Bulgarian Academy of Sciences. Space Research and Technology Institute.
Aerospace Research in Bulgaria. 35, 2023, Sofia

DOI: https://doi.org/10.3897/arb.v35.e17

OPPORTUNITIES TO OPTIMIZE THE MANAGEMENT OF AEROSPACE PROJECTS

Nadia Marinova

New Bulgarian University
e-mail: nmarinova@nbu.bg

Keywords: *Aerospace projects, Global satellite systems, Optimizing, Single dynamic model of the Earth*

Abstract

The creation and effective functioning of global satellite systems will allow to create an information base for solving problems related to the regeneration and rational use of natural resources, the creation of a single dynamic model of the Earth, including geological, climatic, biosphere, ecological and social factors.

Great attention should also be paid to the problem of increasing the safety of human life in the conditions of the rapid development of intercontinental transport links.

Introduction

The well-being of a society directly depends on the ability to provide funds for the development of the most science-intensive and technically advanced industries, which in the future will play the role of the "locomotive" of the economy. An example of this can be the automotive industry in the USA or the electronics industry in Japan.

It became obvious that the new era in the development of humanity is in outer space and is connected with the absorption of the energy of the Sun, the Cosmos and its inexhaustible resources.

Without space, space technology and space research, humanity has no future, no opportunity to solve the key problems of its development. They can include energy provision, informatics and food provision and the problems of preserving the living environment.

The main trends in space activity in the 21st century will be related to increasing the saturation of the information space, which will raise the information security of the countries and their population to a qualitatively new level, directly related to their intellectual potential. The problems of access to information, the services of global information networks, data banks and knowledge bases - all this is unthinkable without promising information technologies, including space methods and means of communication.

Another important aspect of society's life is the problem of the state of the environment. The anthropogenic impact on it reached levels at the end of the 20^{th} century, exceeding which, without taking adequate measures for its protection, can lead humanity to disasters and environmental catastrophes. All forms of impact on the environment become critical - pollution, entry of harmful substances into the air and water environment, degradation of the soil and the ozone sphere, the greenhouse effect.

A key problem in this sense is the creation of systems for monitoring environmental parameters, the state of hazardous productions and predicting the occurrence of dangerous phenomena. This problem is solved globally with the help of space tools for remote sensing of the Earth and atmosphere.

Such priority research and applied tasks as:

- the study of planetary processes, including the dynamics of the atmosphere and the ozone layer, the radiation balance of the planet and the evolution of climate, the biochemical and hydrological cycles of the planet, the global processes in the mesosphere and the world ocean;
- research and control of regional and local mineral deposits, reporting and control of natural resources and sources of environmental pollution;
- study of solar-terrestrial connections and their impact on the biosphere, human activity and human health;
- researching the causes, discovering the prerequisites and controlling the consequences of natural destructive processes (typhoons, earthquakes, floods and other environmental catastrophes).

Remote methods of Earth research are part of the world community's efforts to preserve and restore ecosystems, solve global problems of energy and food security. In this regard, the task of effective international integration has no alternative. The "Mission for Planet Earth" program is also in this spirit.

The creation and effective functioning of global satellite systems will allow to create an information base for solving problems related to the regeneration and rational use of natural resources, the creation of a single dynamic model of the Earth, including geological, climatic, biosphere, ecological and social factors.

Great attention should also be paid to the problem of increasing the safety of human life in the conditions of the rapid development of intercontinental transport links.

Many factors suggest the creation of a global navigation system with high accuracy, allowing users to receive information about their own position on Earth or in space around Earth at any time. In combination with space vehicles, these systems as a close prospect can provide effective guidance of the movement of all types of transport, taking into account the high safety requirements. As a more distant perspective, they can become an integral part of personal monitoring systems, including health monitoring. The COSPAS/SARSAT system has already helped to save more thousands, and the prospective personal monitoring system could be several times more effective.

Of great interest are the possibilities of using the conditions of orbital flight (weightlessness, vacuum) to create substances and materials with properties unattainable on Earth. To date, thousands of experiments have been carried out on spacecraft to study problems in castings, crystallization in weightlessness, obtaining compositions from substances immiscible in terrestrial conditions, and also obtaining ultrapure biologically active substances, drugs and other biological preparations.

One of the key issues for the exploitation of space will be the provision in the future of opportunities for life with productive human activity in the conditions of orbital flight and on planets of the Solar System, which will become the basis for the exploitation of interplanetary space.

Orbital stations, transport, and cargo ships, means of extra-orbital activity, robotic means, etc., are imposed as the main place for solving the mentioned problems. A large volume of research and experiments in space medicine and biology, research of Earth's natural resources, space technologies, astrophysics, development of new types of scientific apparatus and methods for solving research tasks in space and from space is carried out on board the orbital stations. All this, in turn, is used in the creation of the specialized automatic systems for the International Space Station.

The creation and operation of longer-life space facilities is a long-term trend in the strategy of the major space powers – the USA, Russia, China, etc.

One of the main tasks that will be solved at the ISS is remote research of the Earth and environmental monitoring, which also includes the development of new methods and means of remote research and environmental monitoring.

Such projects are valued in the billions of dollars to achieve several goals:

- promoting commercialization in space research,
- expanding international ties by including international partners
- continuous development of space science and technology.

Space stations are being built as science laboratories in low Earth orbit, offering a variety of conditions (eg, power, low-gravity environment, manpower and laboratory space) that can be used by NASA, RKA (Russia), ESA (Europe) and other countries with space exploration ambitions. The station is a very complex, multidimensional R&D project for which good management is an essential necessity.

Several possible options and their implementation for the operation, pricing and evolution of the space station and the range of benefits to be obtained by users have been developed. Although it is sometimes difficult to accept, prices affect behavior and sample usage, which in turn affects the bottom line of any project intended to operate over a long period of time. Modern economic analyzes arm us with an apparatus for examining these applications and evaluating their impact on desired ends.

An economic theory that offers the most predictions is the "theory of mechanisms" or the "theory of implementation."

The basic framework of this organizational design theory is based on two key hypotheses:

First, the information that is needed to achieve organizational goals is initially scattered and difficult to discover through simple observation;

Second, individuals disclose this information and comply with instructions and requirements only if it is in their best interest to do so.

The designer of the institutional rules that determine who does what and says it to whom and who performs what actions may do nothing about the initial distribution of information or the motivations of the various actors in the organization. The designer can only optimize the subject of organizational goals to informational and incentive constraints. But within these constraints there can be a wide range of options, some of which will be much more desirable than others.

According to the model of this theory, first a description of the space station environment (those features of the design that are not really under the designer's control) is presented, then some of the objectives to be achieved are briefly given, and finally some options for competitive pricing.

The space station is a multiple product that is highly uncertain (unstable), and that is a public enterprise, i.e. has a wide range of users from the public and private sectors. Like any product, it includes technology and costs, consumption and benefits, pricing objectives. What determines their content:

First - from the technology and costs. Each space station (SC) is a complex public facility. The basic intensive initial capital investment produces a real-life facility that provides a flow of resources all the time, requiring correspondingly low and possibly relatively constant per-unit operating costs. But the differences between the CS and the standard facility are important. At KS, the technology is not well described and understood. The uncertainty exists because this technology has never before operated in space on this scale. Second, the resources to be produced are also required as inputs: power must not only be provided to the users of the CS, but it is also a necessary input for life support and command systems. Because there is significant uncertainty about how much of these resources will be needed for internal use, there is exaggerated uncertainty about the net values available to users. These costs for internal needs should be known after the CS is fully operational, but for any contractual agreements made in advance this is a significant uncertainty. Likewise, because this technology is new, there is great uncertainty regarding the cost of construction and operation. For this reason, it is a large and complex project for which it is difficult to find comparable (comparable) efforts. Standard public utility or regulated facility models where there is a satisfactory degree of certainty about technology, costs and requirements are simply not applicable as models for CS.

Second - consumption and benefits. There is already an incredible variety of CS users, but the main five categories relate to: commercial users, science and technology missions of NASA and Russia, other US government users (mainly the Department of Defense), international partners (Canada, the European Space Agency Agency, China, and Japan), and all others. Although each of these classes of consumers presents different problems and limitations in terms of pricing policies, they have one thing in common. The benefits and demand are largely unknown to them and to the CS designers and operators. Economists have absolutely no way of using modern economic analysis to determine demand (and therefore, perhaps, to determine value added to consumers) as can be done in designing pricing policy for public electric facilities. Also, one cannot simply ask potential CS users to state exactly how much of each resource they wish to consume and then plan for the approximate aggregate response. Even if they are certain of their benefits, they have little incentive to reveal all their information. If charging does not depend on their responses, then they have an incentive to exaggerate their needs; if billing depends on their responses, then they have an incentive to claim only meager benefits of use. There is no independent market for the data that NASA and Russia can use to verify the validity of the data. Some data is available through the shuttle missions, which, except for the satellite launches, tend to be short-lived research projects launched virtually free of charge. There seems to be a very tenuous connection between these projects and the long-term ones as we imagine the Space Station. A rule of thumb in pricing or other organizational choices is that information about the correct demand or utility should not be assumed to be available.

Third - pricing goals. To provide reasonable analyzes of alternative pricing policies for CS, one should first analyze the objectives. What does it mean for someone to try to end (deal with) pricing policy? Any economist should expect the desired results to be twofold: first, recovery of some or all of the costs of design, development, and operation; second, effective use of the CS once it is in place.

According to Pareto efficiency, given some individual vector or desired outcomes, the total life cycle cost of the station and all its payloads must be minimized to achieve those outcomes. This is a broader view than just minimizing station costs but is more relevant in a broader economic perspective. Minimizing the station's costs in a way that imposes a significant burden on user costs to build and operate its own payloads would not only be inefficient (Pareto), but could also prove politically risky for NASA, Russia, and other actors.

Three other objectives may be at least as important as the first two: first, the presentation (promotion) of the commercialization of space; second, science and technology and third, international relations. They are important because they relate to the three main user groups: private industry, NASA's technology and science missions, Russia and other partners, and potential international partners. It is known that projects with a larger organization and with larger total costs and with smaller operating costs are usually not able to satisfy all five objectives at the same time. For example, an ineffective approach to achieving objectives 3 through 5 is to make the station's resources available for free to these users. This obviously goes directly against the goal of cost recovery. Also less obvious is the controversy about effective use. There will be too few users using too many resources. Therefore, although a small number of potential users will benefit from the policy of "free (free) access", a greater benefit can be obtained from a more effective pricing policy. The last three objectives will gain more if the CS is used and operates in as efficient a way as possible and that these objectives can also be thwarted if the pricing policy is ineffective. Efficiency means "more accurate hits" ie. more resources acquired per monetary resource invested, which means the ability to supply more payload of any type.

Can the conflicting goals of reimbursement be resolved in a reasonable way?

For traditional projects with high costs of organization, low marginal (side) costs and a satisfactory degree of certainty, economists propose pricing by maximizing benefits depending on the costs incurred. This policy requires either direct knowledge of demand functions (to calculate the added value (asset balance) for consumers directly) or a tatonemic process with little distortion. No option is available to CS if demand and benefit uncertainty preclude the former, while cost uncertainty (combined with the discovery principle) precludes the latter.

A simple proposal that would meet the cost-recovery goal with little detriment to efficiency would be to charge a single price per payload equal to the cost of the shuttle flight plus a percentage to cover the remaining costs of staying in The Space Station. This is a reasonable policy under only two assumptions:

- first, that the designers, builders, operators and users of the Space Station are one team; agree with the objectives of the Space Station and, although perhaps asymmetrically informed, be prepared to provide all information in their possession upon request;

- second, that none of the users change their decisions as a result of the price they are charged (prices are set only based on costs, not resources).

Conclusion

It is easy to predict what would happen if the "project plus percentage" formula were established. Payloads will be designed to conserve their mass and dimensions, but not their power and personnel, two of the station's resources that are designed to be in a constant state of increased demand. Since station time is not included in billing calculations, time-consuming missions that require the recruitment of more mission-appropriate specialists will be preferred by users over short missions even when the latter use only a few station resources. Designers try to build the best possible station for the lowest possible upfront (initial) cost. Although they recognize the need to minimize current discounted (discounted) construction and operating costs, the limited congressional budget they are given does not encourage compromise over time. Designers are incentivized to minimize construction costs and hope that operating costs will not be too high. Robotics is ignored - staff will do it. Food preservation methods will be downplayed; shuttle trips will be increased. This will not be done on purpose, it will simply be a reasonable response to the constraints and coercion imposed by the builders. High operating costs mean more expensive, or possibly less, resources once the station is operational. This form of pricing policy clearly leads to inefficiencies and fails to accomplish most of the objectives of the Space Station.

At the stations, almost all easily observable events that can be used for corresponding contracts are composed of the actions of one of the participants and some exogenous (external) event. This is very difficult to separate to the satisfaction of all parties without extensive monitoring and auditing (financial due diligence). Therefore, this type of contingent (conditional) contract is unlikely to lead to effective CS operations. The standard solution to this moral hazard problem is the use of principal-agent (intermediary) contracts.

If moral hazard exists, but it is possible to organize the project so that the uncertainty is either exogenous or under the control of only one of the parties (the agent/intermediary/), and if this agent (intermediary) is less willing to take risk than the others (the principal/principals/), then the effective contract consists in giving the agent (intermediary) full control over the project, thereby giving the agent (intermediary) all the rights to the uncertain benefits and responsibility for the uncertain costs, and paying the others one fixed charge (possibly negative, possibly similarly) that is not contingent (conditional) on any of them. One example: NASA could agree to deliver a fixed vector of resources to each user for some fixed payment (to be negotiated). If NASA is risk neutral, this is the most efficient contract; if any other contract is awarded, there are trade-off terms for it in which both NASA and the user are not very interested.

For large contracts (which include, for example, 1/3 of the designed power to be delivered), NASA is not risk neutral. An efficient contract then involves the agent (intermediary) ceding some of the risk to the principal in return for better trading conditions or for a reduced fixed fee. In profitable operations, this can be done through a revenue-sharing arrangement (for example, the principal receives 20% of the net profit in response to an investment of USD 1,000), but there is no market for most of the results obtained in the CS and therefore in such a contract it must be stipulated under what conditions the resources are to be supplied. A user projecting a large demand for resources over an extended period of time may wish to receive 20% of the station's realized net resources in return for the payment of some fixed sums in advance. This type of user could conceivably be a private venture capitalist who buys to resell or a large non-US government user such as one of the international partners. This type of contract again admits the risky moral problem, but the consumer assumes this risk in response to some discounts (concessions) in the price.

There are at least three other difficulties with principal-agent (intermediary) contracts. NASA cannot maintain its savings due to Congressional funding (its budget is set by Congress); this blunts her incentives as an agent. Over time, the evolution of CS can be managed to compete with new users and new information; a brokerage contract does not necessarily provide the situationally correct incentives with intensive learning by doing. Finally, many aspects of CS use depend on input provided by both users and CS managers. If it is not possible to organize it in such a way as to isolate the effects of each party, then it is necessary to arrange some form of partnership.

In conclusion, when an output is produced as a result of inputs provided by both parties, and when these inputs cannot be easily observed or separated from external exogenous events, then principal–agent (intermediary) type contracts are inappropriate.

References

1. Crouch, Tom D. The Bishop's boys: a life of Wilbur and Orville Wright. New York, W. W. Norton, c1989. 606 p.
2. Winter, Frank H., and F. Robert van der Linden. 100 years of flight: a chronology of aerospace history, 1903-2003. Reston, VA, American Institute of Aeronautics and Astronautics, c2003. 524 p.
3. Hansen, Ole Steen. The story of flight. New York, Crabtree Pub., 2003. 190 p.
4. Taylor, Michael John Haddrick. The Times aviators: a history in photographs. New York, HarperCollins, c2005. 192 p.
5. Turner, John Frayn. Heroic flights. Barnsley, South Yorkshire, Eng., Leo Cooper, 2003. 279 p.

ВЪЗМОЖНОСТИ ЗА ОПТИМИЗИРАНЕ НА УПРАВЛЕНИЕТО НА АЕРОКОСМИЧЕСКИ ПРОЕКТИ

Н. Маринова

Резюме

Създаването и ефективното функциониране на глобалните спътникови системи ще позволи да се създаде информационна база за решаване на проблемите, свързани с регенерацията и рационалното използване на природните ресурси, създаването на единен динамичен модел на Земята, включващ геоложките, климатичните, биосферните, екологичните и социалните фактори.

Голямо внимание следва да се отделя и на проблема за повишаване на безопасността на човешкия живот в условията на бурното развитие на междуконтиненталните транспортни връзки.