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AN OVERVIEW *OF* FUTURE NASA PROGRAMS

by

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This paper presents an overview of programs in the Advanced Systems and Technology Office at Marshall Space Flight Center designed to move NASA into the next century of space exploration. These programs include work in evolved and new booster and upper stage technology. In addition to near term applications, effort continues in advanced concepts focused on the propulsion needs in the decades ahead. In support of Space Station and beyond, tethers will play a growing role with their abilities to move payloads, generate power, and support research in the upper atmosphere. Our knowledge of the Earth will be enhanced with missions to study the winds and lightning, and Earth observation resources will be put to greater use in reducing the damage and losses from disasters. New missions will continue our study of the Sun as well as the heavens with new observations never before possible. This paper summarizes the future transportation and payload missions being studied at MSFC for NASA.

DOPPLER WIND LIDAR

Timely tropospheric wind measurements on a global scale are an important element in understanding the global hydrologic cycle and interannual global climate variability. A 'Windsat' spaceflight mission is the logical next spaceflight mission following the long and successful heritage of measuring winds by Doppler lidar (i.e., ground-based measurements since 1968 and airborne measurements since 1981) . NASA, NOAA, DOD and ESA studies have all concluded that it is possible to measure tropospheric winds from space with current lidar technology. Gas lasers (Cooperating at 10.6 μm wavelength) have been utilized in ground-based and aircraft based Doppler lidars for years. Recently, solid state lasers have successfully flown on aircraft, too. Although a wind measuring Doppler lidar has not yet flown in space, lasers have been flown in space on several occasions including the recent very successful Shuttle Lidar In-space Technology Experiment (LITE) . The objective of LITE was to map atmospheric backscatter using a lidar operating at shorter wavelengths than a wind lidar. Lidar return signals from the atmosphere far exceeded expectations. For example, in many cases the lidar penetrated multiple, optically thin, cloud layers before striking the earth's surface. This success indicates a capability for a small satellite wind lidar that is far beyond what was previously anticipated.

The proposed instrument utilizes a Doppler lidar to measure wind profiles in the Earth's lower atmosphere. One attractive option is built around a coherent pulsed laser, i.e., a coherent Doppler lidar which makes direct wind measurements. The coherent lidar baseline system consists of a pulsed, frequency stable laser transmitter, a continuously scanning transmit-and-receive telescope, a heterodyne detector, and a signal processing subsystem. Windsat is currently planned for delivery in 1999.

SOLAR THERMAL UPPER STAGE (STUS)

A STUS is envisioned as a propulsive concept for the future. The STUS will be used for Low-Earth Orbit (LEO) to Geostationary-Earth Orbit (GEO) transfer and for planetary exploration missions. The STUS offers significant performance gains over conventional chemical propulsion systems. These performance gains translate into a more economical, more efficient method of placing useful payloads in space and maximizing the benefits derived from space activity.

An additional benefit of an STUS is that it will increase or provide a GEO/Geosynchronous Transfer Orbit (GTO) capability for the small launch vehicles that have either very little or no current GEO/GTO capability. This augmentation of the small launch vehicle capability will allow greater access to space for small commercial enterprises and universities. This benefit may also have a potential application to the single stage to orbit (SSTO) launch vehicles which are currently being studied. The STUS would have the potential of greatly increasing the payload capability of an SSTO and further enhancing its cost effectiveness. Work is underway to define an STUS flight experiment called "Shooting Star," scheduled to fly in 1998.

NEXT GENERATION SPACE TELESCOPE (NGST):

Concepts for advanced large space telescopes which will follow the Hubble Space Telescope (HST) have been investigated by NASA and the scientific community even while HST was still under development. Studies of the NGST are continuing today. The historically very long development times, and the great investment in resources to achieve one order of magnitude improvement over HST in both resolution and sensitivity demand precise assessments of the potential options within the technological and fiscal environment which exists today.

Of the new design concepts which have been studied, the segmented contiguous mirror, phased-array telescopes and telescopes with sparsely filled apertures have attracted the most attention for future space telescope applications. Although optical performance considerations play a major role in the selection of a telescope concept, other important aspects such as cost and schedule also become major trade criteria in the design of advanced space telescopes.

A renewed effort is now underway to characterize a next generation space telescope which is capable of answering some of the key questions raised by the superb performance of the Hubble Telescope but still is responsive to the reduced budgetary ranges to which all science projects must become accustomed. Key to structuring such a challenging program is to review current ways of doing business in engineering, technology applications and management, in order to reduce the NGST costs.

TETHER APPLICATIONS

The objectives of the tether development activities at MSFC are to better understand the fundamentals of tethers in space and to develop specific space applications for their use. Several successful tether missions have flown on both manned and unmanned vehicles. Applications of interest include tether systems on a variety of host elements, such as free–flying satellites, the STS, unmanned vehicles, and the International Space Station (ISS) .

Tether flight activities managed at MSFC to date have involved two basic types of tether systems: 1) the Tethered Satellite System (TSS) and 2) the Small Expendable Deployer System (SEDS). The TSS program is a joint effort by NASA and the Italian Space Agency utilizing a large (several thousand pounds), reel–type, Shuttle–launched deployable/retrievable tether system. This system utilizes a conducting tether to deploy a satellite to a distance of up to 20 km from the Orbiter, subsequently allowing performance of experiments and retrieval of the satellite. The first flight occurred in 1992, and the second is scheduled for early 1996.

The SEDS program and hardware elements are considerably smaller than the TSS, and involve only U.S. participants. The SEDS has a total weight of less than 100 pounds, and operates only in the deployment mode. The SEDS was designed to provide a "faster/lighter/cheaper" approach to tether applications, with a capability of being flown as a secondary payload on an unmanned launch vehicle. The first two SEDS missions (1993 and 1994) were used to deploy small instrument packages 20 km downward from the unmanned host vehicle. The instrument packages were targeted to reenter and burn up in the Earth's atmosphere. The third mission is to be flown on the STS and will deploy the small student-developed SEDSAT (SEDS Satellite) upward from the STS payload bay.

An advanced study of a future TSS mission is in progress at this time, and a number of potential future SEDS and TSS missions are also being investigated. Discussions and various other activities are in progress with government agencies, private industry, and universities interested in a wide variety of tether applications.

Advanced studies of potential ISS tether applications during FY96 will include preliminary assessments of using tethers for reboost using momentum exchange and electrodynamics forces, for power generation, for adjustment of the microgravity environment, for deployment of science packages, and for deboost/reentry of small packages and/or trash, and for orbital augmentation of co–orbiting elements.

THE VIRTUAL RESEARCH CENTER

The VRC, an experimental Collaborative Computing Environment (CCE), creates a shared workspace on the Internet through an integrated set of communications tools. Using a private World Wide Web (WWW) and computer graphics, the VRC depicts a virtual lunar colony as a meeting place for teams. Providing a sense of presence among team members allows more natural communication and reduces the need for travel.

The VRC is a three phase prototyping activity for developing an Internet based advanced concepts project management infrastructure. In the first phase, several Internet services were integrated into a web of hypertext pages. Subsequent phases will incorporate commercially available software and new Internet technologies.

Members of the VRC receive a preconfigured web browser and helper applications. These helper applications provide users with the capability to exchange files, store data in centralized archives and conduct desktop conferences.

BANTAM LIFTER CONCEPT STUDY

This vehicle is intended to address the market for very small satellites on the order of 100 kg (220 lb.). Developers of this class of payload, universities, small businesses, etc., are currently faced with launch costs which usually greatly exceed the cost of the payload itself. The prime objective of the Bantam Lifter program is to satisfy this need by reducing the launch vehicle costs to one million dollars or less. As a secondary objective, plans include an on-going program to develop and test various technology innovations and incorporate these improvements into future versions of the vehicle.

It is expected that U.S. small business partners will be invited to participate in the concept development from the outset. Initial launch of this vehicle is anticipated approximately two years after program go–ahead is received. After appropriate flight demonstrations, responsibility for continued operation of the system will be transferred to the commercial sector. NASA will continue to pursue a research and development role by incorporating technology improvements in subsequent concepts, with a “block upgrade” demonstration vehicle being launched approximately every two years.

LARGE AREA X–RAY SPECTROSCOPY MISSION

The Large Area X-ray Spectroscopy Mission is conceived and sized to address a range of fundamental astrophysical questions such as: –the role of flares and microflares in heating stellar coronae– the impact of metallicity on the Eddington limit in accreting binaries- the enrichment of the interstellar and intracluster medium - the formation of galaxies from cooling cluster gas, and – the nature of the environment around quasars and other Active Galactic Nuclei (AGNs). The essence of the concept is to build six identical modest satellites, each carrying a highly packed assembly of replicated mirror shells and X–ray spectrometers, launched into a solar, drift–away orbit (similar to that studied for the Space Infrared Telescope Facility (SIRTF) program. We envision a large collecting area and a relatively high spectral resolution with the ability to study extended sources (up to 1' and 2'), as well as, point–like objects. The program distributes risk over several launches using a number of small, lightweight, inexpensive satellites to achieve the required large area and scientific sensitivity. The development time is relatively short – 3 years from program start to first launch, with subsequent launches every 4-6 months. The relatively benign, solar orbit supports very simple operational scenarios and safe modes, and is conducive to long life (>5 years) .

THE HARD X-RAY TELESCOPE (HXT) MISSION

The HXT mission concept contains focusing telescopes that collectively, observe simultaneously from the ultraviolet to 100 keV and in several narrow bands extending to 1 MeV. In pointed observations HXT is expected to have an order of magnitude more sensitivity and much finer angular resolution in the 10 to 100 keV band than all current and currently planned future missions, and considerably more sensitivity for detecting narrow lines in the 100 keV to 1 MeV regime. The detectors are small, cooled arrays of relatively low mass with very good energy resolution and some polarization sensitivity.

HXT contains two types of hard X–ray telescopes. One type, called the modular multilayer telescope (MMT) utilizes a novel type of multilayer coating and small graze angles to extend the regime of focusing to 100keV. There is a two stage imaging detector at each focus, and a CCD for X–rays. The other type of telescope, called the Laue Crystal Telescope (LCT) is a single adjustable array of several hundred Ge crystals that focus by Laue scattering. The LCT will have high sensitivity for detecting narrow X-ray lines of known energy such as those expected from Type I supernovae.

The UV monitor is a three telescope system that provides coverage in the ultraviolet band for study of time correlated changes across the broad electromagnetic spectrum of an AGN such as are expected in "reverberation" models.

ULTRA LIGHTWEIGHT TELESCOPE, INTEGRATED MISSIONS FOR ASTRONOMY (ULTIMA)

The ULTIMA program has as its objective to achieve near–diffraction–limited images of astronomical objects at visible and/or infrared wavelengths with a space telescope having an ultra lightweight primary mirror combined with adaptive, correction optics . The technologies being developed will provide a system that can be transported to space in densely packaged form to fit existing launcher payload envelopes, then construct/deploy to form space telescopes with large apertures. Such a system would also continually compensate for image distortions due to imperfections, natural disturbances, and equipment induced vibrations/

deflections. The technology program is going forward in two main thrust areas: large aperture, thin film mirror technology and segmented adaptive correctors. The goal will be to make very large primary reflectors of low mass and cost possible.

AFFORDABLE IN–SPACE TRANSPORTATION SYSTEMS (AIST)

An initial study project for Affordable In–Space Transportation (AIST) systems was conducted in 1995 with a project team comprised of NASA and Boeing personnel. The principal objective of this study was to conceptually define 3–4 promising approaches to in-space transportation for delivery of satellites and other payloads, 3,000 to 10,000 pound class, to GEO destinations. The cost goal for these approaches, in combination with lower cost Earth to orbit (ETO) transportation, was $1000 per pound to GEO. The ETO portion of the mission for this study was assumed to be accomplished by a Highly Reusable Space Transportation (HRST) system. The goal of this HRST system is to provide access to LEO for $100 to $200 per pound.

Results of these studies indicated that LEO transportation costs were a dominant cost (either first or second highest) for all of the concepts considered. Sensitivity studies revealed that launch costs must drop below $100 per pound before the LEO transportation costs become a less significant contribution to the overall life cycle cost. Stage production costs were also a large contributor to the overall life cycle costs, especially for the expendable systems. Although the absolute value of these costs should not be taken for face value without understanding the assumptions made in the study, cost comparisons can be made between the concepts. None of the concepts met the $1000 per pound cost goal, however there was about an order of magnitude savings over today's delivery costs for many of the concepts. Although there was not much difference between most of the concepts, the expendable cryogenic system had the lowest life cycle cost for delivery of a 3,000 lb payload to GEO, and the expendable solid system had the lowest life cycle cost for delivery of a 10,000 lb payload to GEO.

HIGHLY REUSABLE SPACE TRANSPORTATION(HRST)

The Reusable Launch Vehicle (RLV) program is planning to demonstrate technology to allow U.S. industry to develop a new generation of space launch systems. These systems will be capable of delivering payloads in the 20,000 to 40,000 pound class to Low–Earth Orbit (LEO) at costs of approximately $1,000–$2,000 per pound-payload a factor of 3-5 below U.S. launch prices in 1995. The RLV program will enable continued U.S. competitiveness in space access during the first decade of the new century. However, the 1994 Commercial Space Transportation Study Alliance report stated that <u>prices</u> of less than approximately $400–$500 per pound–payload (and hence <u>costs</u> less than $300-$500 per pound-payload) will be needed to enable significant expansion of non-traditional commercial space industries such as tourism, industrial space parks, space solar power, etc. Taking into account the inflated levels of return on investment (ROI) needed when new enterprises entail significant business risk, still lower launch costs–on the order of $100–$200 per pound- may be necessary to engender the large commitment of private capital that must be made to create these new industries.

The NASA Headquarters Office of Space Access and Technology (Code X), Advanced Concepts Office (Code XZ) is responsible for the definition and refinement (including selected research experimentation) of innovative, far–reaching new systems concepts that have the potential to revolutionize the future U.S. space program. One such program, the HRST, is addressing the challenge of reducing space launch costs to approximately $100-$200 per pound–payload. This study project is being managed by MSFC for Code XZ, and will involve substantial participation by various other NASA Centers, other Federal Laboratories, industry, and several universities.

The MAGNETOSPHERE IMAGER MISSION

One of the most important discoveries of the space age was the Van Allen radiation belts around the Earth. These belts are vast clouds of intense radiation that are caused by the Earth and its rotating magnetic field being impacted by the supersonically expanding atmosphere of the Sun. After more than 30 years of spacecraft flights through this region, it is known that these radiation clouds contain electrical storms and disturbances that play an important role in the Earth's atmospheric processes.

Through technology advances, pictures of this magnetospheric cloud can now be made similar to the satellite photos of ordinary clouds commonly used for weather reports. Thus, NASA is poised to explore and expose this violent and variable region that surrounds our planet with entirely new types of satellite images.

For the past few years, MSFC has been studying the feasibility of flying a new generation of instruments aboard a small spacecraft to obtain these magnetospheric images. The Magnetosphere Imager mission was conceived by the NASA Office of Space Science (0SS) and assigned to MSFC for further definition.

The MSFC Magnetosphere Imager design team developed a mission concept that will utilize a small, spin-stabilized spacecraft to carry a suite of four instruments into a high–elliptical Earth orbit for two years. The spacecraft, launched by one of the new Med–Lite expendable launch vehicles, will fly over the Earth's poles to an apogee of 7 Earth radii. The mission instruments: Hot Plasma Imager, Plasmasphere Imager, Far Ultraviolet Imager, and Radio Sounder will obtain the first simultaneous global images of Earth's magnetospheric processes in multiple wavelengths of light, energetic neutral atoms and through active radio frequency sounding.

As a result of the MSFC engineering design study and the efforts of the Space Physics Division's Magnetosphere Imager Science Definition Team, this exciting mission that will return never-before-seen or understood glimpses of near–Earth space not only appears to be technically feasible but also affordable. The estimated mission cost, not including launch, is approximately $70 million.

HYBRID ROCKET PROPULSION

Hybrid propulsion offers important advantages for both current and future launch vehicle boosters and upper stages in the areas of safety, reliability, operability, cost and environmental impact. Recently a consortium led by Lockheed Martin Manned Space Systems in New Orleans was formed to design, fabricate, and test a 250,000 pound thrust hybrid rocket motor system. The Hybrid Propulsion Demonstration Program (HPDP) combines the efforts and funding of NASA, Advanced Research Projects Agency (ARPA), Phillips Laboratory, and consortium members.

SUMMARY

This paper has summarized the future transportation and payload missions being studied at MSFC for NASA. These programs planned for the late 1990's and early 21st century will provide a wide range of opportunities for exciting new science and application missions, and low cost transportation systems. We at NASA/MSFC are confident that these programs will continue U.S. leadership in space, and benefit humankind.

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