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I. Introduction

The definition of the NASA program to support astronomical observations from Shuttle/Spacelab is now underway and so it is appropriate to describe the steps that are being taken to insure that instruments to be used in specific scientific efforts such as a flare build-up study have flight opportunities. We should point out immediately that the shuttle program is now slated to begin its flight program with a series of orbital test flights in 1979, with operational missions starting in 1980. It is therefore unlikely that a major program of solar observations from shuttle can be expected in time to support the Solar Maximum Year observations that will start in 1979. As the Shuttle/Spacelab opportunities for solar physics develop in the ensuing years, however, we expect that many instruments will be able to contribute to the problems we have discussed at this meeting.

The development of the scientific resources of the space shuttle is in fact an international program involving NASA and ESA (the European Space Agency). NASA is providing the Space Transportation System consisting of the propulsion systems and basic orbiter spacecraft which returns to earth after its missions, now planned to be 7-30 days in duration, are completed. This orbiter provides a basic volume which is 60 ft. (18.5m) long and 15 ft. (4.6 m) in breadth in which the scientific equipment will be placed. Up to 65,000 lb. (29,000 kg.) can be launched and 32,000 lb. (14,500 kg) can be returned from orbit.

ESA, for its part has undertaken to provide the scientific support equipment, called Spacelab, which will provide the interface between the orbiter and our experiments. Spacelab itself has several major components, which include pressurized modules within which men may carry out experiments in space, unpressurized pallets for carrying unmanned instruments and related support systems. As our instruments do not require direct manipulation by man we plan to mount them on the pallets and perform all astronaut (payload specialist) control from the orbiter. By not using the spacelab module we achieve the maximum utilization of the available volume for our instruments.

In addition to the volume that is available, the Shuttle/Spacelab system has other considerable advantages. The return of the instruments gives opportunities for post-flight calibration as well as the ability to use photographic film. After refurbishment the instruments are available to be used again on subsequent missions, thus lengthening the observing interval and reducing the average cost of instrumentation per mission flown. Shuttle/Spacelab also presents us with the opportunity to use man in orbit to enhance the scientific observations and to maintain the proper operation of the instruments, if necessary. We are striving to provide experimenters with direct control over their instruments from a ground-based operations center (with due regard to considerations of safety of the astronauts and proper operation of the mission) but look forward to having the payload specialists working with the ground-based observers to achieve the maximum scientific results of which the instruments are capable.

II. Solar Observations on Early Missions of the Shuttle/Spacelab Program

To exploit fully the advantages offered by the Shuttle/Spacelab program, we must develop instruments that make best use of the size, weight and refurbishment capability that is offered. Such instruments, which will serve as facilities available to many scientists, usually have an extended period of definition, fabrication and development making it unlikely that they will be ready at the beginning of Spacelab flights. On the other hand, numerous instruments have been developed for the solar physics program, as for the ATM flight, for the OSO series of free-flying spacecraft and for rocket flights, for which back-up units exist and could be flown. Such instruments could be available for the first Spacelab missions if instrument selection and funding could begin in the coming year. The scientific basis for such reflights must be carefully developed and justified, and we foresee that the value of the observations will be much enhanced by using them in coordinated programs having a problem oriented approach. In addition, the Shuttle should provide opportunities for flying new instruments for frontier research. Such opportunities are offered by the current rocket program and we must attempt to offer similar opportunities, with a minimum of documentation and integration time, in the shuttle program.

Technical studies are now underway to evaluate the needs of instruments that will be flown on Shuttle/Spacelab. A suitable pointing system for stabilizing instruments during their observations is of foremost priority. Our goal has been to provide better stability than was achieved on ATM (that already was better than one arc second) so that upgraded ATM instruments can perform to their full capacity. Among several possible pointing systems that are being considered is a derivative of the successful pointers used on the Orbiting Solar Observations. An adaptation of this design to the shuttle is shown in Figure 1. The rectangular boxes mounted within the gimbals are in fact cannisters to provide appropriate environmental control for approximately 340 kg of scientific instrumentation carried within each cannister. Each cannister is independently pointable (within the limits of its gimbal) so that coalignment of instruments within the two cannisters for common object viewing can be achieved by supplying appropriate offset pointing signals to one unit to align it with the other. We envision a capability of carrying, within each cannister, instrumentation up to 1 meter x 1 meter in cross-section and up to 3 meters long. Thus, the largest ATM instrument can be accommodated. As the instruments are balanced at their center of mass, the system is capable of deployment and checkout on the ground prior to flight.

Figure 2 shows how a pointing control such as this would be assembled (with several instrument options shown) and integrated into the Shuttle/Spacelab. Several of such pointing controls on one mission could then be flown for concerted solar observations. One such "dedicated payload" is shown in Figure 3. This array of instruments approximates the Fine-Pointing Payload Elements listed by the Space Shuttle Payload Planning Working group in Solar Physics. It is, of course, unlikely that such a dedicated mission could be mounted in the first year of the Shuttle/Spacelab flights, but its likelihood becomes greater as more instruments are added to our "refurbished and available" inventory. Studies on several instruments have demonstrated that they could be prepared for flight on the shuttle, including limited changes to enhance significantly their scientific capabilities, for far less money than was spent in the original development of the instruments. Among the improvements that would be directly related the flare build-up studies are the incorporation of more film (in photographic instruments such as the NRL XUV Spectroheliograph or the ASE Soft X-Ray Spectrographic Telescope) to record the transient development of active regions prior to flares as well as the flare events themselves. A strong guest investigator program or allotment of observing time offered by a NASA Announcement of Opportunity are two methods being considered to broaden the scientific participation in these observations. Flight opportunities for such instruments will be offered through an Announcement of Opportunity with the selection from among competing proposals being made using established NASA procedures.

III. Development of Facilities for the Solar Physics Shuttle/Spacelab Program

The main phase of solar physics research on Shuttle/Spacelab during the decade of the 1980's centers around the use of facility instruments for multiple-user, multiple flight operations. Three facility definition teams (FDT) have been formed via NASA Announcement of Opportunity to define the large instruments that are anticipated by such study groups as the National Academy of Science Study on Scientific Uses of the Space Shuttle. These teams are the

a. One-Meter Telescope FDT (Dr. Richard Dunn, Leader)
b. EUV/XUV/Soft X-Ray FDT (Dr. George Withbroe, Leader)
c. Hard X-Ray Imaging FDT (Dr. Laurence Peterson, Leader)

In addition, a team has been formed to assure that smaller instruments designed for specific observations and other classes of instruments such as solar monitors that are not on the facility level have flight opportunities. This group is called the Quick Reaction and Special Purpose Facility Definition Team and is under the leadership of Dr. Loren Acton.

These teams are charged with providing detailed scientific justification for each facility, defining representative observing programs to allow in-depth planning of a set of flights, developing detailed technical definition of the facility and defining representative focal plane instrumentation. Each team is also responsible for estimating costs for its facility and addressing science and cost trade-offs for various design options. Interim reports of their preliminary studies have been written and are available. GSFC is now supporting the work of these teams by conducting technical studies as requested by the teams and initiating further work on subsystems that are required to carry out the observations on Shuttle/Spacelab. These studies include conceptual design studies of the instruments (telescopes and focal plane instruments), and evaluation of designs of optical components, guiders, filters, cameras, etc. in the context of the Shuttle environment.

The facilities will ultimately be extremely versatile instruments as focal plane instrumentation (probably supplied by individual or groups of investigators in response to again another Announcement of Opportunity) becomes available. Their application to studies of the flare build-up will cover a wide spectral range of flare emissions from hard X-rays to visible wavelengths, enabling use to examine the photospheric, chromospheric and coronal phenomena that may precede the actual flare event. Both thermal and non-thermal emissions will be studied, with adequate resolution in time and space to gain insight into the basic physical processes of energy storage, particle acceleration and plasma heating that occur in successive phases of the flare event. Because of the short flight times of 7-30 days we cannot expect to observe many events and must look to fre-flying spacecraft such as the Solar Maximum Mission to record an adequate number of events to test the generality of flare models.

Facilities being considered are as follows:

a. <u>A meter-class optical telescope for visible and near-UV wavelengths</u>. This telescope will have a focal length of about 30 meters and be diffraction limited within its field of view of about 4 arc min. Three operational modes for coupling to various instruments include a birefringent filter tuneable from 2750Å to 11000Å, a spectrograph, and a multiple instrument capability programmable during flight. Provision will be made for a Stokes polarimeter at the prime focus. The telescope could be mounted on the Instrument Pointing System (IPS) being developed by ESA. This instrument is suited to studies of the heating of the solar chromosphere by searching for evidence for the formation and dissipation of shock waves, by studying the turbulence spectrum of the photospheric intensity and velocity fields, and by evaluating the relationships of magnetic fields to the structure and behavior of the chromospheric network. High spatial resolution will allow detailed studies of mass transport by giving details of the features which are the source of mass injection into the transition region. In support of flare studies, it will be able to observe the configurations of magnetic fields associated with specific types of solar activity to investigate their role in energy conversion processes, it will obtain visual and ultraviolet high resolution spectra to determine the physical parameters of the initial energy release associated with flares and other impulsive events and will attempt to detect high energy particle streams through observations of impact polarization.

b. An EUV/XUV/Soft X-Ray Facility. The EUV/XUV/Soft X-Ray facility must cover a wide range of the solar spectrum, from below 2Å to 2000Å. As many as three telescopes may be required to cover this range effectively. The instruments that are being considered are a nested Wolter Type I full figure of revolution grazing incidence telescope for the 2Å to 100Å range, a Wolter Type II telescope for the 100Å to 1200Å band and a normal incidence off-axis telescope in the 400Å - 2000Å range. Each telescope would be equipped with an appropriate group of focal plane instruments such as cameras, spectroheliographs and line profile spectrometers. The facility definition team is beginning conceptual studies on these instruments and will offer recommendations on the order in which they should be constructed. By observing a number of emission lines formed over a range of electron temperature, it will be possible to map all magnetic loops that are filled with EUV, XUV or Soft X-ray emitting plasma and thereby obtain information on the configuration of the magnetic field. If there is dissipation of energy stored in the magnetic fields the energy release should produce detectable changes in the EUV, XUV and soft X-ray emissions.

c. A Hard X-Ray Imaging Facility. The Hard X-ray facility will also have several instruments. These are, tentatively,

1. A hard X-ray imaging system, which operates over the 5-100 keV range, with a resolution better than 4 arc sec FWHM, time resolution ~1 sec and a total sensitivity of 0.1 ph/cm^2-sec-keV at 20 keV.
2. A full-sun 5-600 keV spectrometer, which operates between a sensitivity of 10^{-3} ph/cm^2-sec-keV at 20 keV and the most intense bursts ($\geq$ the August 1972 flares) yet seen, with $\geq 10^{-2}$ sec time resolution and energy resolution of $\sim$ 5%.
3. A nuclear γ-ray spectrometer, which operates over the 50 keV to 10 MeV range, and which can detect continuum approximately 10^{-3} ph/cm^2-sec-MeV at 1 MeV, and lines to $\sim 10^{-3}$ ph/cm^2-sec.
4. An X-ray polarimeter covering the 5-100 keV energy range, collimated by the hard X-ray imaging system if possible. Time resolution should exceed 1 sec and sensitivity should permit observation of 5% polarization at a flux of 10 ph/cm^2-sec-keV at 20 keV.'

The high-energy observations require that observing periods coincide with flare activity. This implies rapid response ($\leq$ 1 week lead time) to the presence of activity at the East limb, and extended flight lifetimes. The primary goal of the hard X-ray observations is to determine the mechanisms which accelerate electrons and protons to non-thermal energies during solar flares. The energy spectrum of accelerated particles is most directly obtained from hard X-ray and γ-ray emission spectrum produced when these particles collide with the ambient medium. Objectives of high energy observations which combine high spatial spectral and temporal resolution will be to determine the location of particle acceleration during the flash phase and during subsequent acceleration to MeV and even GeV particle energies, to establish the conditions under which the acceleration mechanisms operate and to investigate the physics of energetic particle storage in the corona.

The facilities would require a pointing control for several thousands of kilograms of instruments. The Instrument Pointing System (IPS) being studied by ESA offers a method of pointing these instruments on Shuttle/Spacelab. IPS being used with a large instrument is shown in a conceptual drawing in Figure 4.

The development of facilities is a long-range program leading to the Solar Telescope Cluster envisioned by the National Academy of Sciences Study mentioned earlier. For the coming solar maximum we look forward to the Solar Maximum Mission (which can be retrieved from its orbit by the Shuttle), supplemented by shorter flights of the Shuttle/Spacelab system as it becomes available. One shuttle instrument package being considered by the Quick Reaction and Special Purpose Facility Definition Team that would be useful in flare build-up studies is a Solar Monitor package to support non-facility instruments. This package would contain a full-disk H-alpha camera and filter magnetograph, soft and hard X-ray monitors and, perhaps, a full-disk XUV telescope. Thus, it would complement the instruments now being considered for the Solar Maximum Mission free-flier. Finally, hard X-ray, γ ray and neutron spectrometers too large and heavy to be considered for the Solar Maximum Mission may find flight opportunities on Shuttle during the period of SMM operations.

IV. Conclusion

The Shuttle/Spacelab program offers an exciting and substantial opportunity for flight of sophisticated instruments for solar research in the 1980's. Problem-oriented missions composed of a number of instruments will be possible as well as flight opportunities for individual instruments developed quickly in response to new knowledge gained from earlier flights. The international scientific community has been asked to participate in defining new facility instruments that are needed. Announcements of Opportunities to participate in the development and use of these instruments will be made by NASA at the appropriate times.

FIGURE CAPTIONS

Figure 1. A Small Instrument Pointing System (SIPS) for Shuttle Sortie Missions. The two independently pointable cannisters of instruments are shown in the orientation they would have during launch or landing of the Shuttle/Spacelab.

Figure 2. Illustration showing ways in which a small instrument pointing system can be used to accommodate either a cluster of instruments originally designed for rocket launch, one larger instrument such as was flown on ATM, or a side-looking instrument. The modular concept of a cannister surrounding the instrument to provide environmental protection and a gimbal frame to support the instrument at its center of mass permits rapid integration on to the pallet-mounted pointing system, thereby minimizing integration time.

Figure 3. A hypothetical dedicated solar physics payload using several small instrument pointing systems. The instruments shown are derived from earlier rocket, OSO-class and ATM instrumentation and represent only a typical payload used to evaluate Shuttle/Spacelab support systems and interfaces that would be required.

Figure 4. Conceptual design of the Instrument Pointing System (IPS) being designed by the European Space Agency (ESA). A facility-class instrument is shown end-mounted on this pointing system.

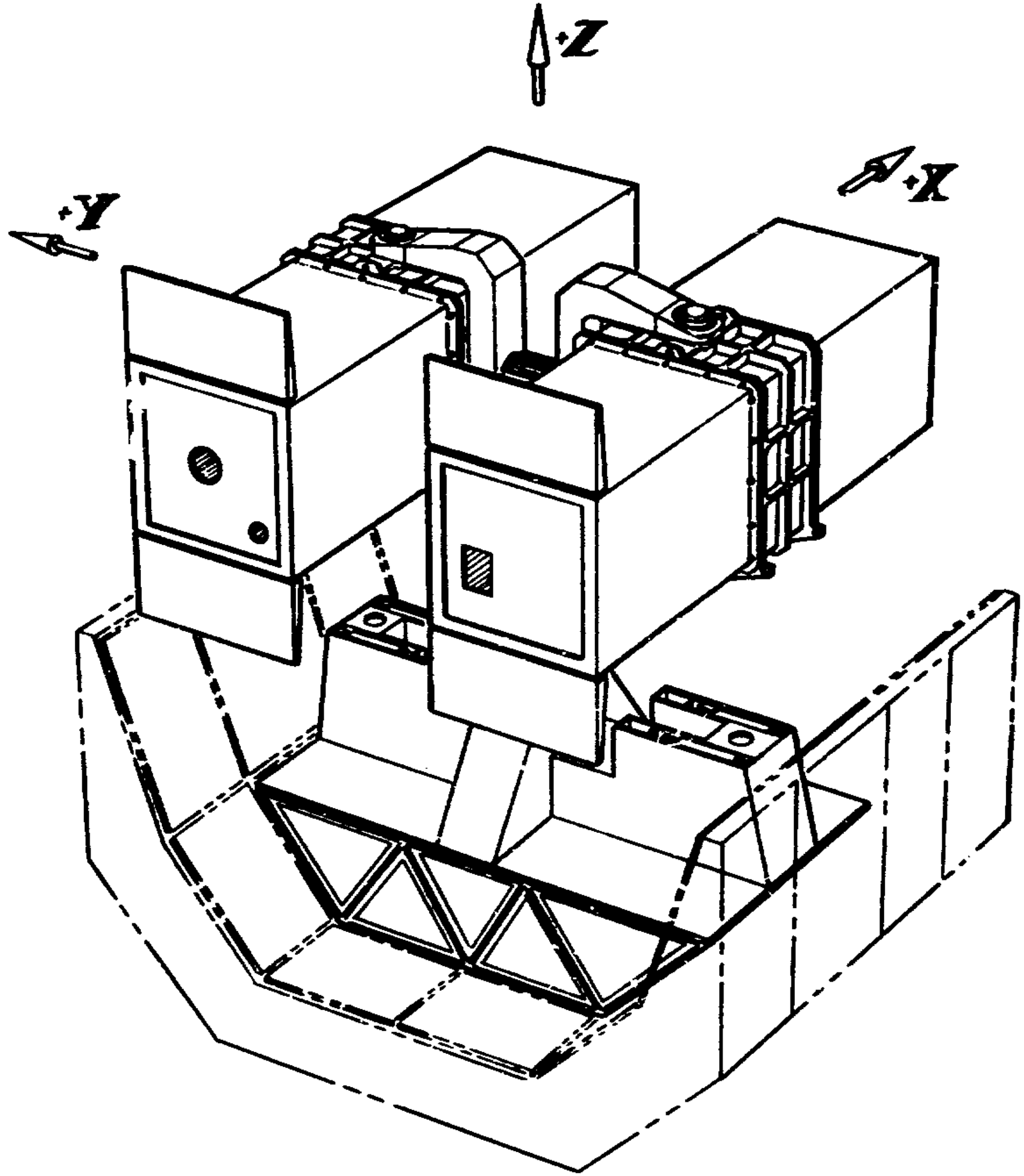

FIGURE 1

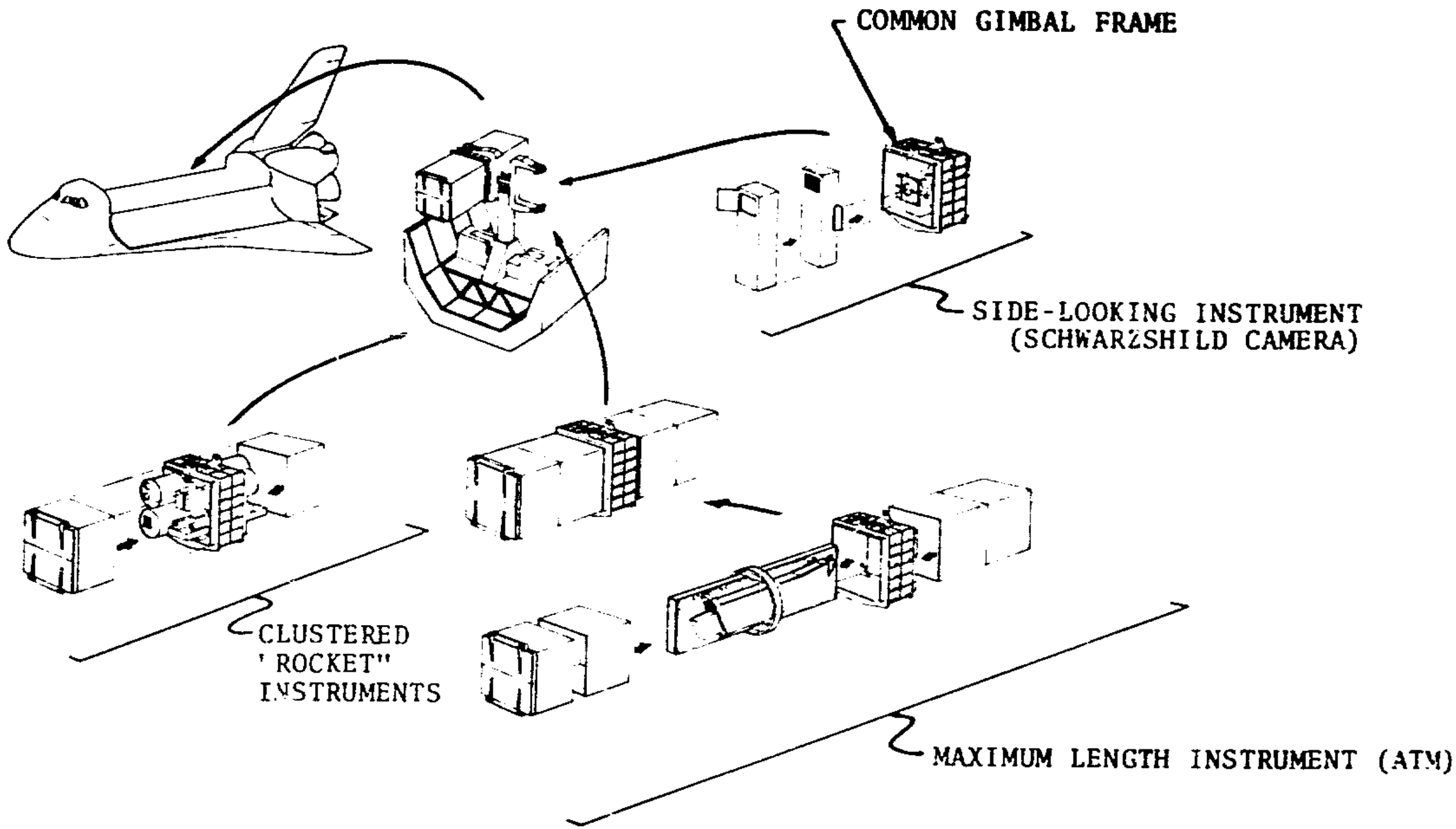
COMMON GIMBAL FRAME
SIDE-LOOKING INSTRUMENT
(SCHWARZSHILD CAMERA)
CLUSTERED
"ROCKET"
INSTRUMENTS
MAXIMUM LENGTH INSTRUMENT (ATM)

FIGURE 2

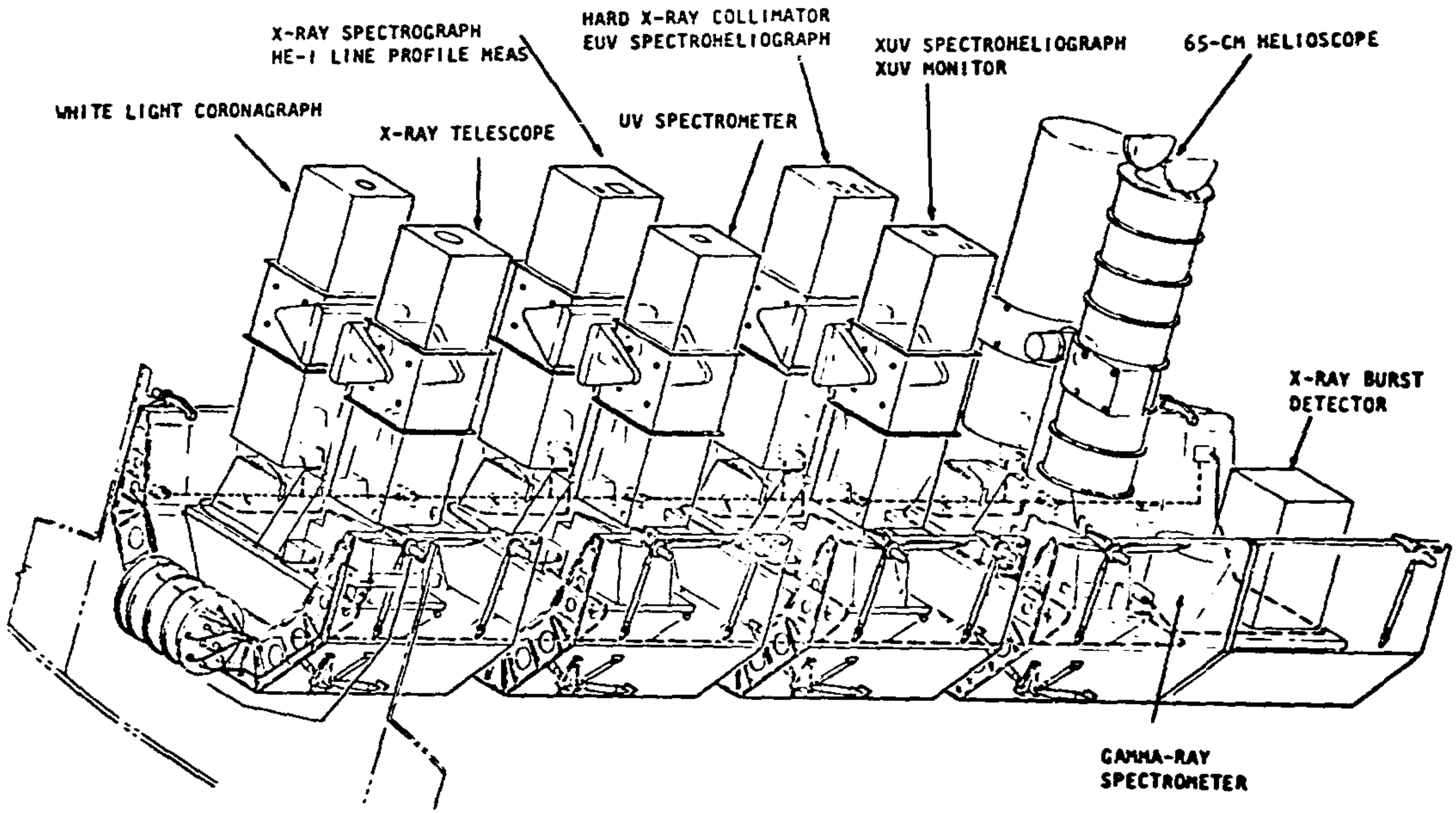
X-RAY SPECTROGRAPH
HE-I LINE PROFILE MEAS
HARD X-RAY COLLIMATOR
EUV SPECTROHELIOGRAPH
XUV SPECTROHELIOGRAPH
XUV MONITOR
65-CM HELIOSCOPE
WHITE LIGHT CORONAGRAPH
X-RAY TELESCOPE
UV SPECTROMETER
X-RAY BURST
DETECTOR
GAMMA-RAY
SPECTROMETER

FIGURE 3

INSTRUMENT POINTING SUBSYSTEM

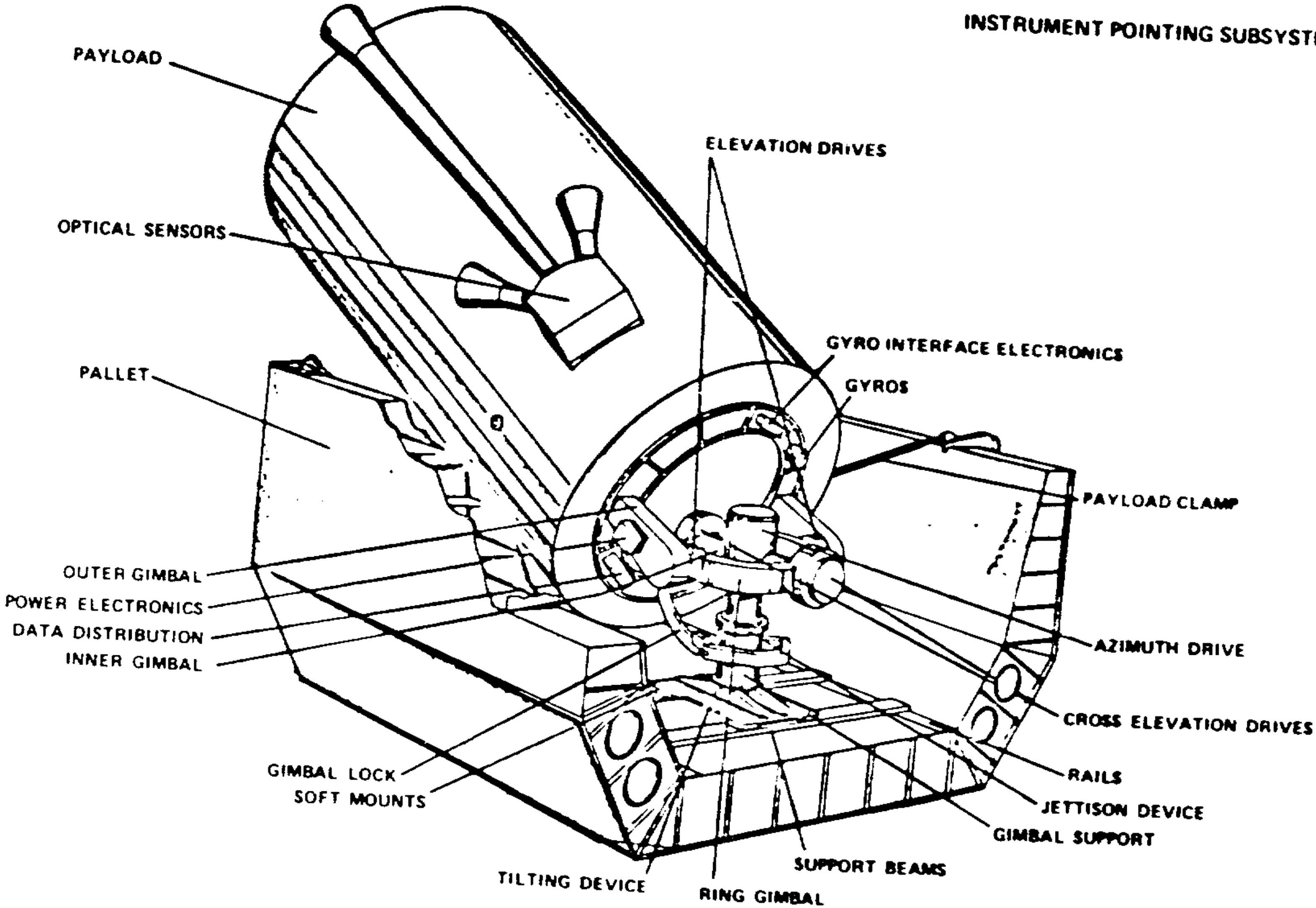

FIGURE 4