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Orbital assembly of very large wide-angle telescopes for EAS observation from space beyond 10^{21} eV with the possible second phases of EUSO on and from ISS

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Space platform was initially embedded as one of the most important ingredient in the von Braun team's visionary plan in early 1970's. Only the Space Transportation System (STS) was then approved. Space Station[1] was later formulated but without this critical value-producing portion of the assembling platform. Infrastructure needed for the Space Port planning exists on ISS. U.S. team with the MSFC BD Office, JAXA Manned Space Division, and Russian Space leaders, now began envisioning the Space Platform to realize an in-space assembly of large science spacecrafts for the Explorations era. Designing of large spacecrafts with 10-m class telescopes for incremental assembly will be feasible. A free-flyer kit for telescopes and spacecrafts for deployment to other orbits and return from their orbits for re-servicing would be highly productive. After three years of its major operations on ISS for $5 \times 10^{19} – 10^{21}$ eV region, an In-Space re-assembly of the EUSO telescope[2] on ISS could make itself a free-flyer in its second phase, flying at higher and lower orbits for higher ($> 5 \times 10^{20}$ eV) and lower energy (10^{19} eV) observations.[1] Follow-up large telescopes could be built on ISS for explorations beyond 10^{21} eV and for more detailed neutrino universe.

1. Introduction

We consider a possible Space Platform/Factory[1] that allows an in-space construction and deployment of large space telescopes and spacecrafts in the upcoming era of the International Space Station (ISS) and possible Explorations for astrophysical and astronomical researches. Contrary to a common belief that the ISS is not of much use for future, in particular, for space science and the Explorations program, we envisage that it can provide unprecedented opportunities of making great observatories and spaceships for various space and astrophysical science missions and for launching human and unmanned activities into near and deep space. Recent new initiatives of NASA Explorations[3] and ESA AURORA are yet to lay out how to assemble large spacecrafts in space. It is logical to emphasize a need of in-space spacecraft assembling platforms and a near-earth spaceport. The existing ISS could serve as the first spaceport for demonstration and verifications of technologies required for future space missions.

The Space Station environment is advantageous for constructing large structures and instruments: Virtual weightlessness and a near-complete freedom from aerodynamical interference provides a powerful platform in which the construction of large and heavy structures is possible. Assembly and launch of very large observatories and interplanetary spaceships will remain nearly impossible in a single rocket launch scheme. ISS can offer an incremental transport and integration scheme, intelligent and powerful aids such as EVA of experienced astronauts, various automatic sensors and monitors, as well as useful robotic arms for system integration. Installation of a powerful booster of the observatories is feasible on orbit, which will allow surer deployment to a desired free-flying orbit and return to the ISS for later re-servicing.

An astronomical telescope of the 10 ~ 20 meter class that can reach the 30th magnitude stars and 10 billion years back in time could be assembled, tuned, and tested on the Space Station or on a low-inclination new space port. Other scientific great observatories for radio, UV, X-ray, gamma ray, and cosmic rays, can also be built on orbit and deployed to their best orbits from the Space Port.

A new era that could begin after 2015 or 2020 could see a fleet of the greatest observatories and spaceships in space. NASA's first-generation Great Observatories have already initiated tremendous advancements in observational scope and scientific wonders of universe, creating a large body of young scientists in optical, x-ray, gamma ray and other astrophysical disciplines. A planning of great observatories in space for various astrophysics researches is a natural evolution, in particular, when there is a prospect of a revolutionary platform on ISS such as "Space Platform" for assembling greater observatories. Such a Space Platform could also become a hub of spaceships to launch them to other orbits or solar-system planets.

2. Historical Precedence

When the Space Shuttle orbiter was envisaged in early 70's, a powerful concept of "Great Observatories" emerged. Following the first great observatory concept of HEAO (High Energy Astrophysical Observatory) in 1960's, NASA conceived four great observatories, taking advantage of the size of the Shuttle cargo-bay that could carry a satellite larger than ever at that time. They are (Hubble) Space Telescope (HST), (Compton) Gamma Ray Observatory (CGRO), Advanced X-ray Astrophysics Facility (AXAF) and Space Infrared Telescope Facility (SIRTF). The HST and AXAF were developed as the MSFC projects, while CGRO and SIRTF were of GSFC and JPL, respectively.

This vision of the STS Great Observatories was well advocated and realized by Charles Pellerin and many others. Very successful performance of HST and CGRO yielded invaluable wealth of knowledge of the Universe as well as wonderful visual images for the general public. Indeed, both provided a really revolutionary new frontier of the observational universe and the civilization. With the launch of AXAF in early 1999, the science achievements of great observatories become even greater.

Considering the tremendous new knowledge provided by these great observatories, the science community could now begin planning far greater observatories with virtually unlimited size and capacity, were they to be built on the ISS. The current ISS construction plan will be completed in several years. Plans to use the ISS beyond microgravity researches have so far been much restrained due to the budgetary constraint during the present first phase of delivering the truss and habitat modules. If we do not plan now, we will suddenly face with the fact in a few years that no necessary logistics for Explorations exists in space.

The Wernher von Braun team at NASA MSFC in early 70's was the first to really envision the space factory and platform concept right after the success of the Apollo lunar mission. It included huge factory-like platforms on a low-earth orbit and on the moon. Three decades since that vision, humanity is going to have such a platform in the ISS, but new Explorations planners tend to oversight this huge asset in space. Planners can convert the currently planned Space Station into an original and extremely powerful Station. It is a natural way to get beyond the limited orbit of the ISS and to realize large scientific observatories and planetary spaceships in space. This concept could put to rest the science community's complaint that the Space Station is incapable of advanced astrophysical sciences or for Explorations, too. A new era could be born. This concept of the Space Factory is in an initial study, using large aperture optical system designs. Our present assessment suggests that there are sufficient technical grounds to assure realistic opportunities for the next generation great observatories and spaceships for Explorations, if we use docking ports and external facilities on ISS.

3. GRAND OBSERVATORIES

The current NASA program or Explorations visions do not include any "Space Platforms." However, the second phase projects of the ISS can readily incorporate an in-space assembly plan for lunar or inter-planetary spacecraft. These spacecraft will require large and complex structures. The first phase ISS structure is expected to be complete by the year 2010-2015. It is not premature to begin now to plan spacecraft assembly and experiment, making use of the natural infrastructure of the ISS. "Space-SUBARU" (Takahashi, 1998; Ebisuzaki, 1998) is a feasibility study to consider a 10-meter class Space Telescope and a Space Factory on the Japanese Experiment Module (JEM), or USA's S3 port. It studied, as its ultimate goal, methods to construct a large optical and IR telescope on the ISS.
NASA and ESA have been designing a 4 – 6.5 m telescope (JWST) (Stockman, 1997; Hadaway, 1998) for a post-HST mission. The main mirror is segmented and folded for launch and the telescope will unfold the mirror segments automatically in orbit. The NGST assumes autonomous fine optical tuning to the diffraction limit. It requires adaptive optics and many actuators to correct the deformation of the mirror. Its full-automatic deployment scheme is an ideal. The active autonomous control system requires the most modern technologies. These many sequential steps of the automatic deployment procedure will have a high risk of catastrophic failures. A very large optical telescope demands very challenging optical accuracy of 0.01 arc second or better. Actuators with this precision are indeed successful on ground, but the technology systems must be proven in space, with an efficient and rapid damping of the inertia of proper resonance. Unlike ground telescopes, or oil-dumped three-axis spacecraft positioning, no high-mass absorber of micro-vibrations of mirror-petals exists for actuation in free space. Most of the well-planned ground telescopes, built recently, actually needed repeated access and repairs to achieve the designed specifications.

This study of "Space Factory" seeks a different approach to realize a very large space telescope and other scientific spacecraft. Study incorporates an assembly scheme of several spacecraft experiments for different astrophysical purposes, considering a step-by-step advancement of the in-space assembly technology. The assembly and testing of less demanding spacecraft will help guide the way to the ultimate Space-Telescope or post HST (and JWST) that require diffraction limited optical accuracy. EUSO and OWL cosmic ray telescopes work with very forgiving resolution of several arc minutes and are suitable test articles for in-space assembly, prior to a verification of much demanding technologies for astronomical optical telescopes.

4. EUSO and OWL

The Extreme Universe Space Observatory (EUSO)[2] and Orbiting-array of Wide-angle Light-collectors (OWL)[1] (Takahashi, 1995; Takahashi, 1996; Ormes, 1997; Streitmatter, 1998) would watch from space the night side of the earth to explore the highest energy universe and neutrino universe. It plans to detect fluorescence lights of air showers caused by highest energy cosmic rays (10^{20}eV). EUSO baseline (2003) is an optical system with double Fresnel lenses, which covers a 60° full field of view (FOV). Multi-EUSO/OWL consists of plural units wit larger entrance pupils, forming a 120° FOV (from the zenith). Six such units can observe the entire earth's horizon $(6000\ km)^2$ viewed from a 1000-km orbit (Takahashi, 1998ab). Two such units allow 120° x 60° FOV.

EUSO is an ESA mission concept for a possible launch in early2010s on ISS (or as a free flyer). EUSO demands only 0.1 degree optical resolution, which is 10,000 times the diffraction limit and relatively easily achievable. Thus, it will be a conceivable first step for the Spaceport to pave the way of assembling a very demanding Space-Telescope. EUSO would permit wide-area earth observation for other phenomena: Upper atmospheric lightning such as Blue-jets, which may (or may not) have a relevance to up going tau-showers. Elves and Sprites and other ionospheric plasma airglow can be observed more frequently. Seismic activities that were often reported to give rise to airglow before earthquakes can be studied as the variation of the background data. Gamma ray bursts illuminate the entire upper atmosphere and EUSO can detect them at the sensitivity similar to the CGRO BATSE. If the EUSO is flipped for the day-phase, it can be used for surveying earth-threatening meteorites and asteroids.

Figs 1 and 2 show how the initial EUSO telescope can be deployed at the ISS CEPF (Columbus External Payload Facility), and later, how it can be re-deployed as a free flyer from ISS by attaching a free-flyer kit.

Fig. 1 Deployment of EUSO at the CEPF on ISS, transported by HTV unmanned transportation vehicle.

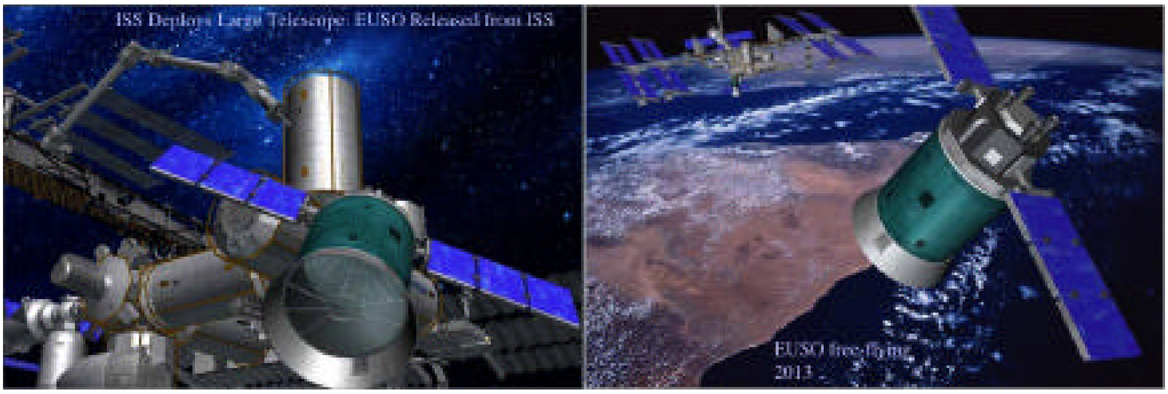

Fig. 2 Re-deployment of EUSO as a free flyer

5. Conclusions

A large area (as the detector size) can become usable with in-space cosmic ray observatories that can make hundred-folds of the size of the Auger experiments. Future space explorations would allow such a large observatories in space, when the on-going ISS construction and the Explorations program evolve and merge.

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