HIGH-ENERGY FACILITY DEVELOPMENT PLAN

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and

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Abstract. Plans for the deployment of a comprehensive set of instruments designed to study the high-energy emissions of solar flares have been developed as part of a series of studies for an Advanced Solar Observatory (ASO). These studies have identified the Space Station as the preferred mode for the deployment of the full ASO. The accident of the Space Shuttle Challenger in 1986, and the growth in the estimated costs for the Space Station during the fiscal year 1989 budget discussions, have created an uncertain climate within the United States Space Program, making it difficult to predict the schedule for major programs such as the ASO. Approaches to the deployment of instruments for the study of high-energy solar emissions alone, or in conjunction with other solar instruments are discussed. As an independent entity the High-Energy Facility could be on a co-orbiting platform.

1. Introduction

In the mid-1970’s, it was widely anticipated that the Space Shuttle would initiate an era of rapid and inexpensive access to space for large-scale scientific instruments (Space Science Board, 1974). The concept of a comprehensive Shuttle-borne Solar Observatory which was developed during the earliest studies of potential Shuttle instruments (Jefferies et al., 1974) was refined and extended by the National Academy of Sciences Astronomy Survey Committee Solar Physics Working Group (Walker, 1982; Walker et al., 1983). The principal recommendation of this group was that NASA undertake the development of an Advanced Solar Observatory, containing three instrument assemblies: (i) a High-Resolution Telescope Cluster capable of high-resolution observations of the multithermal plasmas of the photosphere, chromosphere, and inner corona at soft X-ray/XUV, extreme ultraviolet, ultraviolet, and visible wavelengths, and of the solar interior by the study of the solar oscillations, (ii) a Pinhole/Oculter Facility capable of high-resolution observations of the far corona by the use of occulted telescopes, and of hard X-ray and gamma-ray emitting flare plasmas by the use of transform imaging techniques (Hudson and Lin, 1978), and (iii) a High-Energy Facility capable of spectroscopic and polarimetric observations of the high-energy emissions of flares with high temporal resolution, and of the low-frequency radio emission generated by particle acceleration events. The ASO concept, and the High-Resolution Telescope


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Cluster have been described by Walker, Moore, and Roberts (1986) (see also Walker, 1988). The Pinhole/Oculter Facility has been described by Tandberg-Hanssen, Wilson, and Hudson (1986) and by Tandberg-Hanssen et al. (1983). The objectives and instrumentation for the High-Energy Facility are the subject of this volume.

The objectives of the ASO, which are described in detail by Walker, Moore, and Roberts, can be summarized as follows:

(i) To provide instruments which are capable of observing solar phenomena on the inherent physical scales of the underlying processes that control these phenomena. Evidence suggests that for the Sun this fundamental physical scale, which is primarily that of the fine structure of the solar magnetic field, is approximately 50–100 km.

(ii) To allow the Sun to be studied simultaneously utilizing the entire electromagnetic spectrum, from high-energy gamma radiation to low-frequency radio waves. This capability will allow phenomena, such as solar flares which manifest themselves at all temperatures present in the solar atmosphere, to be observed in their entirety.

(iii) To provide the diagnostic capability necessary to determine the detailed physical conditions extant within the solar plasma on spatial and temporal scales which will allow a direct comparison of our present understanding of physical theory with the phenomenology displayed by the solar plasma.

With the publication of the report of the Astronomy Survey Committee (1982), and the establishment of an ASO Science Working Group by NASA, the United States strategy for space solar physics appeared to have been established. The ASO instruments, because of their size and cost, were to be built over an extended period, and deployed on the Shuttle in a series of increasingly comprehensive Sortie missions. The first ASO instrument, the 1.25 m aperture Solar Optical Telescope (SOT) was approved and the focal plane instruments selected (Jordan, 1981; Dunn, 1981) even before the Astronomy Survey Committee recommendations were published. In retrospect, this strategy was seriously flawed, primarily because the cost of a Space Shuttle launch (see, for example, Easterbrook, 1987), and consequently the cost of instruments built to Space Shuttle quality standards, proved to be much greater than anticipated. The cost of a series of Shuttle Sortie (Spacelab) missions and consequently the cost of SOT as a Spacelab instrument became unacceptable. However, the concept of the Space Station as a platform capable of supporting large instruments (Banks, 1987a, b) represented an apparently superior, and less costly alternative. In 1986, a redefined SOT, reduced in aperture to 1.0 m, and renamed the High-Resolution Solar Observatory (HRSO) was approved as a Space Station payload. Deployment on the Space Station was accepted as the preferred mode for the remainder of the ASO instruments, including the High-Energy Facility (Walker, Moore, and Roberts, 1986). Unfortunately, two events have resulted in the disruption of this plan. The first, the Challenger accident (Rodgers et al., 1986) resulted in delays of up to four years for Shuttle and Spacelab payloads, resulting in substantial cost increases. The second event, the increase in the estimated cost of the Space Station (Aviation Week and Space Technology, 1988), resulted in a rescoping of the capability of the initial configuration (called the Block I configuration) to support complex attached payloads, and a streachout of the Space
Station development schedule. These events have resulted in the cancellation of HRSO as a Space Station instrument. This situation has further resulted in a climate of uncertainty with regard to major NASA programs such as ASO.

It is with this climate of uncertainty in mind that we address the prospects and plans for the deployment of the High-Energy Facility.

2. Alternatives for the Implementation of the High-Energy Facility

The implementation of a High-Energy Facility as an independent observatory or as part of an Advanced Solar Observatory remains, in our view, a primary goal. Currently, NASA is studying the deployment of an extended or E-HRSO on a free-flying spacecraft. This plan (which is not yet approved) envisions the 1.0 m visible light HRSO, augmented by somewhat smaller ultraviolet and XUV instruments, as a ‘moderate mission’ payload of ~2000 kg. (The NASA definition of a ‘moderate mission’ is discussed below.) Evidently, current NASA plans envision advanced solar instrumentation dispersed on a number of platforms. Indeed, various components of the ASO need not be deployed at the same time nor on the same platform. The concept of an ASO can, at least over the next decade, encompass a collection of instruments on different platforms, which can, with careful planning, operate as a single observatory. With this possibility in mind, we examine the alternatives for the deployment of the High-Energy Facility below.

Currently, NASA orbital missions can be classified into six categories, major missions, moderate missions, explorer missions, Space Station attached instruments, Shuttle Attached (Spacelab) instruments, and instruments mounted on platforms in polar or Space Station like (‘co-orbiting platforms’) orbits. (This last option is part of the Space Station complex.) Major missions address instruments in the 5000 kg or greater class, and cost typically $1000 M or more. Moderate missions address instruments in the 1000–2500 kg class, and cost typically less than $500 M. Explorer missions are divided into ‘Delta-Class’ and/or Shuttle launched missions which address instruments in the 200–1000 kg class and cost typically less than $150 M, and ‘Scout-Class’ which address instruments which weigh less than 200 kg, and cost less than $50 M. Space Station and Shuttle attached instruments appear to have less well-defined weight and cost boundaries.

The High-Energy Facility instruments naturally divide into two categories, spectroscopic and polarimetric instruments, which require only modest pointing (~ 0.1°), and hard X-ray and gamma-ray imaging instruments which require arc second pointing. High-Energy Facility instruments are incompatible with the Explorer mode (due to the weight limit) and Shuttle-attached mode (due to limited duration). Although compatible with a major mission, the very substantial costs of these missions, and the extensive list of well-studied major missions (AXAF, SIRTF, etc.) awaiting approval, suggest that this is not a practical approach for the High-Energy Facility. Because of the size and divergence in pointing requirements of the High-Energy Facility instruments, it is likely that for the moderate mission mode, two spacecraft would be required to accommodate
the High-Energy Facility. The final, and in our view the preferred approach is deployment on the Space Station or on a co-orbiting platform. The alternative of a moderate mission should not be dismissed, however, it is unlikely that a detailed study of such a mission will be undertaken by NASA until the disposition of the E-HRSO mission currently under study is resolved. Since the co-orbiting platform is not part of the Block I Space Station configuration, we consider only the Space Station attached option.

3. Space Station Implementation Approach

With the definition of plans for the Space Station, one possible implementation approach for the full Advanced Solar Observatory has come into focus. The Space Station can provide the accommodation capabilities required by the ASO and is, therefore, a logical base upon which to build this research facility. Since the Space Station will be designed to accommodate large instruments such as ASO, the Space Station can enhance the ASO evolution by supporting:

(i) Man-in-the-loop operations as a continuation of the experience acquired from earlier solar missions such as the Skylab ATM, Spacelab I, and Spacelab II.

(ii) Pointing requirements for large instruments such as the High-Resolution Telescope cluster, the Pinhole/Occluder Facility, and the High-Energy Facility.

(iii) Evolutionary buildup of instruments over a period of years using manned extravehicular activity.

(iv) Payload accommodation for services such as electrical power, thermal control, command and data transmission and servicing.

3.1. Evolution Support

The Space Station will provide supporting capabilities which can be useful in the buildup of the Advanced Solar Observatory. Furthermore, the Space Station will be designed to support instrument servicing, which will provide important functional capabilities as described below.

(i) Mobil Service Center (MSC) – This system consists of a long (several meters) robotic arm mounted on a rail system which allows it to traverse the length of the Space Station. Special Purpose End Effectors may be developed which will permit this system to perform highly dextrous operations such as telescope or instrument mounting and changeout, instrument assembly, configuration changes, film pack or digital optical disk replacement, alignment and calibration, instrument repair, etc.

(ii) Instrument Storage – The provision of special locations, where sensitive instruments may be stored in an area which is thermally controlled and protected from contaminating environments. This capability will support the planned addition of instruments to the Space Station.

(iii) Work Area – Special provisions are being planned in the evolved Space Station to provide a dedicated area to support servicing functions. This area should be well equipped with special tools, such as electronic test and calibration equipment, necessary to assemble, integrate, align and calibrate instruments to be attached to the Space Station.
(iv) Logistic Missions – Frequent flights of the Shuttle and/or expendable launch vehicles to the Space Station will provide provisions for the crew and replenishment services to the Space Station. These missions will also support the delivery of instruments and consumables to the ASO.

3.2. ASO INTERFACE ASSEMBLY

The ASO will use the basic capabilities and resources to be provided by the Space Station such as electrical power, thermal dissipation, command and data transmission, etc. However, appropriate structures and systems must be designed and developed to provide an interface between each of the major ASO instruments assemblies (the High-Resolution Telescope Cluster, the Pinhole/Occulter Facility, and the High-Energy Facility) and the Space Station.

These ASO interface assemblies will include the necessary experiment computer, video monitors, digital display units, controllers, pointing systems, mounting adapter, etc., to enable the ASO instruments to be operated on the Space Station to perform coordinated observations. This equipment also will provide the optimum systems by which on-board or ground-based Mission Scientists may most effectively interact with the instruments and their observing programs. Control console/operation stations will be mounted inside the Space Station. These control stations will have the capability of providing the Mission Scientists with high fidelity video of the solar features being observed. In addition, digital displays will enable the Mission Scientists to observe spectrographs in the graphics mode or alpha numeric data which might include digital power readouts as well as housekeeping data on the health and well being of the scientific instruments.

The most critical interface element which must be provided is an instrument pointing system. The High-Resolution Facility Telescope Cluster, the Pinhole/Occulter Facility and the imaging components of the High-Energy Facility will acquire sub-arc sec quality images. A detailed engineering study of the requirements for pointing and stability implied by this capability is currently in progress, under the direction of the Marshall Space Flight Center. It appears likely that the standard Space Station Payload Pointing System, which will provide arc min level pointing, will be adequate as a basic interface for the ASO. The requirement for sub-arc sec stability will be met by image motion compensation within each instrument (see, for example, Illing, Zaun, and Bybee, 1988).

3.3. THE HIGH-ENERGY FACILITY INSTRUMENTS

We anticipate that the high-angular resolution hard X-ray and gamma-ray components of the High-Energy Facility will be co-mounted as a pointed assembly with the Pinhole/Occulter Facility. The spectroscopic and polarimetric components of the High-Energy Facility, which have modest pointing requirements, can be mounted on an inexpensive tracker independently of the full ASO.
4. Implementation Plan

The implementation plan for the High-Energy Facility that we propose, takes a two-pronged approach. The first part addresses the definition of the interface structures which will be required to mount the High-Energy Facility instruments to the Space Station, and provide the necessity support (power, pointing, command and telemetry interface, etc.). As we pointed out earlier, we propose to co-mount those instruments requiring fine pointing onto a Standard Space Station pointer with the Pinhole/Occluder Facility, and to mount the spectroscopic and polarimetric instruments, which have modest pointing requirements on a simple tracker. The detailed accommodation study currently under way should provide a detailed plan for this approach. The feasibility of using a co-orbiting platform will also be studied. Based on the results of this study, a proposal will be prepared in response to the anticipated NASA Space Station Announcement of Opportunity.

The second part of our strategy is to make full use of the recently announced NASA Max 91 opportunity for long-duration balloon flights (Dennis et al., 1988) to develop and utilize hard X-ray and gamma-ray imaging, spectroscopic and polarimetric instrument which can then serve as prototypes of the instruments for the Space Station High-Energy Facility. In addition, it is anticipated that the ongoing NASA Scientific Research and Technology program will provide support for the development of any new technology necessary for the High-Energy Facility instruments.

5. Conclusions

We conclude that the High-Energy Facility, as well as the other components of the Advanced Solar Observatory can be supported on the presently planned Space Station. [This approved configuration is referred to as Block I, to distinguish it from a more advanced configuration (Block II) which is expected to have expanded provisions for the accommodation of attached payloads. Block II is not presently approved or funded.] The capability to support the ASO requirements on the Block I configuration, especially the pointing requirements, should be fully documented by a detailed engineering study currently under way. We see no reason why progress on the development of the support structures needed to accommodate the High-Energy Facility (and the other ASO instruments) to the Block I Space Station, and progress on the development of the High-Energy Facility instruments (as part of both the 'Max 91 Long Duration Balloon Flight Program' and the Space Station instrument development program) cannot begin in 1989.

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References


