

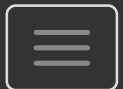
Building a robotic, LEO-to-GEO satellite servicing infrastructure as an economic foundation for 21st-century space exploration.

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Building a Robotic, LEO-to-GEO Satellite Servicing

Infrastructure as an Economic Foundation for 21st-Century Space Exploration

Gary A. P. Horsham (NASA Glenn Research Center, USA), George R. Schmidt (NASA Glenn Research Center, USA) and James H. Gilland (Ohio Aerospace Institute, USA)

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Abstract

The strategy for accomplishing civilian exploration goals and objectives is in the process of a fundamental shift toward a new approach called "Flexible Path." In this paper, the authors present a strategically aligned, government-industry partnership focused on the commercial development of Low Earth Orbit to Geostationary Orbit (LEO-to-GEO (LTG)) space over the next quarter century. A LTG satellite-servicing infrastructure and architecture concept is presented along with a brief assessment of the key applicable technologies. The evolution of the communications satellite industry is also discussed within the context of an emerging commercial in-space servicing industry. Large-scale, robotic, LTG satellite servicing is considered an essential economic pre-condition and next parallel or sequential step on the road toward robust, capital intensive human-robotic exploration beyond LEO. Such a step might produce the necessary pre-requisite economic value that can be used by future decision makers to justify further investment in exploration. A high-level implementation plan is offered.

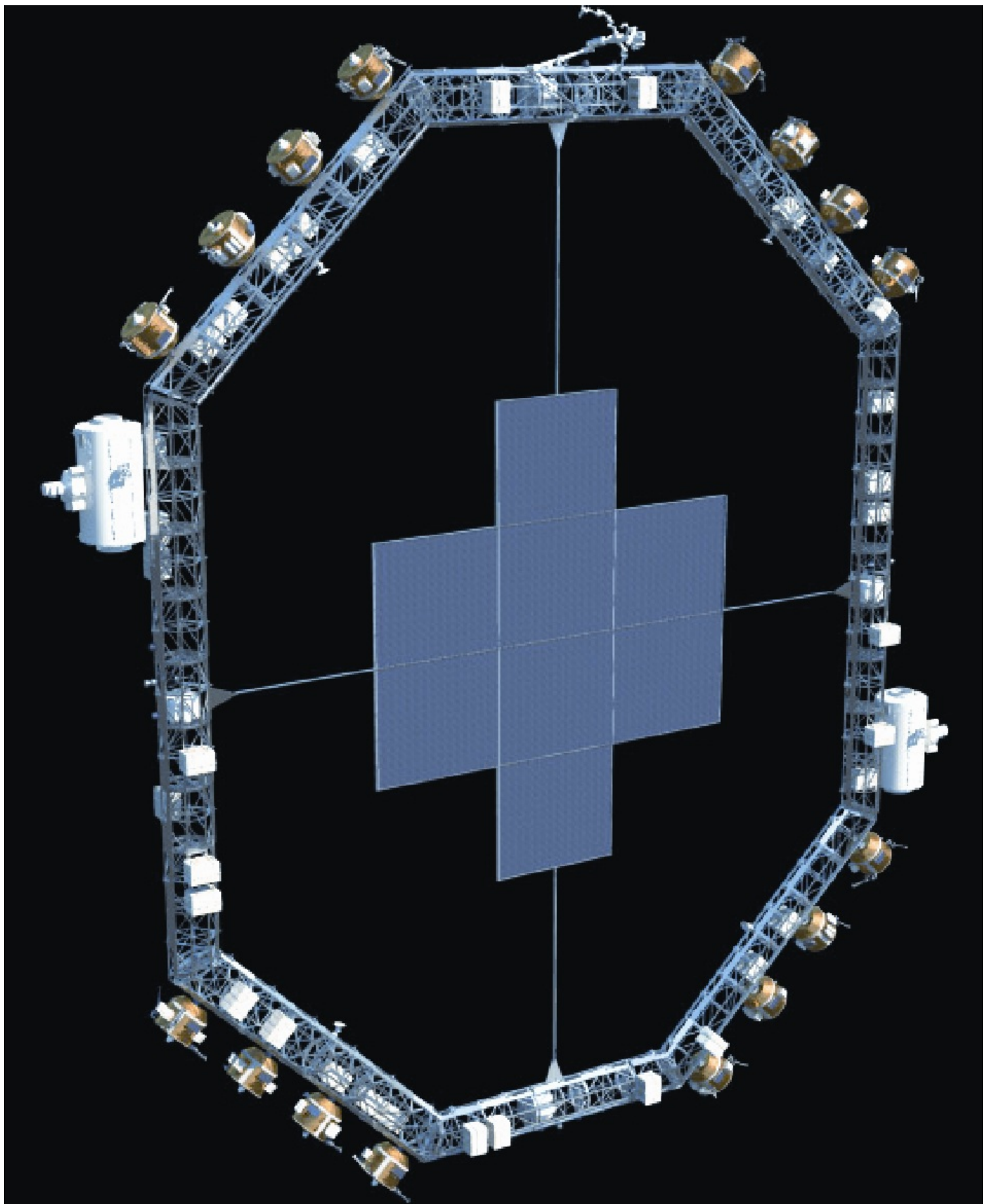
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1. Introduction

The modern world remains extremely dependent on thin strings of several hundred civil, military, and commercial spacecraft/satellites currently stationed in space. They provide a steady stream of commerce, defense, and knowledge data. This dependency will in all likelihood increase significantly during this century. A major disruption of any kind in these essential systems and networks could be socially, economically, and politically catastrophic, on a global scale. The development of a space-based, robotic servicing economy could be useful in mitigating this growing risk, from an efficiency and security standpoint. This paper attempts to suggest what makes sense to invest in next for the logical, economic development of Earth orbit—i.e., after ISS completion. It incorporates results from recent NASA studies in 2010 to understand the barriers and challenges faced by U.S. industry and the formulation of a commercial business case (NASA Headquarters, 2010; NASA Goddard, 2010a). It also expands on the results of early 2000s advanced market research and analysis studies (Horsham, 2003) that sampled the opinions of several satellite industry executives and presents these results within a broad policy context.

The concept of a “Space Harbor”¹ (Figure 1) that serves as the central component of a national, space-based or on-orbit/in-space, robotic or automated servicing infrastructure is introduced as the next logical step for United States leadership in space. This is viewed as a reasonable and appropriate follow-on to the development of expendable launch vehicles (ELVs) and satellites in the 1950s and 1960s, the Space Shuttle/partially reusable launch vehicle (PRLV) in the 1970s and 1980s, and the International Space Station (ISS) in the 1980s, 1990s and 2000s. Large-scale experience in LTG spacecraft/satellite servicing and protection by robotic means is assumed to be a “stepping-stone” toward the development and preservation of the large scientific exploration facilities and human-robotic exploration systems that are envisioned by NASA for operation beyond GEO. A balanced, return on national investment strategy for space, focused on the provision of enhanced national/homeland security for increased protection (from orbital debris and other threats), national economic/industrial expansion for increased revenue, and national scientific exploration for increased knowledge creates a strong goal in alignment with the new National Space Policy of the United States (Obama Administration, 2010). Satellite servicing is defined in this paper as the offering of services to owners or operators that involve the direct manipulation of on-orbit hardware or assets for the purposes of refueling, upgrade, repair, inspection, relocation, removal, etc.

Figure 1. Notional “Space Harbor” with 16 servicer spacecraft at a sub-GEO location



The aforementioned NASA studies have resulted in the preliminary definition of five near-term “commercial in-space servicing” market sectors: (1) Propellant Transfer and Depot/Storage; (2) Satellite Servicing (i.e., Repair, Maintenance, Refueling, etc.); (3) Orbital Transportation/Transfer; (4) On-orbit Assembly; (5) Orbital Debris Removal/Mitigation. This paper presents a discussion of the long-range prospects for spacecraft/satellite servicing and protection by robotic means (i.e., by tele-operated remote control and/or full-autonomy) as a common government-industry strategy for the logical, systematic development of space beyond LEO.

Two key premises underlie this paper. Firstly, in the latter half of the 20th century, the feasibility of a LEO




humans-in-space-centered space operations program was tested. The results-to-date indicate that the real and perceived benefits of having people in space need to heavily outweigh the risks inherent in transporting, keeping them there, and returning them to the Earth. Space, in terms of the LTG economic operations zone, or the beyond GEO exploration zone, appears to be the domain of semi- (i.e., tele-operated) and fully-autonomous (i.e., artificially intelligent) robots. Secondly, any major strategic/long-range exploration agenda will remain politically vulnerable and unsustainable without the establishment of a viable economic foundation.

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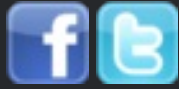
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