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Consideration of Adding a Commercial Module to the International Space Station

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Abstract. The National Aeronautics and Space Administration (NASA) is currently assembling the International Space Station in Low Earth Orbit. One of NASA's program objectives is to encourage space commercialization. Through NASA's Engineering Research and Technology Development program, Boeing is conducting a study to ascertain the feasibility of adding a commercial module to the International Space Station. This module (facility) that can be added, following on-orbit assembly is described. The facility would have the capability to test large, engineering scale payloads in a space environment. It would also have the capability to provide services to co-orbiting space vehicles as well as gathering data for commercial terrestrial applications. The types of industries to be serviced are described as are some of the technical and business considerations that need to be addressed in order to achieve commercial viability.

INTRODUCTION

The National Aeronautics and Space Administration (NASA) is currently assembling the International Space Station (ISS) in Low Earth Orbit. Through NASA's Engineering Research and Technology Development Program, Boeing performed a study to ascertain the economic feasibility of adding a commercial module to the ISS once on-orbit assembly is completed (or nearly so).

Boeing conducted this study under the terms of a cooperative agreement with NASA Johnson Space Center. Effort that was initiated in July 1997 was completed in November 1998. The conducted activities focused on finding a market need, whereby sufficient revenue was available to ensure an adequate return to the investor, and on technical designs to provide a baseline cost for the construction and deployment of the commercial module.

STUDY OBJECTIVES AND APPROACH

The overall objective of the study effort was to ascertain the economic feasibility of adding a commercial module to the International Space Station. (Figure 1) This module would be developed, constructed, launched and operated with commercial (private) capital. The return on this investment would be the profit stream associated with sales of services to commercial and government customers. Since the purpose of the commercial module was to complement ISS to maximize its value, it was established that the commercial module not duplicate any services provided by the baseline ISS. It was also desirable that basic resources be an integral part of the commercial module infrastructure. Items like power, thermal and data handling capability tend to be in short supply on most spacecraft, and the commercial module had to provide for these items.

Based on these study objectives the activities conducted on the program resolved into two distinct but related efforts. A design concept evolved that allowed the determination of the cost of the commercial module. This together with the required launch costs represented the investment. A strong effort was made in the design process to minimize non-recurring costs by using as much existing space hardware as possible. A market evaluation was also undertaken to ascertain the revenue as well as the expected profitability of the venture. This combined with a discounted cash flow analysis allowed the determination of the rate of return (or return on investment). The type of venture considered herein usually requires a rate of return in the 20-30% range (before tax) to be desirable.

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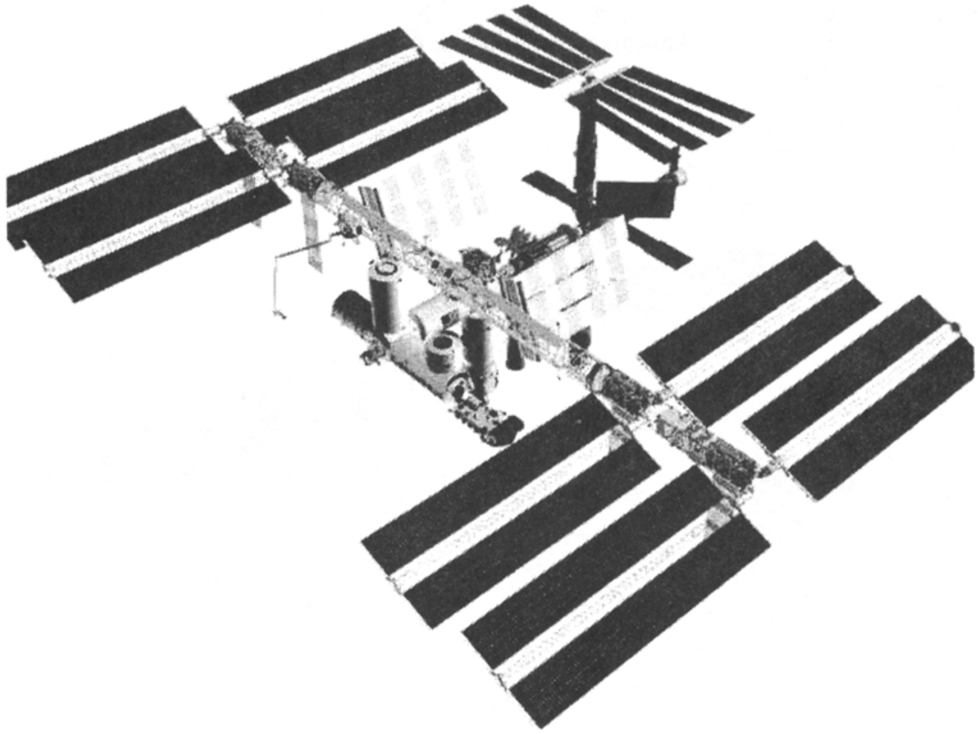

FIGURE 1. International Space Station.

COMMERCIAL MODULE ATTRIBUTES

To establish a viable business case, the first element to be sought is a market need and an associated revenue stream. This need starts with activities to be conducted in space in the near future. Therefore, the first effort undertaken was to survey the activities currently conducted in space. Literature surveys were undertaken to ascertain how these areas would grow in the future. These analyses were augmented with personal contacts with government and industry personnel involved in space-based activities. Market areas that appeared worthy of further investigation were (1) commercial remote sensing; (2) technology testing of energy, thermal and sensing equipment; and (3) entertainment. This approach is generally termed *needs-based marketing.* The module attributes are the resultant design features necessary to satisfy the above market needs.

To address these markets concurrently, a large external facility with a nadir view of earth is required. Test sites for technology items are also required as well as power capability in the 5 to 10 kilowatt range (hence, a dedicated solar array, battery and distribution system). Camera equipment to acquire still and active imagery will also be necessary. Lastly, a means of transmitting data to earth-based stations to allow for data processing and distribution was deemed necessary.

Care was taken to allow the market to "drive" the design. Many space ventures are initiated by settling into a comfortable design and then seeking a market. This approach (*product-based marketing*) often fails because the market realities are not recognized and allowed to drive the design.

COMMERCIAL MODULE DESCRIPTION

The approach taken to the design of the commercial module was to minimize non-recurring (initial investment) costs. This is because the recurring or operational costs, which would consist of taking hardware to orbit, operating it, and processing data, would be present regardless of the configuration of the module. Accordingly, the module design utilizes space-qualified elements, to the maximum extent possible. These serve as the basic building blocks.

Since a "one of a kind" item was being produced, this approach, which would tend to minimize non-recurring costs, was chosen. Figures 2 and 3 depict the commercial module and its installation on the International Space Station.

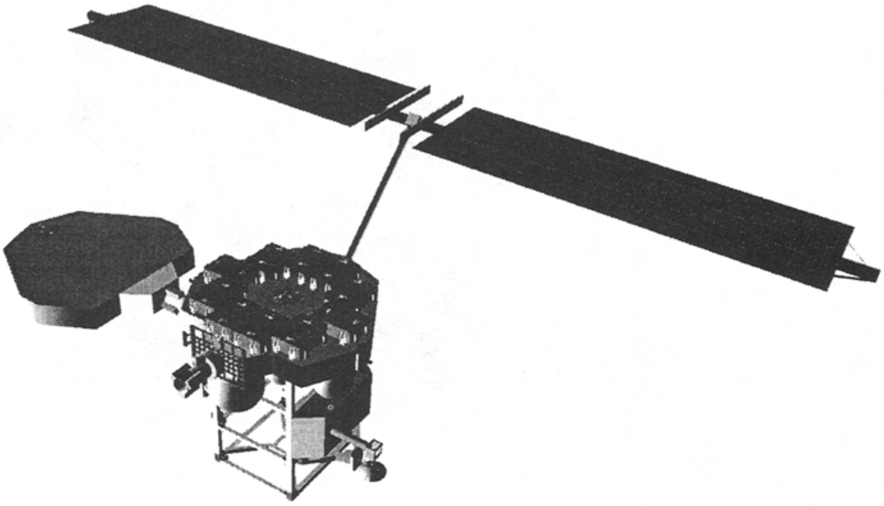

FIGURE 2. Commercial Module.

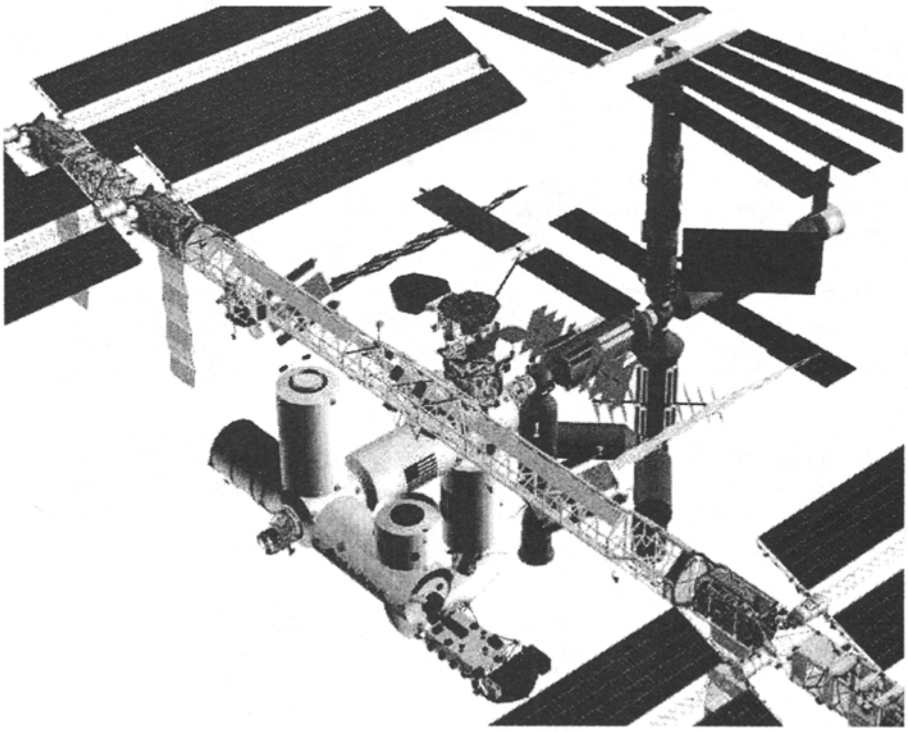

FIGURE 3. Commercial Module Installation on ISS.

Table 1 lists the main building blocks making up the module. Shown therein is the genesis for each element. The key structural building block is a derivative of the *Extended Duration Orbiter* (EDO) pallet, which is used in the Space Shuttle Orbiter to carry fuel cell reactants necessary for long duration missions.

TABLE 1. Commercial Module Hardware.

Components/Systems	**Hardware**	**Fidelity**
Base platform	EDO pallet	Flown
Tanks	EDO tanks	Flown
Spacer	Long Spacer Interface	Mature
Experiment boxes	modified ORU box	Flown
Electric Power	Milstar array derivative	Mature
Thermal Control	Heatpipe or passive	Mature
Payload transportation	ISS/STS-80/87 hardware	Flown
Robotic interface & systems	ISS hardware & systems	Mature
Core Interfaces	**ISS Subsystem**	**Design**
Electrical power	Primary EPS	ISS baseline
Mechanical	Z1/Long Spacer	ISS baseline
Software control	Command & Data Handling	ISS baseline

As noted in Table 1, much of the hardware to be used has its genesis in the US-manned space program. In addition to its use as a structural building block, the EDO pallet tanks can house high-pressure fluids. The experiment boxes and much of the other hardware have the ISS design as their basis. The solar array, chosen as the baseline power source, is a variant of the one used on the Milstar program. This array has extensive flight history. It is very similar to the ISS array in that it uses a similar deployment method and a flexible Kapton substrate for the solar cells. The array has nominally been sized to provide 10 kilowatts of power.

The Orbit Replaceable Units (ORU) used to house electronics in the ISS power system will constitute the standard experiment or payload containers. They are 3 ft by 3 ft (0.9 m by 0.9 m) in footprint and 18 in. (0.46 m) high. Six individual payloads can be accommodated at one time.

Siting of the commercial module on the ISS is an important consideration. Because it is important to have an independent power source, the location must be such as to allow convenient viewing of the sun with minimal shadowing of other ISS solar arrays or thermal control devices. Figure 3 shows installation of the commercial module on one potential location, the Z-1 truss. This is a convenient site from the viewpoint of solar array installation and the ability to have a clear view of outer space. Many other sites are being considered because of the nature of the markets to be served and the need for nadir views, which are not convenient from the Z-1 location. The siting issue is more fully discussed in the ensuing section, which deals with the market.

MARKET EVALUATION

Evaluating the market potential for an ISS-based commercial module was approached by focusing on market areas with a certain degree of currency. This means similar activities are being conducted today with growth expected in the near future. By approaching the marketplace in this manner, we were able to avoid the pitfall of a product-based approach. We then were able to start with markets that had established needs and revenues. The market areas that we focused on showed, through multiple sources, a substantial potential for growth between the present and 2003.

The largest market segment that we envision serving with the ISS commercial module is the remote sensing and geographic information systems market. Currently, several industries use remote sensing data. These include oil and gas, environmental monitoring, agriculture, mining and utilities. Although much data provided to these industries comes from sensors based in aircraft, a significant trend to use spacecraft is being predicted. Industry surveys by SpaceVest and others (*1997 Outlook- State of the Space Industry by SpaceVest, KPMG Peat Marwick, Space Publications, and Center for Wireless Communications*) place the total market size at over $3 billion in the 2000-2003 time frame. The market will be demanding digital terrain maps, multispectral and hyperspectral imagery. Of this total market a substantial number of applications (primarily agricultural) require sun-synchronous viewing. Because of this, the available market for the ISS commercial module will be between $1 and $2 billion. We have estimated a revenue stream for the ISS-based module in the $100-$200 million range. This magnitude was verified by several personal discussions with representatives of the oil and gas industry and with service providers to the environmental assessment industry.

Another market that appears to hold promise is that associated with technology demonstration testing in space. The size of this market area was estimated through personal contacts within NASA, DOD and the commercial solar array industry. Three major components of this market were identified. One related to testing large (above 5 kilowatts) solar arrays; specifically concentrating devices. The push of the communication satellite industry to higher power levels is being felt in the need to use higher efficiency solar cells, which coincidentally are more expensive than the current cells. Concentrators would be used to reduce the quantity of solar cells. Testing in space would allow verification of a concentrator panel assembly to a degree not possible on earth. The other two components of this market were government sources (DOD and NASA) concerned with technology demonstrations in space. The overall size for the technology demonstration market is estimated at $35 million.

The final market deemed to contain sufficient potential is the entertainment area. Cable television is expanding and the future holds the promise of a grouping of space-based programming. Based on personal contacts within the cable television industry, $10 million per year was estimated as the revenue stream from this market area.

The three markets described herein will total between $150 and $250 million per year. This revenue stream is typical of what would be expected starting in the 2000-2002 time frame. Several markets were eliminated as not being sufficiently promising for consideration. These included free flyer servicing (including NASA, DOD and commercial customers) and orbital debris removal. Within the above market value, no account was made for the possibility of selling utility services back to ISS. The latter certainly would be available. However, it needs to be considered as part of an accommodation agreement between the owners of the commercial module and NASA.

With the revenue stream of the commercial module dominated by the remote sensing market, use of the Z-1 location may not be the best choice. Although the Z-1 site allows the convenient attachment of a 10 kilowatt solar array, it brings with it issues relating to obtaining a clear nadir view. The ideal positions, whereby a nadir view would be best obtained, raise issues relative to a solar array installation. This is specifically true in those sites where it is desirable to attach the commercial module to US-provided ISS elements. It appears to be less true insofar as the internationally provided elements are concerned. Such an approach would complicate business arrangements. However, locating the commercial module near the extremities of the ISS assembly (where the international modules are sited) seems to be more favorable in that it would allow a nadir view coincident with providing room and outward viewing for a solar array. The other alternative would be to split the module; site the power generating portion on the zenith side of the ISS while locating the remote sensing devices on the nadir facing surfaces.

CHALLENGES

The foregoing identifies a potentially large revenue base through a niche in the emerging remote sensing and geographical information system market; this market is expected to grow to over $3 billion in the next 5 years. With this revenue base (augmented by technology and entertainment), adding a commercial module to the ISS has the promise of fulfilling substantial customer needs (by providing a desirable set of services and products), while at the same time rewarding the investors with a 20-30% return on capital invested. Achieving this promise introduces a number of challenges. Several areas need to be addressed further to make the business case progress from promising to clear-cut. Some activities have already been initiated. However, further investigation and analysis will be necessary to reduce any uncertainty in the results.

Market Penetration

The ability to view substantial portions of the terrestrial surface will affect the revenue potential. Placing a module for remote sensing on the ISS will provide cost advantages by eliminating the need for a separate infrastructure that would be required on a stand-alone spacecraft. Additionally, periodic flights to ISS by humans make the changing/upgrading instruments a real and advantageous possibility. On the other hand, the overall growth of the remote sensing market is critical and it depends on the ability to obtain the sensing systems at a reasonable cost with no decrement in the technologies. Should the overall remote sensing market not develop as hypothesized then the profitability of this venture is placed at risk.

Module Siting and Cost

As discussed in the previous section, siting is critical to being able to serve a major market while being able to provide for self-generated power. Many possibilities exist including splitting the module functions in a physical sense and siting in a location controlled by an international partner. The latter option introduces a degree of business complexity that will require additional evaluation.

Module cost is clearly a major element in the cash flow analysis that allows the investors to recoup the up front investment. This issue has been addressed by maximizing the use of existing space assets to minimize design and up front engineering expenses.

NASA Agreements

Agreements with NASA will strongly affect profitability of the venture. These will mainly affect the profit margin (revenue less operating cost) rather than the non-recurring expense. Obtaining reductions in launch cost from existing commercial rates will be important. Secondly, cost of on-orbit services (such as access to robotics, extravehicular activity, data handling, etc.) provided by the ISS need to be considered against the value of utilities provided to ISS.

Project Timing

The last, and possibly the most significant, challenge is project schedule. Because the remote sensing market is expected to reach substantial levels around 2002, the commercial module needs to be in place on ISS on or around that time. Failure to have the infrastructure in place when the market matures will cause customers to look elsewhere for service providers. Uncertainties in ISS launch schedules toward the end of on-orbit assembly can adversely affect financial viability of the project. Installing the commercial module prior to the completion of the baseline ISS would be necessary to reduce this uncertainty. However, such an approach would require agreements with NASA and generally complicate the overall scope of the agreements.

CONCLUSIONS

A potentially large revenue base for an ISS-based commercial module has been identified. It has the potential to return between 20 and 30% to investors in the venture. However, several uncertainties exist that will require continued evaluation. These pertain to market penetration, module siting, agreements with NASA for services, and timing for the venture.

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