of people falls to 0 or is superior to 50000, which is assumed to be the minimum value to achieve full autonomy (PT). Several conclusions can be drawn. First, there is a strong constraint on human resources (Fig. 1 and Fig. 2). If the percentage of active persons has to be kept very high, there are not enough people for assistance to children and very old persons. If it is not too high, the colony rapidly grows but the birth-rate is automatically regulated by the requirements on human resources. The same regulation occurs with elderly people. We set the average death to 70 years old. If A_l (age limit for no assistance) is greater than 70, few people require assistance. On the other hand, if people live on average much older than A_l, (see Fig. 3) the number of active persons mobilized for assistance may endanger the development of the colony depending on the value set for $\%maxN_{ass}$. In certain circumstances, the colony would therefore have to face ethical problems.

Culture also has an important impact. If %cult is set very high and N_{cult} is low, for instance 2 children, the colony slowly declines. If %cult is not too high, the birth-rate may become sufficient for the development of the colony but the growing rate may be very slow. Another important parameter is the percentage of fertile persons. If it is low, for instance less than 80%, the number of children per woman has to be more important. In that case, if %cult is not negligible, N_{cult} should be greater than 3 to enable population growing.

Finally, it is important to note that with the same parameters, the result of the simulation can be very different (see Fig. 5 and Fig. 6).

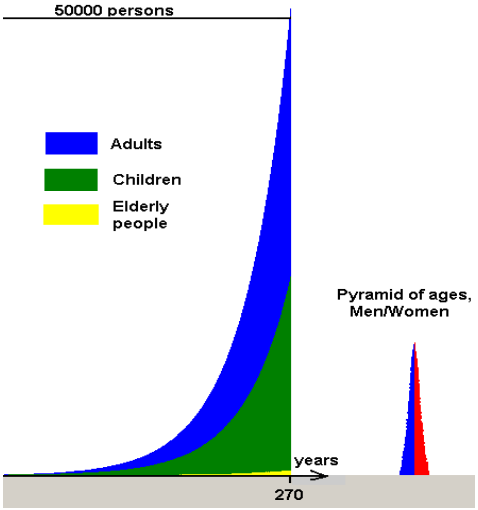


Fig. 1: Initial population: random in [1;60]; $A_d=A_l=70$; $\sigma_d=5$; $A_{min}=20$; $A_{max}=40$; **$\%maxN_{ass}=20$**; %cult=0; %NF=10. 50000 people reached. Average number of children per woman (end of sim.): 4.6.

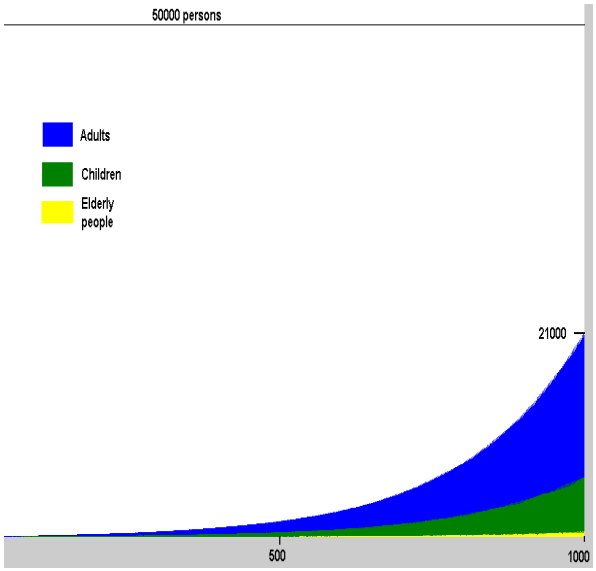


Fig. 2: Initial population: random in [1;60]; $A_d=A_l=70$; $\sigma_d=5$; $A_{min}=20$; $A_{max}=40$; **$\%maxN_{ass}=12$**; %cult=0; %NF=10. Simulation stopped after 1000 years. Average number of children per woman (end of sim.): 2.4.

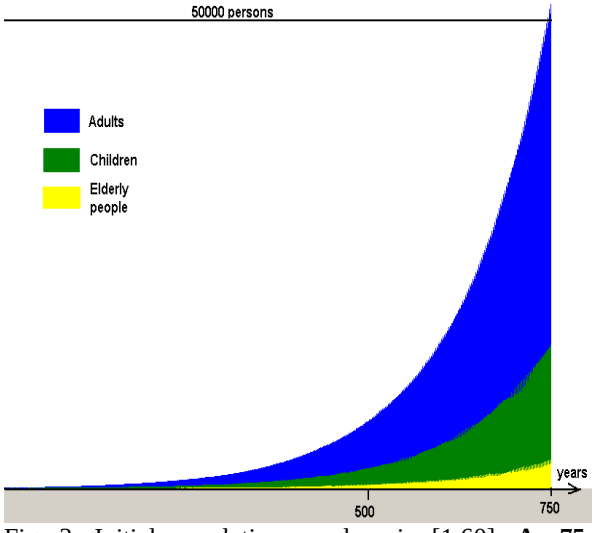


Fig. 3: Initial population: random in [1;60]; **$A_d=75$**; $A_l=70$; $\sigma_d=5$; $A_{min}=20$; $A_{max}=40$; **$\%maxN_{ass}=15$**; %cult=0; %NF=10. 50000 people reached after 750 years.

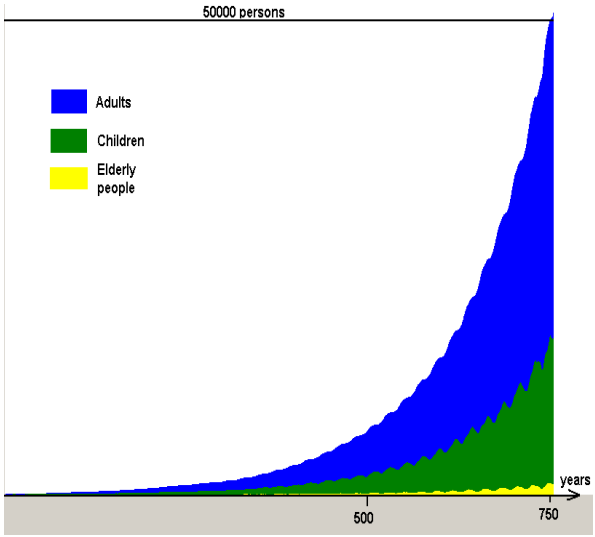


Fig. 4: Initial population: random in [1;60]; $A_d=A_l=70$; $\sigma_d=5$; $A_{min}=20$; $A_{max}=40$; $\%maxN_{ass}=15$; **$\%cult=100$; $N_{cult}=3$**; %NF=10. 50000 people reached after 753 years. Average number of children per woman: 2.4. Some fluctuations occurred in the simulation. They are probably caused by the constraints on births and human resources.

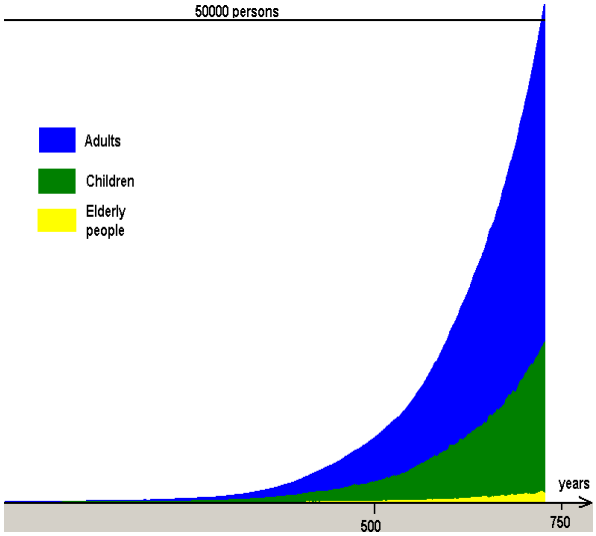


Fig. 5: Initial population: random in [1;60]; $A_d=A_l=70$; $\sigma_d=5$; $A_{min}=20$; $A_{max}=40$; **$\%maxN_{ass}=15$; $\%cult=90$; $N_{cult}=2$**; **$\%NF=20$**. 50000 people reached after 725 years.

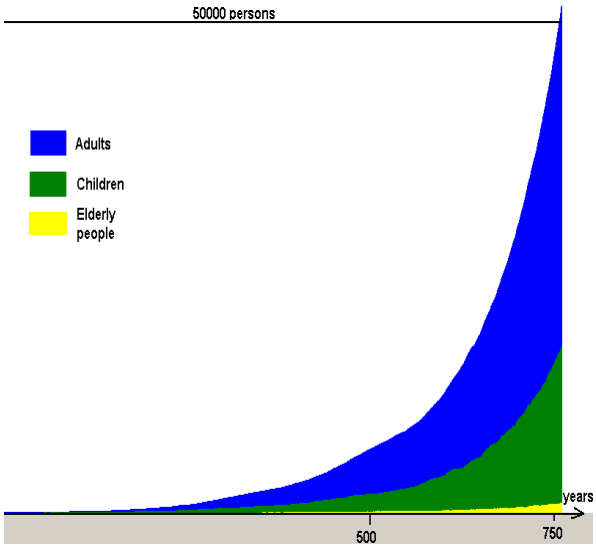


Fig. 6: **Initial population: random in [18;60]**; $A_d=A_l=70$; $\sigma_d=5$; $A_{min}=20$; $A_{max}=40$; **$\%maxN_{ass}=15$; $\%cult=90$; $N_{cult}=2$**; **$\%NF=20$**. 50000 people reached after 760 years. However for 3 tests with the same parameters, the population declined to 0 and for 1 test the simulation stopped at 1000 years with 2000 people.

III. CONCLUSION

A simulator has been developed to study the demographic development of a Martian colony. Numerous tests have been performed. The main conclusion is perhaps that it is very difficult to predict the results, depending on the initial set of parameters. In the best scenario, starting with 100 colons, the population reaches 50000 people in less than 300 years. However, constraints on human resources, human factors and assistance to children and elderly people may strongly slow down the growing rate. In some cases the development is even not possible.

The simulator can be provided on demand.

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