Chapter 2

PROJECT MANAGEMENT

1. Introduction

ABOUT PROJECT MANAGEMENT. FACTORS

Our goal is to have the settlement completed with limited resources satisfying an optimal cost versus time ratio. Cost is minimized by rational resource utilization and supplies shipment and by constantly providing a construction work force able to (at least partly) self-sustain.

The limiting factors are:

- The amount of supplies that have to be shipped (cost limitation)
- The total population that can self-sustain in given conditions (physiological and cost limitation)
- Construction time
- Resources availability.

There is no need to state that the resources are very limited. One may think that once an extraction/processing facility on the Moon is operational the resource problem is solved. Unfortunately, the Moon lacks high concentrations of some metals and minerals that are of high importance for the settlement's construction, industry and life support (such as Cu, Zn, Pb, Cl, N, C). The water frozen on the Moon is also in limited quantities. According to [1], processed lunar soil may provide up to 90 percent of the required industrial elements. The rest of 10%, however, remain to be shipped or extracted from elsewhere.

The focus of the analysis is on completing the settlement within an affordable range of costs and a rational amount of time (completion stating that it has reached its population goal of 100'000, population that is essentially able to self-sustain from all points of view).

The development plan includes the relationship population-supplies and the relationship supplies-industry-resources. Planning is made both for the construction stages of the lunar extraction/processing facility and for the space settlement's construction.

Any realistic project management should analyze the relationship cost/time and should include some extra time in the schedule for unforeseen difficulties. The management is based on the following criteria:

- Cost/time relationship
- Feasibility (cost, time, physical feasibility)
- Safety (an amount of time should be allocated for structure checking and for equipment fine-tuning).

The cost/time relationship refers to the time needed for the commissioning of the project and to the costs implied. For example, if the construction time is significantly lowered (to just 2-3 years) the costs will also rise and the risk of some failure too. Increasing construction time above five years may also prove costly, as the project may lose interest from investors. Rational planning should include supplies management, lunar station assembly, development of industry (both for the lunar extraction facility and for the colony itself) and finally population management for the early and late stages of the settlement's construction.

THE PROPOSED DESIGN

In order to minimize costs and construction time, the proposed solution is to have a lunar extraction facility (that also processes and ships tools/parts/materials or other supplies to the space colony). The lunar station is constructed and operational before the launch of the first module of the space colony. There are two goals:

- To construct a lunar extraction/processing facility that has the ability to physiologically and industrially self-sustain, to build parts, tools, electronics and to ship them to the colony's construction site, to extract various materials and to sustain the colony during its construction phase;
- To construct a space colony (self-sustainable from all points of view) in a limited amount of time, with resources and parts received mainly from the lunar extraction facility.

The lunar facility is intended to support the construction of the space colony. However, its activity will not be ceased after the construction of the space colony. Some industries not only occupy a large amount of space, but also are not cost-worthy to be included in the settlement (such as the metallurgical industry, the mining industry, part of the machinery industry). These industries should be located where raw materials for them may be extracted. These industries are required for the construction of the settlement and are included in the lunar facility. The lunar facility will continue to support the settlement even after its construction has been completed. If not, materials should be shipped from the Moon and processed in the settlement. If the lunar facility ceases its activity after the construction of the colony has ended, the colony will no longer be self-sustainable (as it has to extract materials from somewhere for its robotics and space industry – or ship them from Earth – not viable).

In order to reach the goal of 100'000 population for the colony, two construction phases are stated (3rd section of this chapter). The settlement is structurally completed in its first construction phase (5 years). In this period, a population of 10'000 is established. Accommodation, agriculture development, industry development, health and education systems are all gradually developed to support the final 100'000 population. This second construction phase may last up to 15 years.

STATE OF THE ART

Management is an essential part of any realistic project. Project management is in direct relation with ensuring the feasibility of a project. However, this topic has not been dealt with in various past designs, including our own [2, 3, 4, 5] and scarcely in other designs [6, 7, 8]. For example, [7] and [8] discuss the problem of launch and in-orbit procedures, but do not present any planning. In [6] it is mentioned that the construction of the settlement will be in phases – which are discussed. However, there is no schedule/detailed analysis.

To find out whether a project is or is not realistic, both a time/cost analysis and a supplies management should be done. Safety is another important aspect. Lowering construction time (and implicitly reducing the time allocated for checking and equipment tuning) may have a significant impact on the safety and durability of such a structure. A significant amount of time was allocated for checking the colony before it is populated (between ½ and 1 year). In addition, a sector of the population is allocated for maintenance.

The problem of effectiveness in project management and risk/safety analysis has been stated by NASA in [9] and [10].

2. Planning for the lunar extraction facility

The project will start with the lunar extraction/processing facility. The existence of an operational lunar facility before the assembly of the settlement itself is considered of vital economical importance. It has been proposed in various other designs.

The importance of a lunar extraction facility for future space colonies and for the development of a space industry has been stated in [1]. *"Analyses even of designs not optimized for lunar elements reveal that at least 60 percent of the required silicon, aluminum and oxygen could be obtained from the Moon and the total mass lifted from Earth could be reduced about 80 percent by utilizing lunar materials. [...]The space economy could begin approaching the richness and cost structures of our present terrestrial economy."*

The facility may also partly support with supplies the settlement's construction population in the early stages. If settlement modules and parts are produced and partly assembled on the Moon, the advantage is both in cost and in construction time. The crew assembling the settlement will complete its construction in less time if they receive modules - rather than just primarily processed metal.

Crews assembling the settlement will not benefit in its early construction stages of pseudogravity and will require additional space for processing metal and for constructing parts if they receive only raw materials from the lunar facility. This is not economically viable.

The proposed completion time for the lunar extraction facility is seven months. The proposed schedule for the lunar extraction facility operations is in table II.1. The schedule was made considering that the space settlement should be completed for the receival of the 10'000 population [first construction phase] in four years (including the time for the construction of the extraction facility).

Notice that the ½ of the sixth month is allocated for checking/tuning of the electromagnetic catapult and the related equipment, for safety and efficiency reasons (checking phase represented as a dotted line in table II.1).

Table II.1. Construction and operation phases for the lunar extraction facility

Time / Operation	Month #0	Month #2	Month #3	Month #4	Month #5	Month #6	Month #7	Month #8	2nd Year
Launch; Drilling tunnels									
Agriculture facilities Construction									
Agriculture production									
Building habitat									
Build industry – mining									
Mount solar panels									
Mount metallurgical Industry									
Mount machinery Industry									
Small chemical Industry									
Electromagnetic catapult Building									
Catapult operation									
Mining operations									

SUPPLIES MANAGEMENT

The second problem is the supplies management. Supplies include the tools and materials required for the construction of the extraction facility, the raw materials for its early construction phases, and consumables required for life support (food, water, oxygen). For example, before the chemical industry is operational, various chemicals will have to be shipped to the facility in order to develop the food industry.

Table III.2. Population allocated per operation; relationship between supplies, time and industry development

Operation	Population	Time [months]	Food, water, oxygen supplies	Tools, chemicals, other materials	Industry development
Launch/drill phase	25	0	100%	100%	-
Building habitat	25	1	100%	100%	-
Agriculture and food industry	100	2	75%	100%	-
Industry-mining	100	3	50%	100%	-
Mounting, then operation of industry facilities	300	4	35%	75%	Mining industry
Catapult building and operations	20	5	15%	60%	Small chemical industry
Maintenance	50	6	10%	40%	Metallurgical industry
		7	5%	5%	Machinery industry

Notice that the population given in the second column is the population repartitioned for the given operation. It is not in dependence with the third column.

The population allocated to building the habitat (including the drill phase) will be redistributed after its construction. The population of the lunar facility is gradually increased, based on the construction/operation phase.

The industry development column is in dependence with the time (third column). It refers to the month in which the stated industry is fully operational or at least supports the needs of the extraction facility. When an industry supports the needs of the facility, the supply quantity is diminished. The fourth and fifth columns refer to the quantity of supplies that need to be sent in order to support the extraction facility. These are expressed in percentage of the initial needed supply quantity.

3. Settlement Development Plan

The space settlement's construction begins after the completion of the lunar station. The construction will have two phases. The goals for each phase are:

1. Housing, agriculture, recycling requirements for an initial population of 10'000. Economy and administration start – gradual

development in order to cope with the requirements of a 100’000 population. This phase should be completed in a period of four years (see table II.4).

2. Self-sustainment for a population of 100’000 from physiological, economical, industrial, social, cultural, educational and scientific points of view. Task to be completed in 15 years maximum.

The first phase is related to the construction of an operational settlement housing a population of 10’000. The bulk assembly [the torus’s structure] is completed for a population of 100’000. However, the interior is finished only for a population of 10’000 people. That population can start the development of industry, education, and utilities in order to cope with the requirements of a developed society with a population of 100’000 or over. As shown in the first chapter, self-sustainment from economical, social, cultural points of view require a population of over 100’000.

This two-stage model has been proposed on consideration that the settlement should be operational for research activities in the minimal amount of time possible (4-5 years) and that a society takes an amount of time to be developed in an economically sound enterprise (up to 15 years).

The initial population will play the essential role in developing the settlement. That population has the task both to complete the internal construction, to develop the economy and to do research in order to insure economical viability of the colony even from an early stage. Attracting investors and settlers is another goal for the initial population.

Part of the 10’000 population will have the challenge to develop the industry, education system and utilities for the target population of 100’000. Development of industry may take two years or more. After the seventh year, the task is to develop a competitive economy. Self-sustainment will be achieved by the end of the 20th year, as shown in table II.4. The timetable was set keeping in mind that safety is a priority and considering the cost/time balance. A large amount of time was given for the development of the economy and the society, as these are the most complicated tasks – that may insure the success of the colony.

Table II.3. Schedule for the first construction phase of the space settlement; includes the construction and activity of the lunar station.

Time / Operation	Semester I	Semester II	Semester III	Semester IV	2nd Year	3rd Year	4th Year
Lunar station assembly							
Lunar station fully operational							
Space station launch (module #1)							
Space station assembly							
Space station checking, fine-tuning							
Space station operational							

Safety is a priority. Structural and equipment checking must be performed before the arrival of the 10’000 population. Checking and tuning could take as much as ¼ of the total construction time of the settlement (estimated at 4 years).

Table II.4. Detailed schedule of the space settlement’s development; construction phases are indicated, along with the population during each stage;

Construction stages	**Time**	**Population**
First settlement module launch	8th Month	25 people, required for assembly of next modules
4 modules completed and assembled	10th Month	100 people; agriculture starts
Space settlement 1% completed: housing, agriculture, recycling requirements for 1000 people completed	18th Month	1000 people able to self-sustain physiologically
Bulk assembly completed	End 3rd Year	1000 people
Checking, tuning stage; Solar panels mounted and interior completion for at least 10% of the final population; Mounting of external resistance structure; Generation of pseudogravity may start. [*first construction phase completed*]	3rd and 1/2 Years to 4 years	1000 people
Population completion up to 10’000 people; Tasks: agriculture development, Industry assembly, operational university, operational recycling facility, utilities development.	End 5th Year	10’000 people
Settlement operational for recieval of population over 10’000; Task: Developing economy	End of 7th Year	10’000people
Recieval of population up to 100’000. Tasks: Gradual growth of – industry; development of education system; health system development; utilities, agriculture, recycling development for entire population. [*second construction phase completed*]	End of 20th Year	100’000 people; Settlement self-sustainable from physiological, economical, industrial, social, cultural, educational and scientific points of view.

4. Conclusions

Our development plan proposes the construction first of a lunar extraction/processing facility and a two-phase construction of the space settlement. The reason for constructing first the lunar facility is mainly economical, as it should support the colony with materials and parts during its construction and next during its economical development. Proposing a rational supplies management has minimized costs. The supplies need was shown in direct relationship with industrial development.

Safety was considered an important aspect. Amounts of time have been allocated for checking of equipment and structure after bulk assembly of settlement/extraction facility is completed.

A schedule was proposed for the space settlement's construction, including two stages. The first concern was to ensure the physiological requirements for a 10'000 population that may gradually develop economy (first construction phase, 4-5 years). The second goal was to insure self-sustainment from physiological, social, economical, educational and scientific points of view for a 100'000 final population (proposed completion time of maximum 15 years).

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