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La Jolla, California

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NGL 05-005-003 FINAL REPORT ✓

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NGL-05-005-003 FINAL REPORT

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I. Introduction and Summary

This report describes the technical activities, scientific results, related space hardware projects and personnel supported under NASA grant NGL-05-005-003 which was administered by the High Energy Astrophysics Program Office of the Office of Space Science. The funding period for this grant spans virtually the entire history of space science under NASA, commencing in 1962 and finally lapsing in 1982. During this period a wide variety of research topics were pursued by Principal Investigator Laurence E. Peterson; however, the emphasis has been on development of observational and instrumental techniques in hard X-ray (0.001 to 100 keV) and medium energy gamma-ray (0.1 to 10 MeV) astronomy. Many of these techniques were developed explicitly for use on high altitude balloons where most of the scientific results, listed in Appendix A, were obtained. Appendix B tabulates the extensive observational activity using balloons which was conducted under this grant. In addition to balloon observations, this grant supported the longer term goals of NASA via adaptation of techniques to dedicated space missions. Virtually every research activity discussed below has resulted in, or will eventually result in, a major space hardware development effort as described below under "related programs". Finally, in Section IV - Personnel, we indicate the important impact this grant has had in the training of new researchers. It is remarkable to note that all of the graduate students supported under this grant remain active in space science.

II. Technical Activities and Scientific Results

A. The Early Years

During this period, extending from 1963 (the inception of the UCSD X-ray and γ -ray group) through roughly the end of the decade, a variety of research topics and instrumental techniques were developed. Scientific goals included pioneering observations of the stronger discrete sources, the sun and solar system, and the diffuse γ -ray emission as well as measurements of atmospheric and lunar secondary gamma-ray emission. These objectives were pursued through a variety of instrumental approaches including passively and actively shielded scintillation counters, active collimators, solid state detectors (discussed in more detail in subsection C below) and Compton telescopes. Many of these initial developments formed the basis for future NASA space missions (see § III). Observations and measurements were obtained through intensive ballooning activity, amounting to some 44 flights in a period of six years.

The UCSD X-ray and γ -ray group was founded in 1963 when Laurence E. Peterson, a recent Ph.D. recipient of the University of Minnesota, was appointed to the faculty of the University of California. This also marked the beginning of the subject grant of this report. Initial activities were focused on analysis and reduction of data from the S-16 satellite (later designated Orbiting Solar Observatory 1, or OSO 1) which was launched when Professor Peterson was still at Minnesota.

This OSO 1 carried two experiments for the Minnesota group, a passively collimated hard X-ray scintillation counter telescope and a higher energy range simple Compton telescope. These instruments, shown in Figure 1, were not

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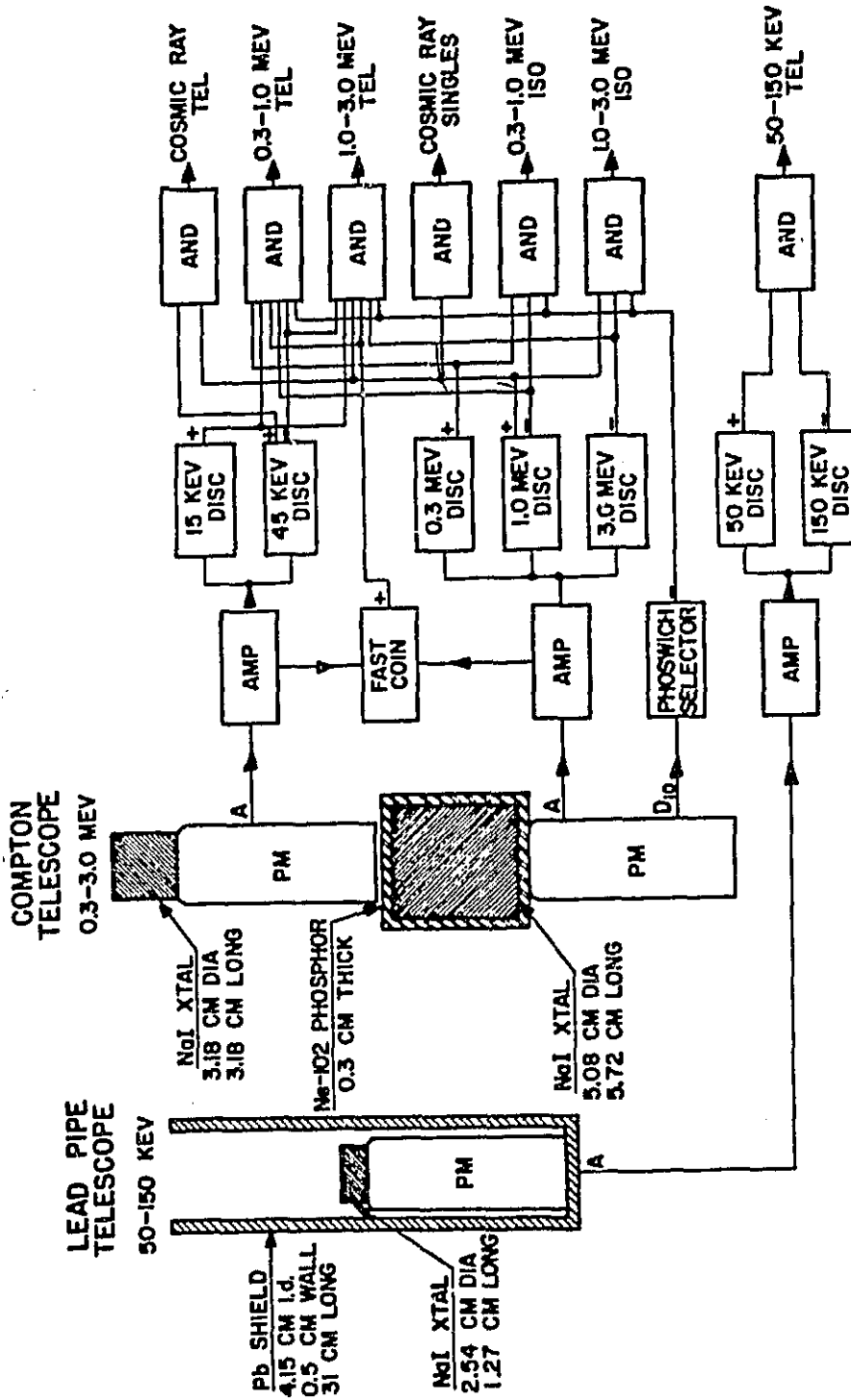


FIGURE 1 - OSO-1 Detectors - The first Orbiting Solar Observatory carried a passively shielded hard X-ray detector having 5 cm² collecting area and a rudimentary Compton Telescope. These instruments did not provide useful astronomical data due to secondary background problems which were subsequently resolved through development activity supported by this grant.

scientifically productive, mostly because of secondary background effects which were poorly understood at the time of the hardware design. This secondary background problem was studied under support of this grant and solved via the introduction of active shielding techniques. The culmination of this activity was the "S-57" (later designated OSO 3) detector, shown in Figure 2, which incorporated the first active anti-coincidence CsI shield in an astronomical instrument. The first UCSD pointing control gondola, shown in Figure 3, was also developed at this time. Detailed study and evaluation of this instrument was conducted under this grant, resulting in pioneering observations of many cosmic X-ray sources including the Crab Nebula, Sco X-1, and Cygnus X-1. In addition, observations of the quiet sun were obtained from balloons to complement the wealth of new solar flare data obtained from OSO 3. The OSO 3 detector development was closely followed by extensive studies of instrumentation for MeV range γ -ray observations (discussed in subsection E). This necessitated the development of a large NaI anticoincidence well, able to shield a 4 inch diameter detector. A logical extension of this work was to utilize the large anticoincidence well to shield a larger area low energy detector. Collimation was accomplished through use of the first "honeycomb drilled collimator", which was fabricated from active anticoincidence CsI material. The overall instrument had an effective area of $\sim 40 \text{ cm}^2$ viewing a $\sim 12^\circ$ FWHM field of view. A new larger servo gondola, designated Servo 2 and shown in Figure 4, was developed to support the larger detector system. Developments in this general area eventually led to: 1) the honeycomb and large area phoswich systems discussed in subsection D below, and 2) the OSO 7 solar and cosmic instrument developments (discussed in § III).

Other, less extensive, activities conducted in this period included in

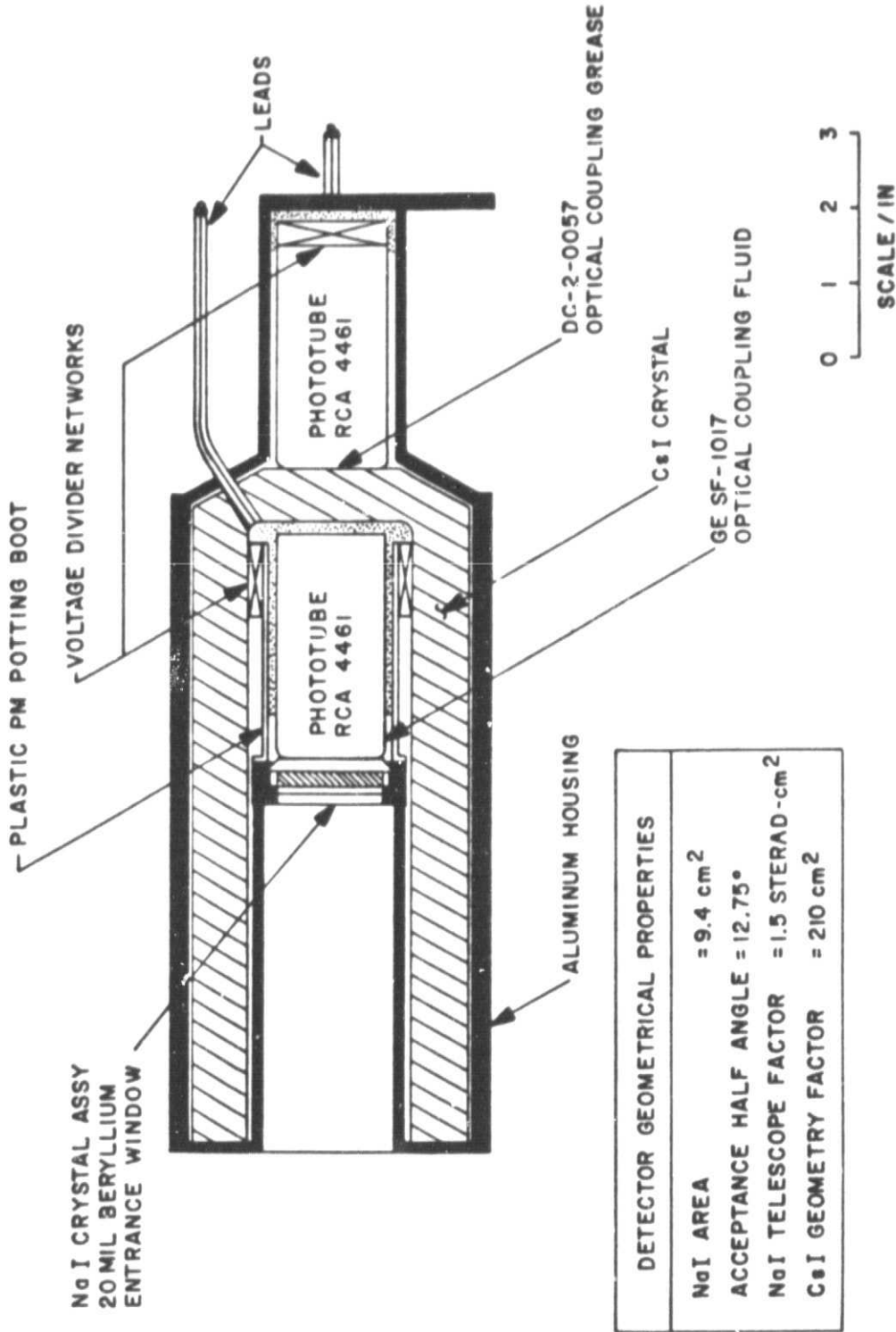


FIGURE 2 - The OSO-3 High Energy X-Ray Telescope - This actively shielded detector system provided systematic monitoring of solar flare activity and measured the spectra and variability of many cosmic X-ray sources. It also accomplished the first definitive measurement of the isotropy of the diffuse X-ray background.

FIGURE 2

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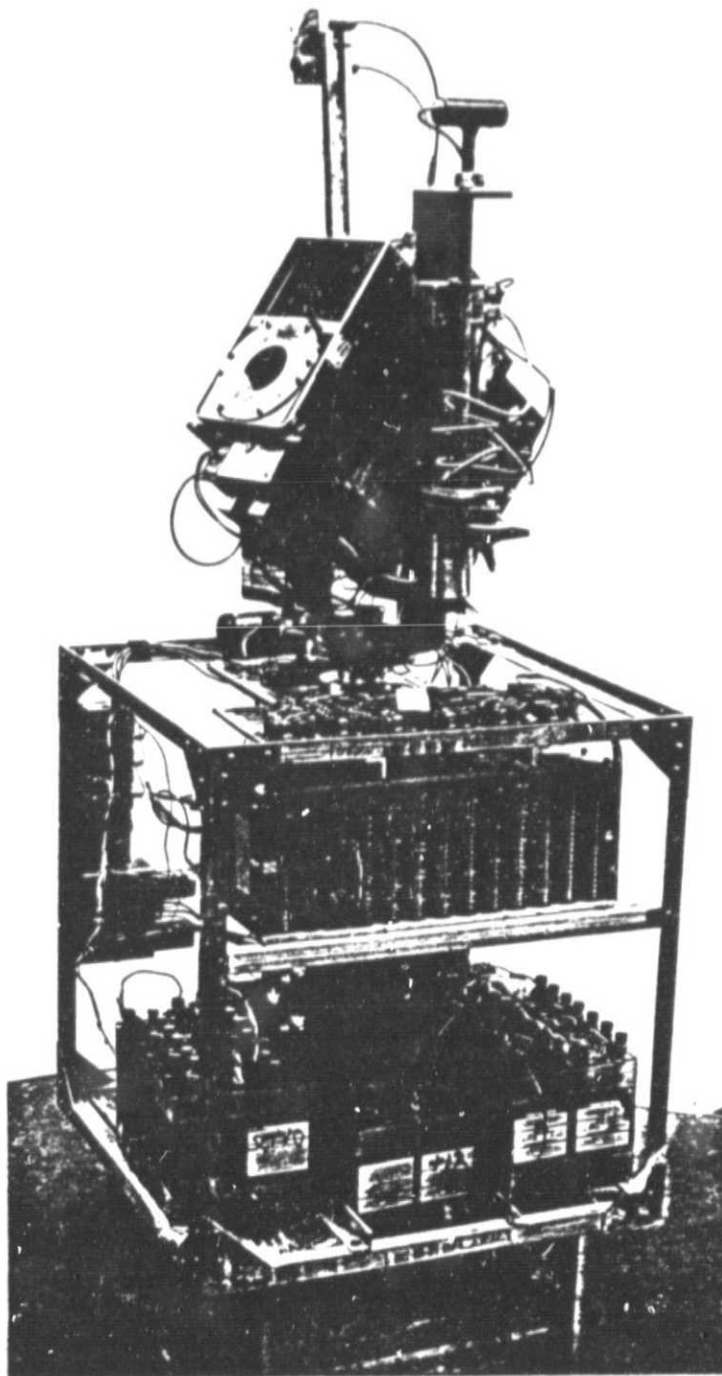


FIGURE 3 - Servo 1 - This balloon gondola carried the OSO-3 flight spare instrument, and provided azimuthal stabilization with 1.0 degree accuracy. The detector was fixed in elevation at the value anticipated for the local transit of the object source. The observation was then accomplished by holding the azimuth due north or south while the object transited the aperture of the telescope. The total weight of this system was roughly 200 lbs.

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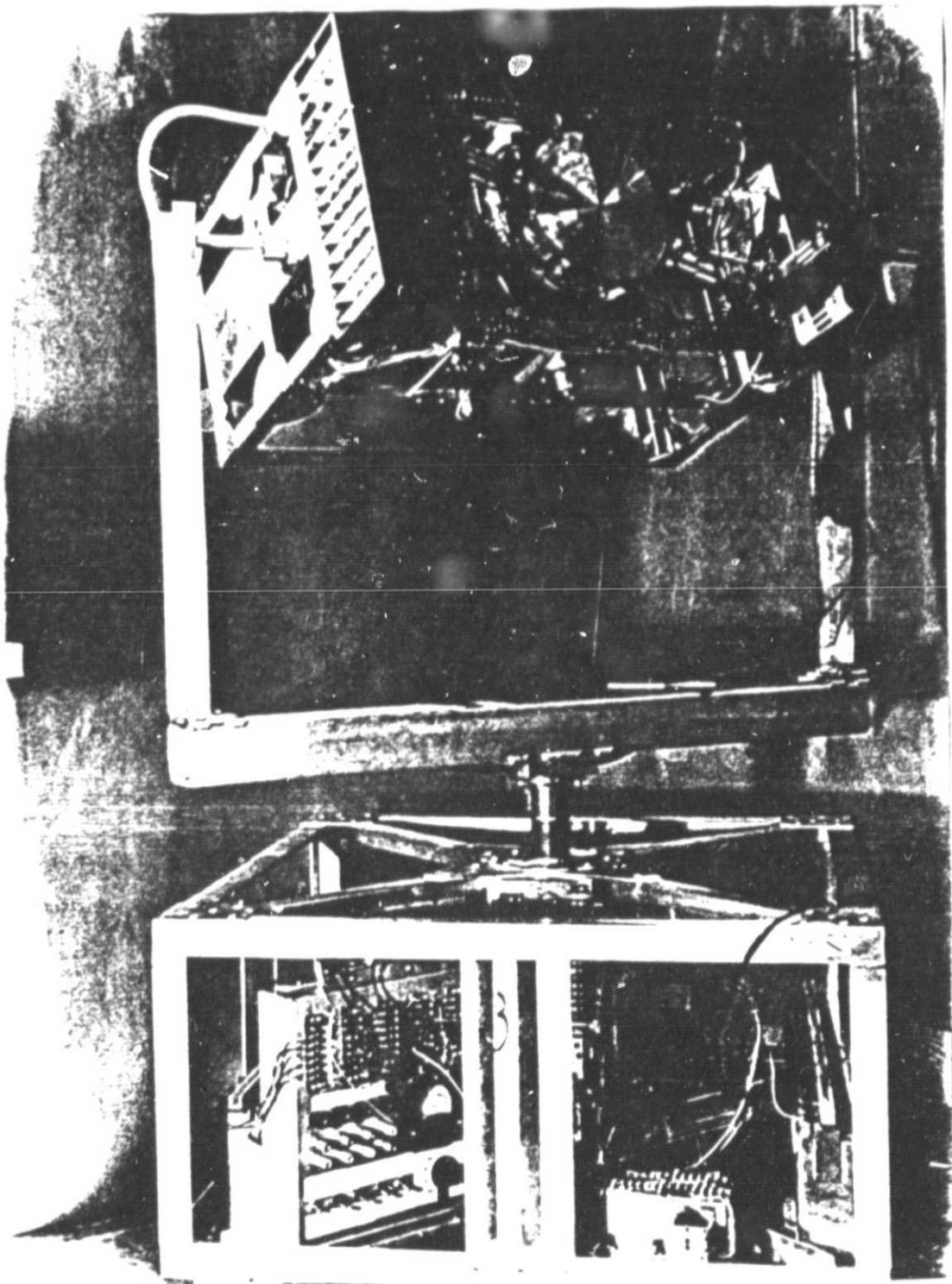


FIGURE 4 - Servo 2 - This gondola was designed to support observations using the honeycomb collimated detector having 40 cm² effective area. This system provided 2 axis pointing by commanding the elevation and azimuth servos to drive to a series of pre-programmed positions. Observations of a given source could thus be extended to several aperture transits permitting relatively long observation times with narrower field of view collimators.

situ measurements of cosmic-ray induced effects in photomultipliers, secondary gamma-ray production in passive materials and alternative shield configurations (discussed in subsection E below), and a study of a hard X-ray and γ -ray explorer concept using techniques developed in this grant.

B. Infrared Instrumentation and Observations

In addition to on-going support for the program of observational X-ray and γ -ray astronomy, this grant provided funding to initiate a program for instrumentation development and observations in infrared astronomy. This program commenced with the appointment to the UCSD research staff of F. Gillett and W. Stein from the University of Minnesota and Princeton University, respectively. The goal of the infrared program was to develop detector and supporting instrumentation for observations of the $12.8 \mu \text{ Ne}^+$ line from ground based and eventually balloon-borne apparatus. Due to rapid developments in this embryonic branch of astronomy, this somewhat specific objective was soon broadened to cover the more general 2.8 to 15μ wavelength range. Early observational accomplishments included detection of an infrared excess from the planetary nebula NGC 7027, detection of $12.8 \mu \text{ Ne}^+$ from IC418, measurements of the infrared spectrum of several stars at $\delta\lambda/\lambda = .02$, detection of an H_2O vapor absorption feature in the infrared spectrum of NML Cygnus, and observation of the 2.8- 14μ spectra of Jupiter and Venus and interpretation in terms of their atmospheric constituents. These successes led to more ambitious plans for construction of a dedicated ground based infrared telescope facility. This was jointly proposed in 1968 by the UCSD and University of Minnesota groups for NSF funding. Funding was granted and the new facility was completed for observations in late 1970. Although the early goals of this research effort included adapting

the new infrared techniques to balloon and space based platforms, the high rate of scientific return from ground based observations combined with the limitations of level funding necessitated a decision to concentrate on ground-based observations.

Support for infrared astronomy continued under this grant through 1972 at which time these activities became separately funded. Ground based infrared astronomy has continued and grown at UCSD and now constitutes one of the four principle research areas pursued within the Center for Astrophysics and Space Physics.

C. GeLi Detector Development

The application of solid state detector techniques to astronomical observations was pioneered through activity under the supervision of A. Jacobson. The objective of this activity was to directly confirm the presence of the products of nucleosynthesis in a supernova remnant by observation of their characteristic γ -ray lines. To accomplish this a Lithium drifted Germanium (GeLi) detector was adapted to space operation by enclosing it in an active CSI shield, interfacing it to a "high resolution" 256 channel pulse height analyzer and integrating it into the original UCSD servo gondola.

Figure 5 shows the detector and shield system. The 9 cm^2 planar germanium detector, which attained a nominal energy resolution of $\sim 4 \text{ keV}$, was developed by Princeton Gamma-Tech. The anticoincidence shield was economically implemented by utilizing an OSO flight spare shield for the forward collimating element in conjunction with a custom fabricated rear shield segment. The detector was interrogated by adapting the newly developed data system (developed for the

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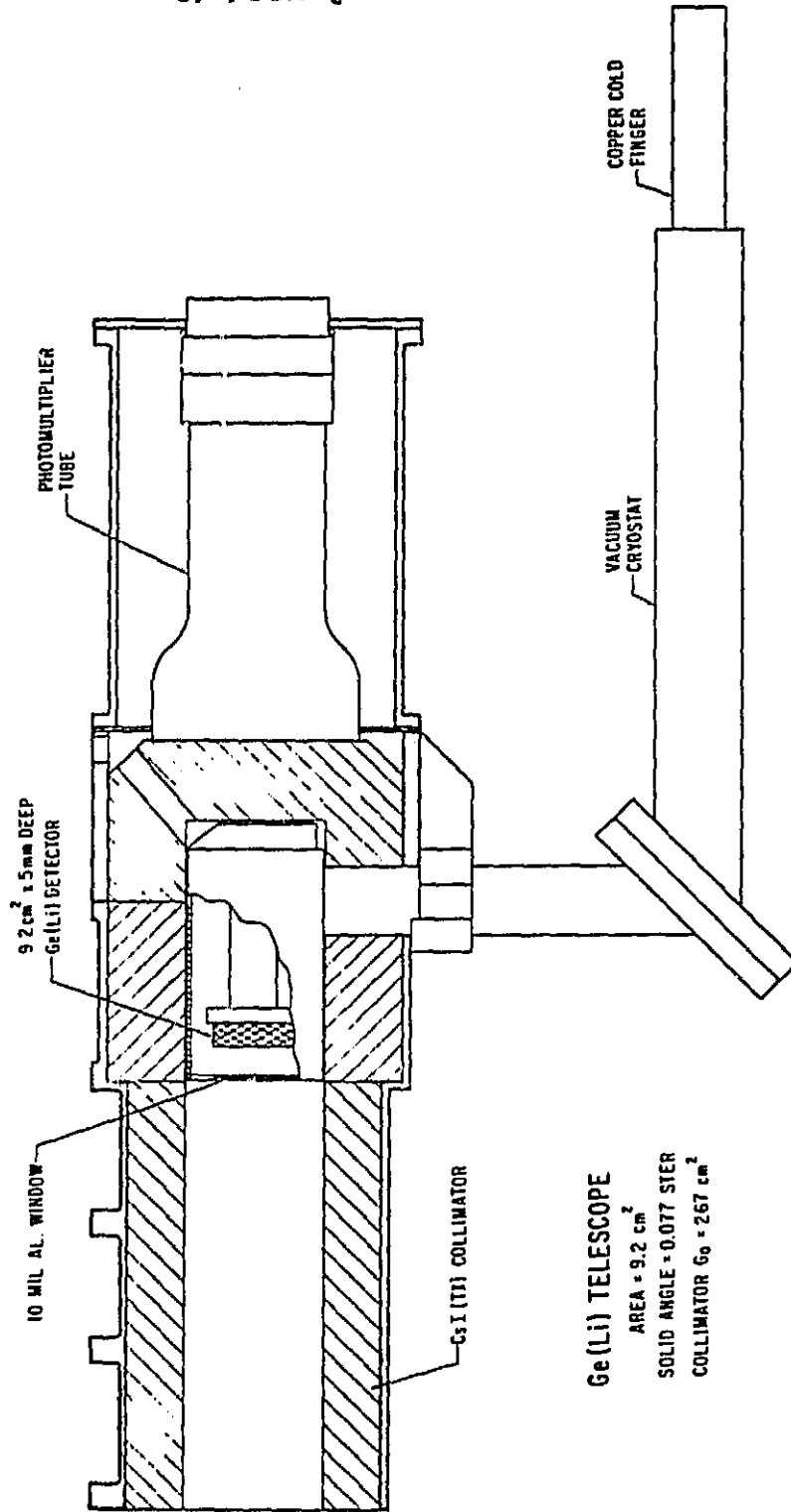


FIGURE 5 - The GeLi X-Ray Telescope - This was the first solid state detector to be used for observations of cosmic sources. The germanium crystal had about 9 cm² effective area and was shielded by a cesium iodide cup which was conceptually similar to the OSO-3 shield (see Figure 2).

shielded scintillation counter telescope) to it. The complete telescope assembly was then installed in the UCSD pointing control gondola, as shown in Figure 6. After two balloon failures the system was flown successfully in a 23 July 1967 flight to observe the Crab Nebula. The detector and balloon systems performed nominally yielding several hours of background and source data. No gamma-ray line emissions were observed within an upper limit of $\sim 10^{-3}$ ($\text{cm}^2\text{-s}$) $^{-1}$. It is interesting to note that with the exception of two unconfirmed reports of variable line emission at 73 and 440 keV, line emission has not yet been observed from the Crab even within limits an order of magnitude lower. The techniques developed in this system are still used today. Solid state detector technology has improved, with individual crystals now available in volumes of 10 times that flown in this system, and with several extensive arrays of such large detectors currently under development. Thus, in a sense, this development set the stage for high resolution γ -ray astronomy, which is now the prime activity of the UCSD balloon group (see § III).

D. Phoswich Detector Development

This was an on-going activity in support of early pioneering hard X-ray photometric observations, HEAO detector development, the US/Japan program to image the Crab Nebula, and most recently, detector development in support of the X-ray Timing Explorer (XTE) program. The first UCSD phoswich detector was an evolutionary step taken to improve the background characteristics of the earlier simple shielded scintillation detectors. The original example of a simple shielded detector was the OSO 3 system (see subsection A) which comprised 10 cm^2 active area in a unit weighing ~ 20 kg. The first variation of the OSO 3 concept was the "Honeycomb" detector which had 80 cm^2 gross collecting area. The

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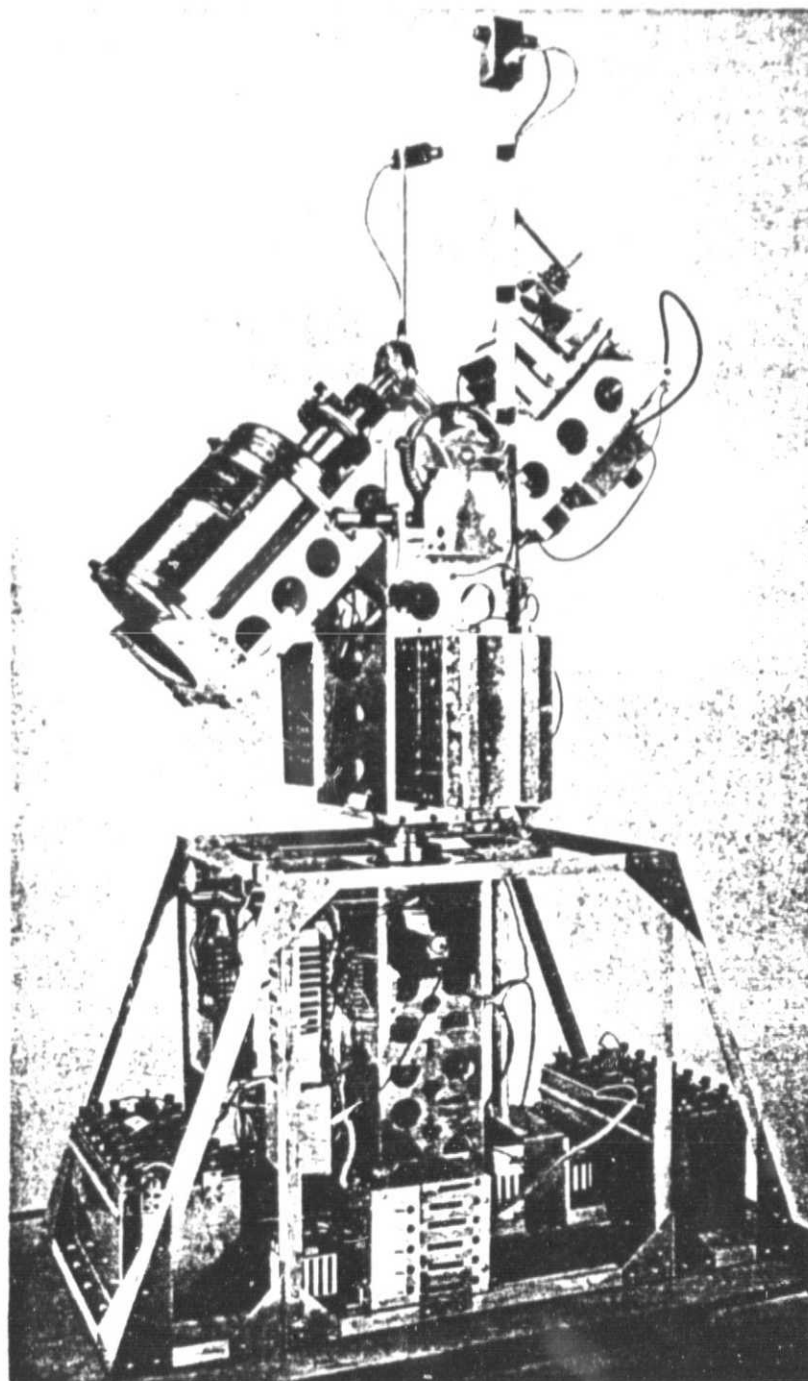


FIGURE 6 - The Complete GeLi Flight System - The GeLi telescope was integrated with the Servo I gondola (see Figure 3). The system was updated to provide pre-programmable azimuth and elevation positioning.

detector was shielded by a NaI cup and a 50% area efficient drilled CsI honeycomb collimator having a field of view of $\sim 12^\circ$ FWHM. This $\sim 40 \text{ cm}^2$ effective area system weighed roughly 50 kg. The phoswich shielding concept was introduced to reduce the overall bulk of the shielding by interposing the rear shield element between the photomultiplier and the primary detector element. Discrimination of shield energy losses from the primary detector energy losses was accomplished by using pulse shape analysis techniques. A further advantage of this detector configuration was that passive matter in the immediate vicinity of the primary detector was minimized which reduced particle induced secondary γ -ray background effects in the system. The "Honeycomb Phoswich Detector", shown in Figure 7, also included a second collimator segment to further restrict the field of view to $\sim 5.9^\circ$ FWHM. This detector is described in detail by Matteson et al. (1978), who also analyze its background characteristics. Overall, the system comprised $\sim 40 \text{ cm}^2$ effective area with a weight of $\sim 40 \text{ kg}$.

As a parallel development, the servo gondola system was modified to support balloon observations using the Honeycomb Phoswich Detector. This gondola, shown in Figure 8, provided $\sim 15 \text{ min}$ pointing accuracy using a modified equatorial mount and ground command control. This system was used by several graduate students to obtain data on Sco X-1, the Crab Nebula, and the Cygnus complex of hard X-ray sources.

The concepts developed for this system provided the basis for the UCSD/MIT instrument on the first High Energy Astronomical Observatory, HEAO 1. The phoswich concept was also utilized in the development of a Medium Energy γ -Ray Detector used for balloon observations (see subsection E).

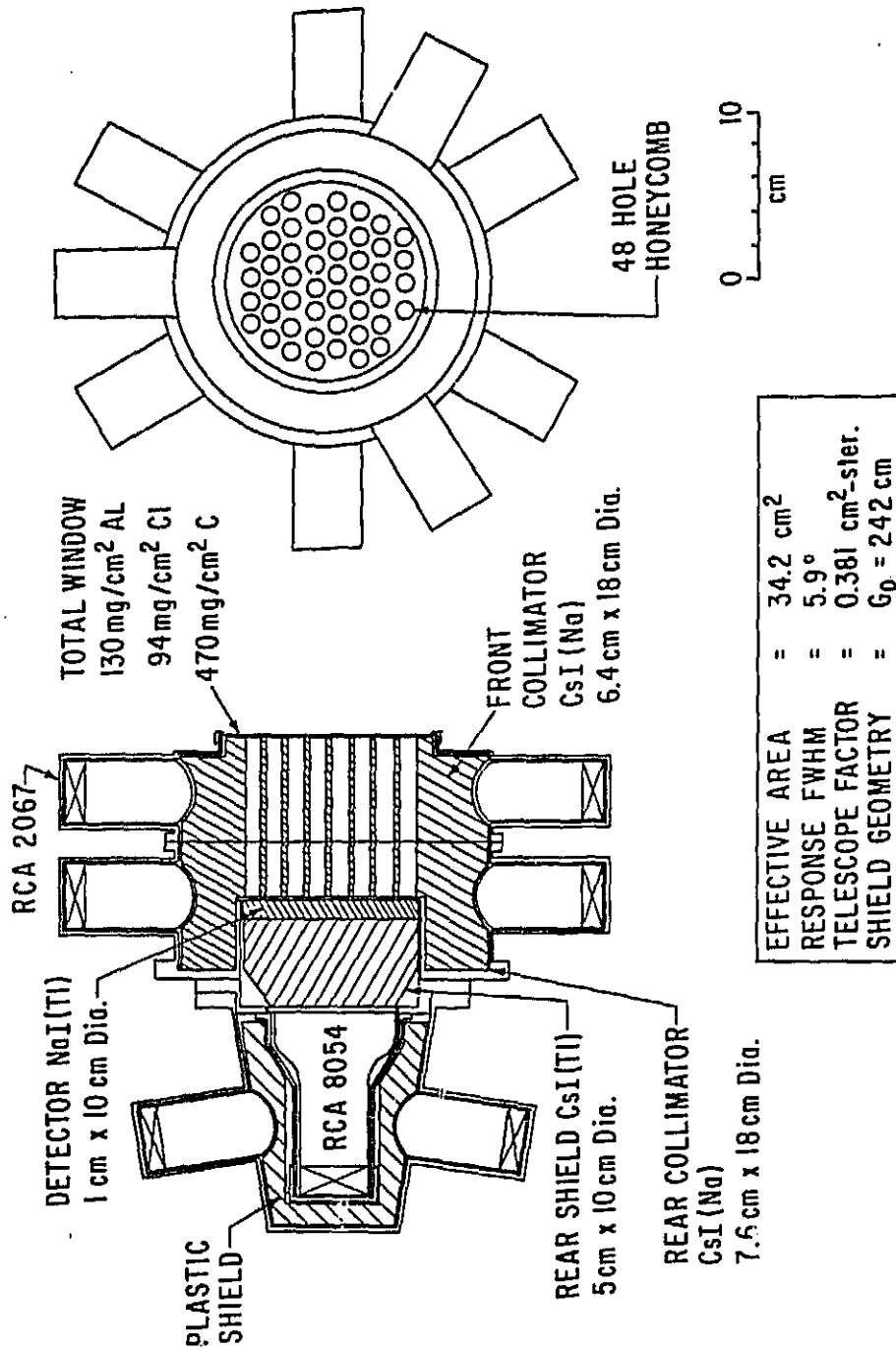


FIGURE 7 - The Honeycomb Phoswich Detector - This was the first UCSB phoswich detector system. The system used a drilled cesium iodide active anticoincidence collimator with multiple photomultipliers operating in a coincidence mode to attain a very low shield threshold. The detector also had a plastic scintillator particle shield to eliminate direct particle effects in the photomultiplier. Although this concept attained very low background, its complexity limited its potential for expansion to larger areas, thus, a new concept the Large Area Phoswich was developed (see text).

FIGURE 7

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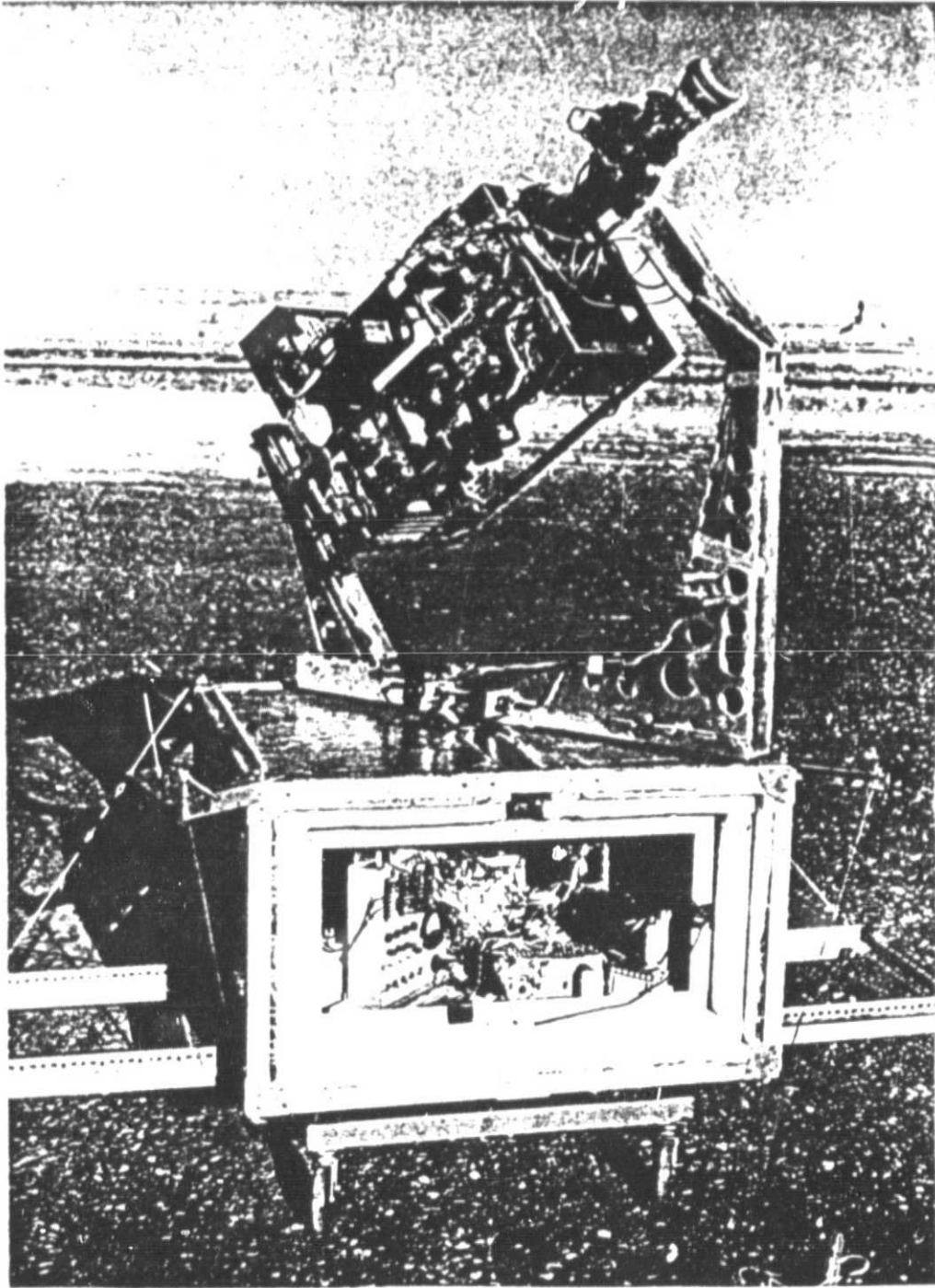


FIGURE 8 - Servo 2' - This modification of the original Servo 2 gondola incorporated an equatorial mount to provide continuous tracking of object sources and thus attain longer exposure times and higher sensitivity. The gondola used a polaris star tracker to provide real-time confirmation of its .3 degree pointing accuracy. The overall system weighing some 600 lbs represented the final evolutionary stage for this gondola concept. Subsequent developments, involving much larger detector systems, would require a new approach.

These systems, although quite successful, were not amenable to expansion to the larger collecting areas required for continued sensitivity improvement. To address this, a simplified version of the original design, the Large Area Phoswich, was developed. This modification of the original phoswich substituted graded Z passive material for the honeycomb collimator and the lateral shield elements. This configuration allowed larger gross collecting area with area efficiency in the 90% range. Although a higher absolute background would result from using passive shield elements, the higher area efficiency would result in an approximately equivalent background per unit effective area. The first version of this detector, shown in Figure 9, had 450 cm² effective area with a weight of ~40 kg. This unit (designated Large Area Phoswich 1 or LAP1), was used as a major component of the US/Japan collaborative system for imaging observations of the Crab Nebula (see subsection G) and by W. Paciesas for observations of discrete sources leading to his Ph.D. dissertation.

LAP1 was well suited for photometric type observations as required by our program to image the Crab. The design was, however, deficient for our longer term objectives involving moderate energy resolution observations in a space mission. To address this, a second version of the Large Area Phoswich, LAP2, was built having less collecting area (300 cm² vs 500 cm² for LAP1). This detector incorporated a thick quartz light guide for uniform light collection and a "standard" NaI/CsI configuration (cf. the CsI/NaI configuration of LAP1) to provide a lower noise threshold and optimum energy resolution. This unit was flown as part of the UCSD/UCB collaborative payload for spectroscopy and photometry of solar and cosmic sources (see subsection G). The anticipated performance increment was attained, however, at the expense of necessitating a somewhat more complex pulse shape discrimination technique for elimination of

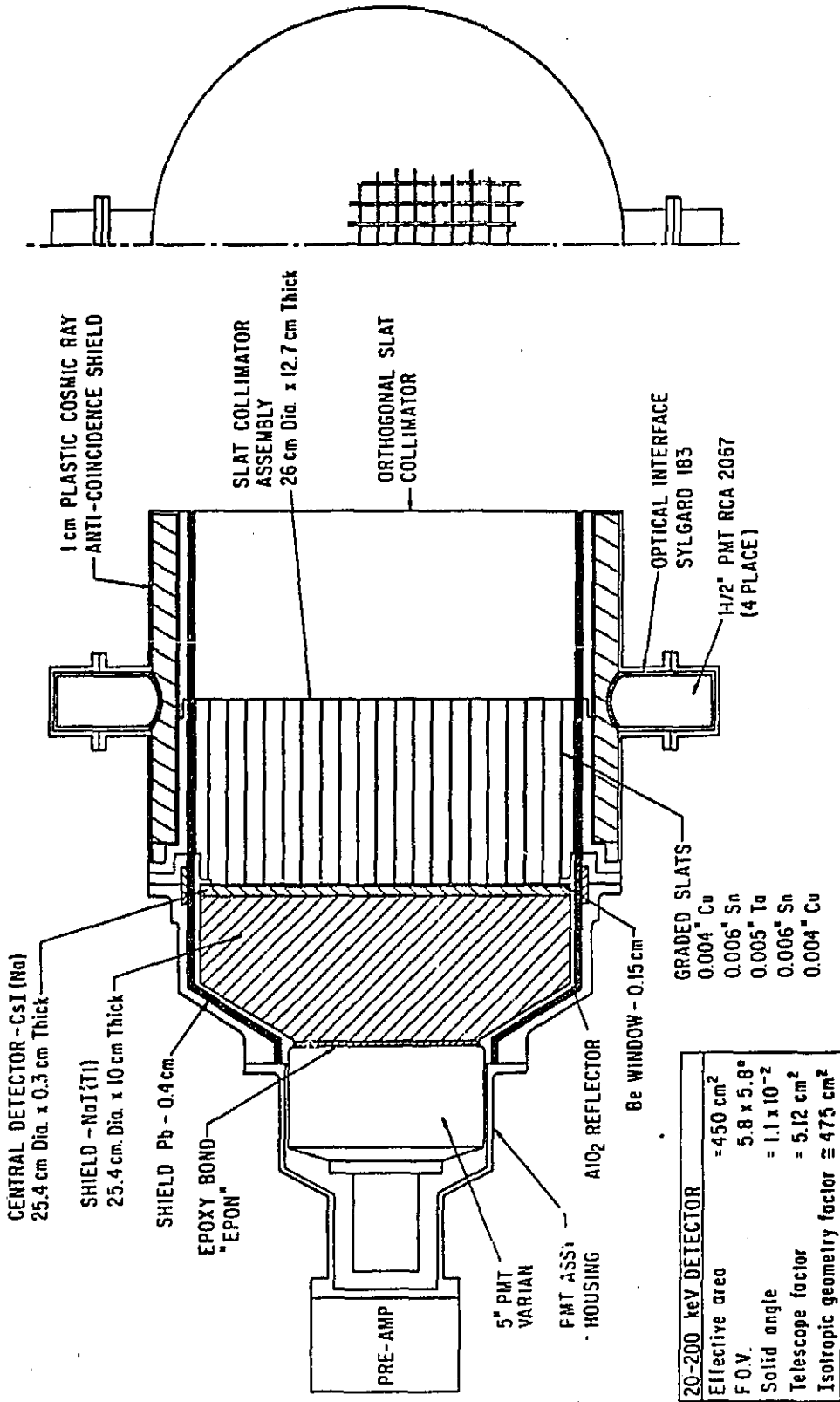


FIGURE 9 - The Large Area Phoswich - This 500 cm² detector represented a radical departure from previous phoswich concepts. The system used a series of passive slat collimators and thin lead cladding to provide anticoincidence shield to reduce secondary background effects generated in the collimator, a concept which was found to be only marginally effective. The primary problem in this detector was marginal light collection at low energies which compromised the pulse shape discrimination system. A subsequent version of this detector would be reduced in area to provide better performance.

Cerenkov events in the quartz light guide.

These experiences have culminated in a third phoswich design which was successfully proposed for inclusion in the pending X-ray Timing Explorer mission (see § III). This design is also incorporated in the photometer section of the UCSD/UCB Long Duration Balloon Payload.

The design concepts for phoswich detectors developed under this grant have also been incorporated in the UCSD/MIT instrument flown on the first High Energy Astronomical Observatory, HEAO 1 (see § III). In addition, many scientific groups throughout the world presently use the design principles developed under this grant. Large balloon-borne phoswich arrays have been built and flown by the groups at MIT, Max Planck, Tubingen, and TIFR, Tata India.

E. Medium Energy γ -Ray Detector Development

This activity encompassed a variety of specific objectives which bear on a common theme - the understanding of 0.1 to 10 MeV gamma-ray background mechanisms and development of techniques toward mitigation of these background effects. Specific objectives include 1) study of the atmospheric secondary gamma-ray spectrum, 2) investigation of various shielding techniques, 3) measurement of secondary background production in a variety of materials, and 4) observation of possible MeV range extra-terrestrial gamma-ray sources. These objectives were pursued through intensive balloon experimentation totaling more than 20 flights in about eight years.

Initial studies of the properties of atmospheric γ -rays were conducted using a simple 3" x 3" Na I scintillation counter (Figure 11) which was enclosed in an anticoincidence shield for rejection of direct cosmic ray interactions.

MEDIUM ENERGY γ -RAY DETECTOR

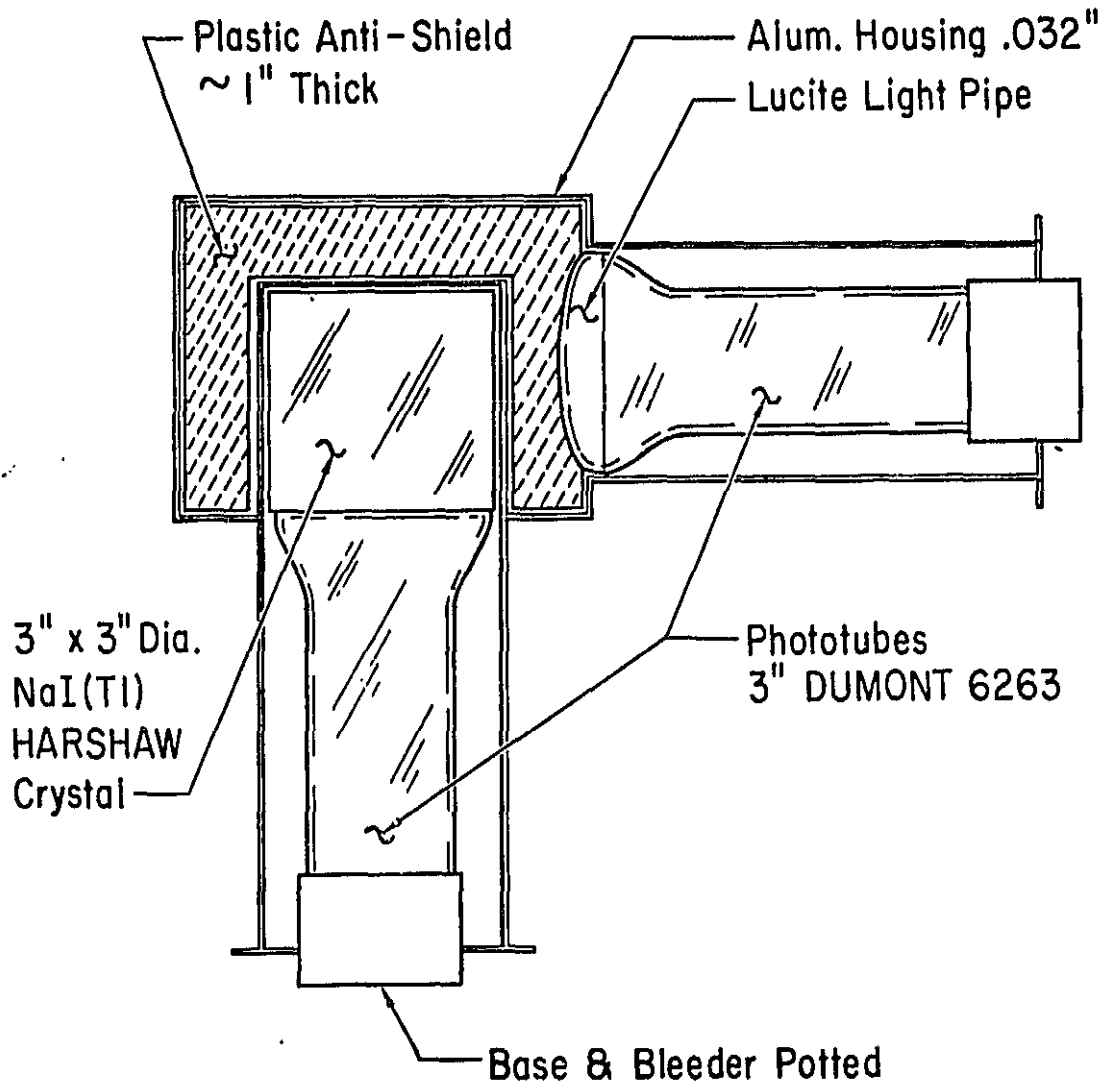


FIGURE 10 - Medium Energy γ -Ray Detector - This relatively primitive detector system was the basis for much of the early background investigation work. Conceptually similar detectors were flown on the ERS-18 and Apollo 16/17 missions. The Apollo mission provided the first observation of the MeV range spectrum of the cosmic diffuse γ -ray component.

This detector was flown several times to measure 0.1 to 10 MeV and 1.0 to 100 MeV atmospheric gamma-ray spectra. Flights were performed at atmospheric depths ranging from the Pfozter maximum ($\sim 100 \text{ gm/cm}^2$) to nominal X-ray astronomy altitudes ($\sim 3 \text{ gm/cm}^2$) in an effort to understand the mechanisms for production of atmospheric gamma-rays. Spectra were searched for evidence of Carbon, Nitrogen and Oxygen excitation via characteristic gamma-ray lines. The 511 keV electron/positron annihilation line was detected and measured as a function of depth. Finally, the angular distribution of atmospheric gamma-rays was measured at various depths using the advanced directional γ -ray telescope shown in Figure 11. These data were used to develop a comprehensive model for production of secondary gamma-ray production in the atmosphere and formed the topic of the Ph.D. dissertation of James Ling.

The second major objective in this area was to study methods for shielding detectors to enable observations of solar and cosmic sources. A variety of techniques were investigated ranging from the simple particle shield described above to full active gamma-ray anticoincidence using massive NaI shields as shown in Figure 11. In addition, novel, potentially low cost techniques involving laminates of high Z absorbers and scintillation plastic were tested. The general conclusion of these efforts was the determination that low background MeV-range gamma-ray detectors required high efficiency and high sensitivity anticoincidence gamma-ray shields to be effective. This result is reflected in the design of the UCSD/MIT gamma-ray instrument flown on the first High Energy Astronomical Observatory (HEAO 1), shown in Figure 12.

A third objective of this activity was to study the production of characteristic nuclear line emission in materials exposed to the primary cosmic

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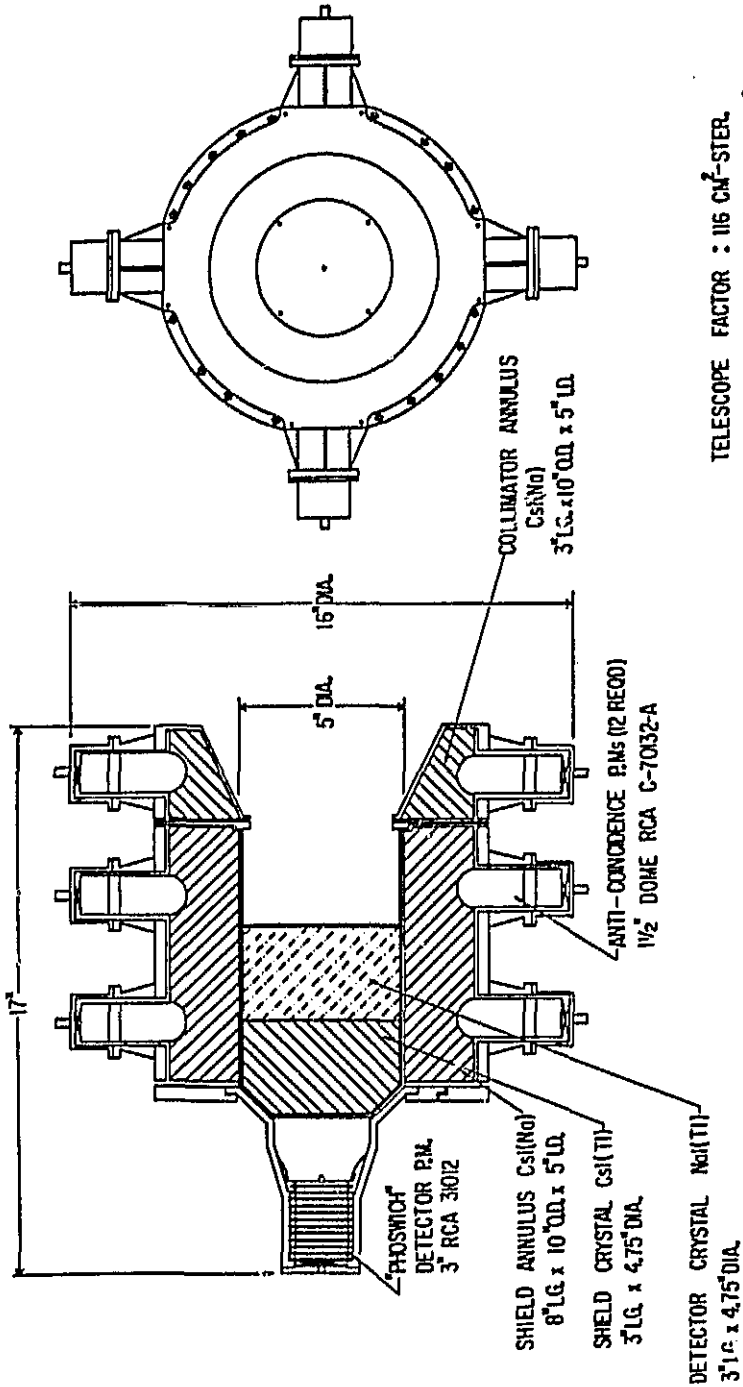


FIGURE 11 - Diffuse Cosmic γ -Ray Telescope - This system was originally developed to study the diffuse γ -ray background from balloons. It was most successfully used to measure the spectrum and directional distribution of secondary atmospheric γ -rays and to make initial observations of the stronger cosmic point sources. The diffuse component objective would be later attained from HEAO-1 using an instrument based on concepts developed in this system (see Figure 12).

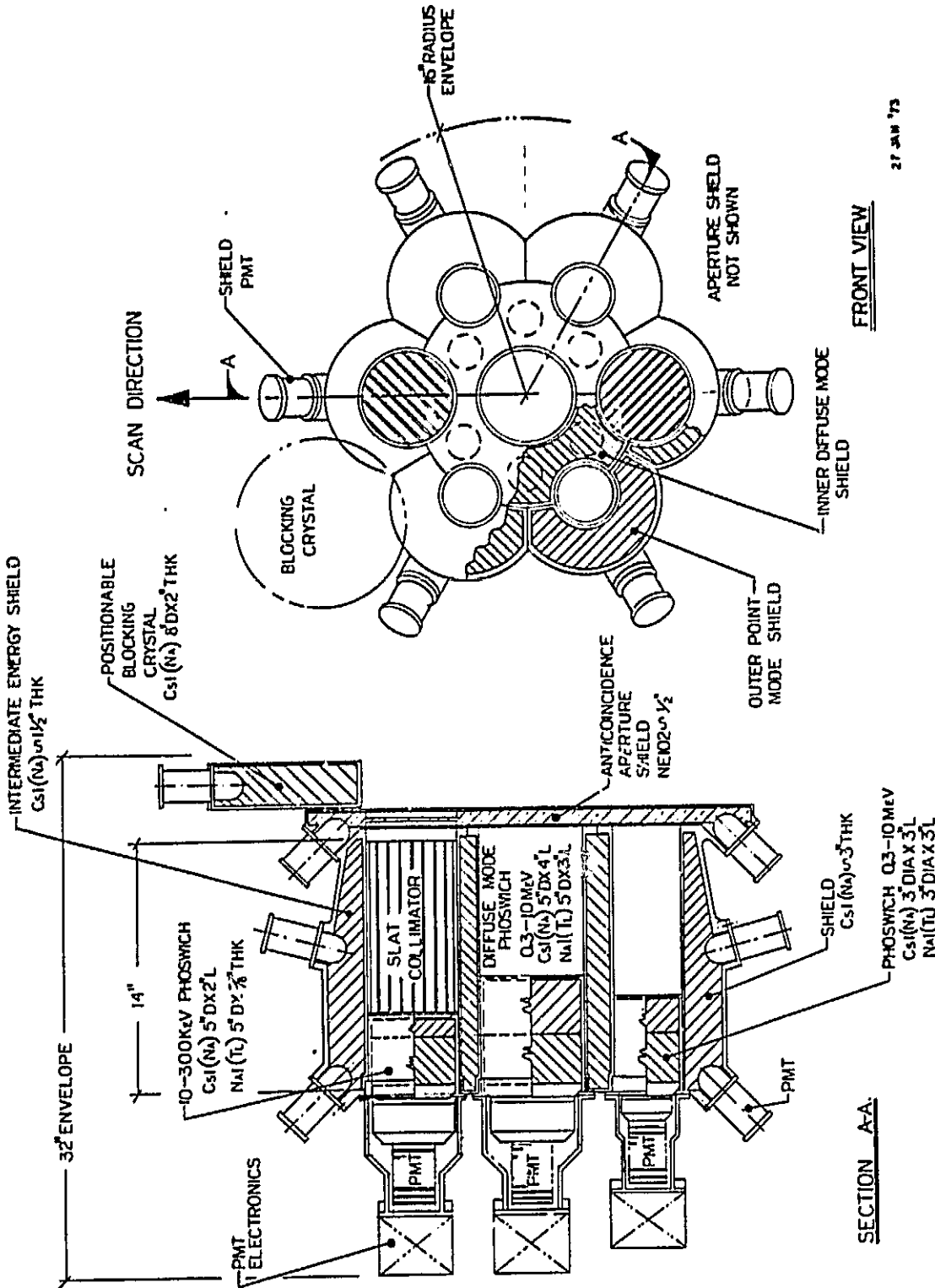


FIGURE 12 - The HEAO-1 MeV Range Gamma-Ray Telescope - This instrument represented the culmination of many years of detector development under this grant. As finally configured the system included 3 detector types, each optimized within a specific energy range, to cover the entire 0.01 to 10.0 MeV hard X-ray and medium energy gamma-ray range. The instrument also used a movable aperture shutter shield segment to facilitate measurement of cosmic gamma-ray sources in the presence of relatively high background.

ray flux. This would be directly relevant to the Apollo 15/16 experiments which would perform a chemical mapping of the lunar surface from the lunar orbiter. One balloon flight was performed in which a quantity of dunite was flown in proximity to a scintillation counter to simulate the Apollo experiment. Other measurements were made with detector enclosed in a thick iron cube to directly determine the production spectrum. An interesting result of this experiment was that the background within the iron "shield" actually exceeded that for a naked detector above about 1 MeV.

An additional speculative objective of this activity was to search for gamma-ray emission from several likely extraterrestrial sources including the Crab Nebula, Sco X-1, the Cygnus region, the sun and the diffuse gamma-ray background. These observations were generally unsuccessful using the simple detectors due to the low source fluxes and the presence of excessive background. A later attempt to observe the Crab using the large actively shielded instrument was successful. This became the topic of the Ph.D. dissertation of Duane Gruber. Attempts to measure the diffuse background from balloons were also inconclusive due to the difficulty in distinguishing the desired signal from the secondary background produced in the atmosphere above the balloon. This objective was finally to be realized using observations from HEAO 1 (see § III).

F. Hard X-Ray Imaging

The scientific objective of this project was to map the hard X-ray emission of the Crab Nebula to an angular precision of 10 arc seconds. This hard X-ray image of the classical remnant of the 1054 AD supernova would reveal the size, shape and location of the emission region at the highest energies relative to its more well known optical features. The essential result of this effort was

that the hard X-ray nebula was found to be offset from the pulsar with a fundamentally different symmetry than the optical nebula. This configuration is consistent with an equatorial wind/toroidal shock model coupling the pulsar to the outer nebula.

A substantial instrumentation and supporting hardware development was required to obtain the above result. The high resolution imaging hard X-ray telescope was a collaborative effort with the Institute for Space and Aeronautical Science (ISAS) at the University of Tokyo. The Japanese group, under the leadership of Professor M. Oda, would provide a four-grid, one dimensional modulation collimator having a response pitch of 20 arc seconds, plus the associated photo-aspect components to permit determination of the precise (5 arc second) aspect solution in support of the X-ray observations. UCSD developed a large area version of its phoswich scintillation detector (see subsection E) and a new two-axis servo controlled gondola to orient the 400 lb instrument, encode and transmit the data, provide command control, and perform other essential engineering functions. The modulation collimator telescope assembly is shown in Figure 13. The servo gondola (Servo 3) is shown in Figure 14.

The developmental process for the above hardware proved arduous, indeed stretching the capability of a modest level-of-effort program, when two devastating set-backs occurred during balloon flights. The initial engineering flight of the new system occurred in April, 1974, and revealed a number of areas in the instrumentation requiring further development. As a result, an improved signal processing system was incorporated into the detector electronics, a mercury floatation bearing for azimuthal decoupling was developed for the

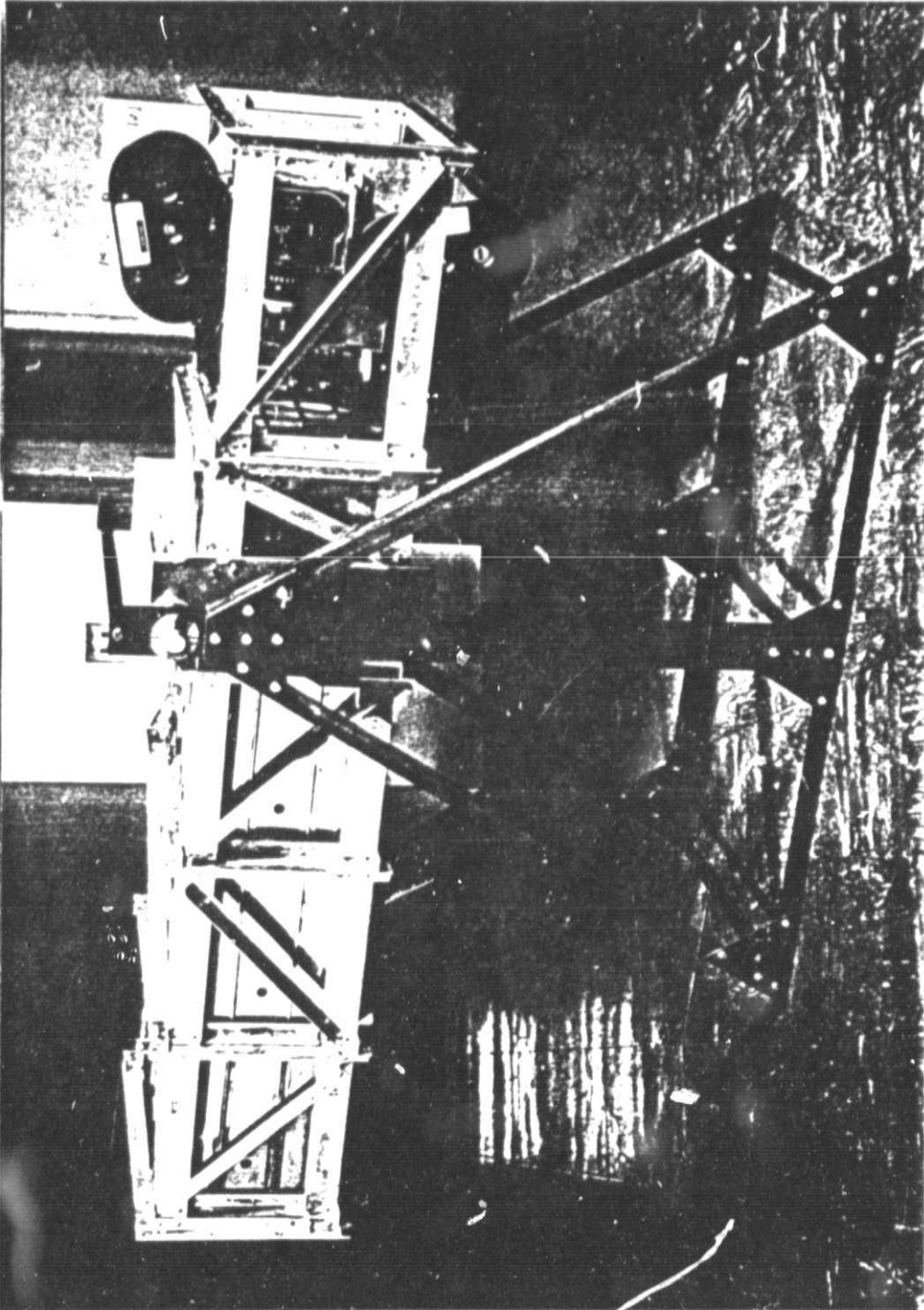


FIGURE 13 - The Modulation Collimator and Photo-Aspect System - This unit, roughly 2 m in length and weighing 500 lbs, formed the basis for the US/Japan collaboration to image the Crab Nebula in high energy X-rays. The collimator used 4 Invar grids with a pitch of 50 μ to attain an angular resolution of 20 arc seconds. The photo-aspect system photographed stellar fields in two orthogonal directions to give a 5 arc second aspect resolution with 1 second time resolution. The collimator was integrated with the Large Area Phoswich detector and carried in a new servo gondola (designated Servo 3).

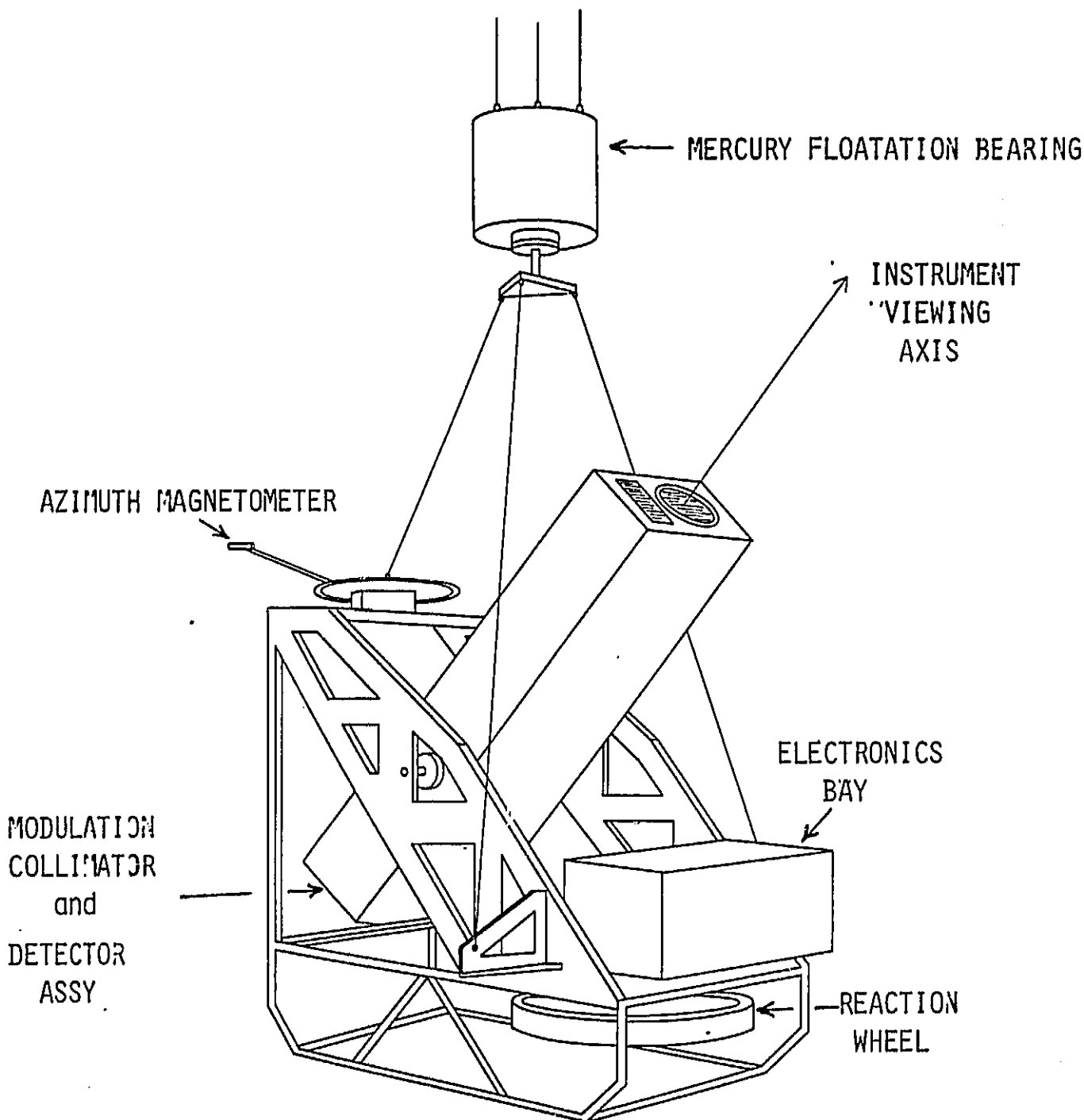


FIGURE 14 - Servo 3 - This gondola was developed to support observations using the modulation collimator telescope. The completely deployed system was 16 feet high and weighed nearly 2000 lb. This early version utilized a mercury floatation bearing for azimuthal decoupling and attained pointing accuracies of ~ 0.1 degree. Later refinements of this system included the Revolving Race Rotor shown in Figure 16.

gondola servo system, and improvements were made in the overall structure of the gondola. The modified gondola/detector system was next flown in January, 1975, to verify its performance parameters and obtain photometric observations of several cosmic X-ray sources. This system, however, was severely damaged when balloon failure necessitated a premature shutdown into the swampy Sabine River bottom land. The system was recovered with substantial, but repairable, water damage. It was then refurbished and flown twice in the summer of 1975 to yield new results on NGC 4151 and Her X-1. Following this successful demonstration of the system performance, the Japanese modulation collimator and aspect system were integrated into it and it was prepared for a winter 75/76 flight to image the Crab. Unfortunately, the system was severely damaged for the second time when it burned after premature shutdown due to balloon damage at launch. Following this setback, the UCSD components were rebuilt using insurance compensation, with the Japanese also rebuilding their entire system. The January, 1976 fire was undoubtedly the low point of the project. It is indeed remarkable that the members of the project were able to recover, rebuild the system and pursue their original goal.

Following a second one-year rebuilding period the system was successfully flown twice, one flight in February, 1977, and one flight in January, 1978. The original observational objectives were finally attained. There followed an extensive data reduction and analysis effort which has culminated in several papers presented at scientific meetings and published in the literature.

G. UCSD/UCB Collaboration

This activity followed the successful completion of the US/Japan

collaboratory imaging observations of the Crab Nebula. The objective was to utilize state-of-the-art detector techniques for high spectral and temporal resolution of transient hard X-ray phenomena. To accomplish this an array of four high purity planar germanium detectors was developed at Berkeley by collaborators R. Pehl (Lawrence Berkeley Laboratory) and R. Lin (Space Science Laboratory). This system, shown in Figure 15, attained an energy resolution of 0.6 keV at 100 keV, a figure which to date remains the best resolution used in astronomical observations of hard X-rays.

This spectroscopic system was combined with an improved version of the UCSD servo control gondola to make a unique system for the study of solar and cosmic transient phenomena. The updated servo control gondola incorporated a unique low friction suspension rotor (concept shown in Figure 16) as an evolutionary improvement over the mercury floatation bearing. This "Revolving Race Rotor", or R³, is now expected to be the standard system for future UCSD Servo Gondolas (see, for example, § III - Balloon Spectroscopy Program), and its concept and design have been adapted by other NASA sponsored investigators.

Two balloon flights were conducted using the above system. The Crab Nebula and Cass A were observed in the first flight yielding new limits on possible narrow line emissions from both supernova remnants as well as limits on variable line emission from the Crab pulsar, NP0532. The sun was the prime objective of the second balloon flight with additional follow-on observations of the Crab. The solar observations were richly rewarded with the occurrence of an intense hard X-ray flare which coincided with H α , soft X-ray and microwave events. The excellent resolution of the X-ray spectrometer revealed a previously unknown component of solar bursts, namely, a "superhot" isothermal component at

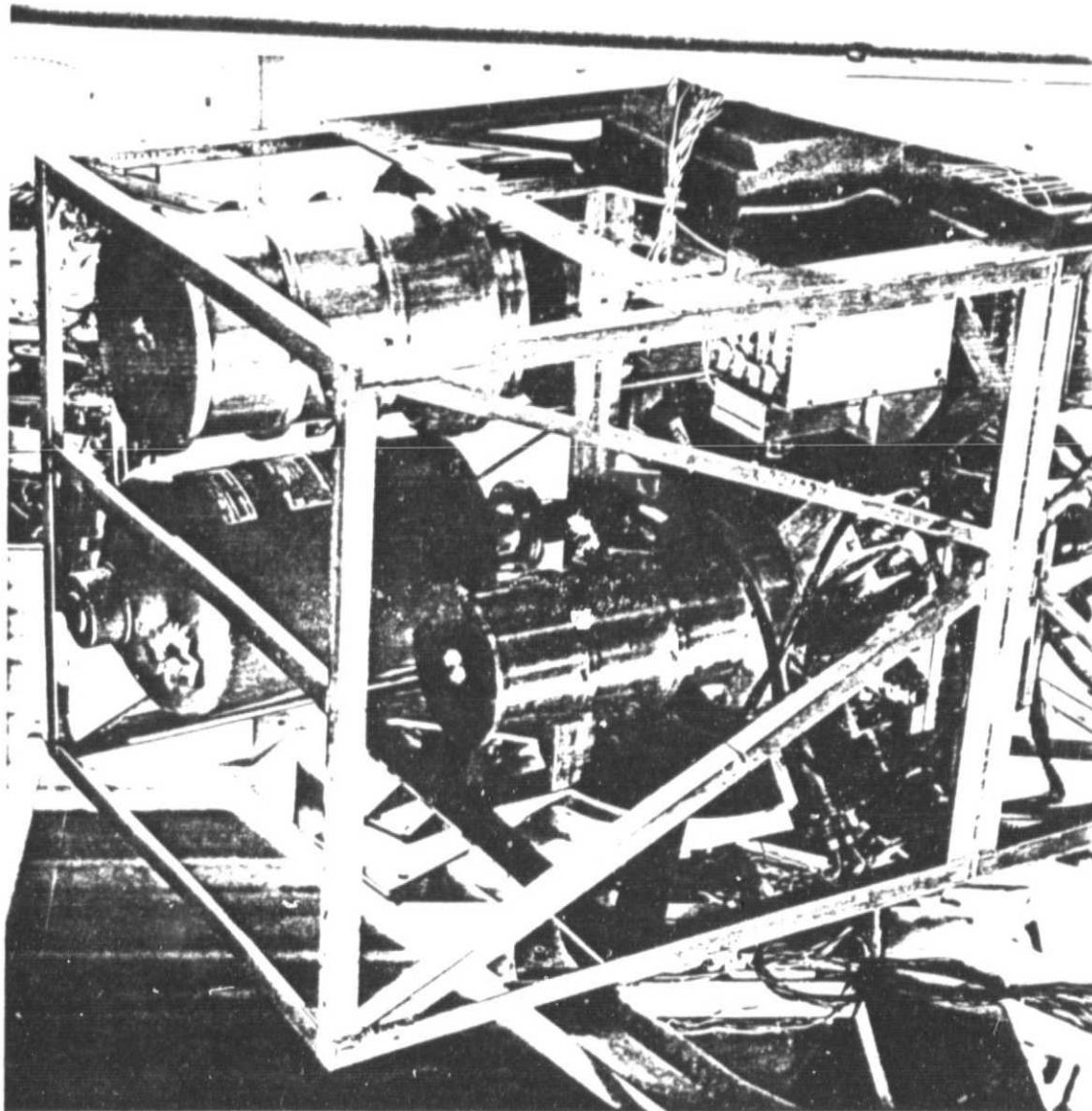


FIGURE 15 - The UCSD/UCB Instrument Module - This instrument complement consisting of the 2nd generation Large Area Phoswich and the Planar Germanium Spectrometer are shown mounted in the Servo 3 gondola. This system obtained the first high resolution (energy & time) measurements of a hard X-ray solar burst as well as observations of several cosmic sources. An evolutionary version of this system is now under preparation for a long duration balloon flight to obtain extended observations of solar and cosmic sources.

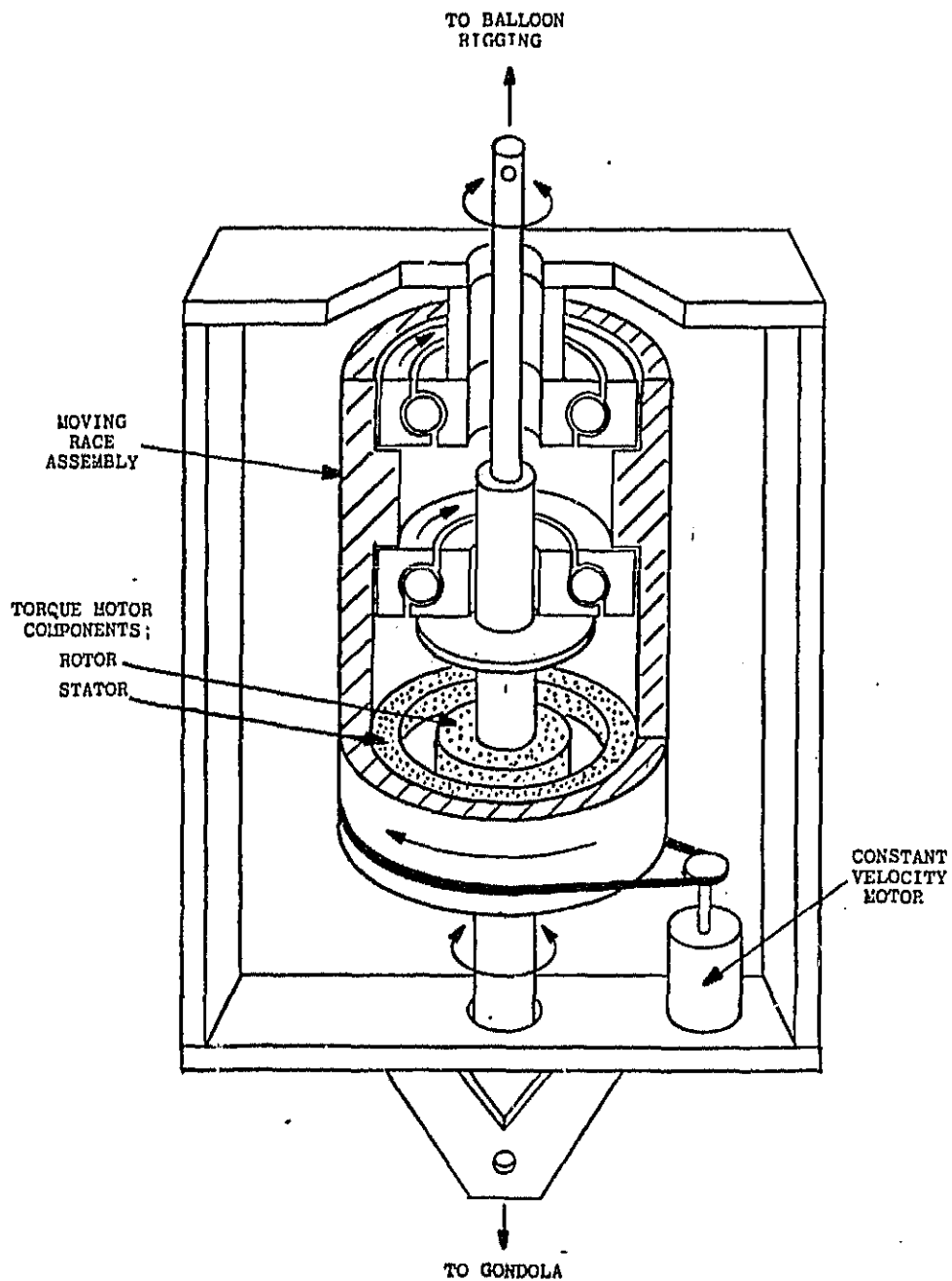


FIGURE 16 - Revolving Race Rotor Concept - This concept provides the basis for precise stabilization of large balloon payloads by decoupling the gondola from the upper suspension train.

a temperature in excess of 30 million degrees. In addition, the large collecting area of the phoswich detector (large by solar observation standards) permitted detection of 10 millisecond temporal structure in the burst as well as the presence of numerous low-level non-thermal " μ -flares" from the same active region that produced the big flare. The overall significance of these μ -flares remains unclear; however, the aggregate effect of their underlying energetic particle populations could be important for heating of the active corona.

These pioneering observations have created incentive for more extensive observations at high spectral and temporal resolution in the future, especially in the coming solar cycle. Toward this end the instrumentation discussed here has been adapted for operation in a Long Duration Balloon gondola (see § III). In addition, this activity has spawned an extensive new collaborative program to develop high resolution spectroscopic instrumentation for use in cosmic γ -ray astronomy (see § III).

III. Related Programs

Research funded by the subject grant supported the more general goals of NASA Space Science Program by contributing to the development of instrumentation and techniques that eventually were applied to space missions. In this section we briefly describe the major UCSD projects which originated in this manner and their relationship to the activities discussed above.

A. Orbiting Solar Observatories

OSO 3, the third orbiting solar observatory, carried a 7.7 to 200 keV X-ray telescope the design of which was largely based on research supported by this grant. The instrument, shown in Figure 2, was launched on 8 March 1967, and produced 14 months of complete data coverage. The data were formatted into two modes, emphasizing solar and cosmic point source observations. Solar mode data produced an extensive compilation of solar hard X-ray bursts. The sector mode data were analyzed to study the spectra and variability of about a dozen of the strongest sources and an X-ray map of the hard X-ray sky. The map, in turn, was used to determine the isotropy of the diffuse X-ray background, a result which remains highly significant to this day. was used to determine the isotropy of the diffuse X-ray background, a result which remains highly significant to this day.

OSO 7 carried two UCSD instruments designed to study cosmic and solar X-ray source phenomena. The Cosmic instrument was designed to study the spectra and variability of cosmic X-ray sources over the 7 to 500 keV energy range and collected useful data from its September 1971 launch through the spring of 1973. This instrument also evolved from earlier balloon borne detector systems. It has produced data which extended the spectra and monitored time variability of many

cosmic X-ray sources, in particular, the galactic diffuse component (Wheaton, Ph.D. thesis) and several extra-galactic objects (Mushotzky, Ph.D. thesis). A comprehensive catalog of cosmic high energy X-ray sources was produced using these data.

The second UCSD experiment on the OSO 7 was designed to study solar X-ray emission over the 2 to 300 keV energy range using a proportional counter and a NaI scintillation counter. This instrument was designed to separate the thermal from the nonthermal components of impulsive or flare-correlated emission. The system was particularly successful in this regard and observed over a hundred events. For many of these, the time evolution of the temperature and emission measure (thermal component) was separated from that of the spectral index and number of bremsstrahlung electrons (nonthermal component). These parameters were needed for models involving the most energetic part of the solar flare, to determine the energetics of the various plasma components and to determine the "thick" vs. "thin" target characteristics of the emission region.

B. APOLLO 15/16

The UCSD γ -ray group participated in the Apollo Gamma-Ray Spectrometer experiment which measured γ -rays from the lunar surface in order to map natural radioactivity and chemical composition, and thus provide information indicating the thermal and differentiation history of the moon. Dr. J. R. Arnold of UCSD was the Principal Investigator; other co-investigators were Dr. A. E. Metzger of Jet Propulsion Laboratory and Dr. J. I. Trombka of Goddard Space Flight Center. The γ -ray group was principally responsible for operations during the transearth (return) coast of the missions, when the spectrometer, mounted on the end of a 25-foot beam, measured primarily γ -rays from the diffuse component of cosmic γ -

rays. The Apollo 15 experiment was designed to obtain data which would allow a definitive measurement of total spectrum to ~ 30 MeV with enough operational modes to determine the various background effects. The resulting complex spectrum generated intense debate among theoreticians attempting to interpret it and other observers who were critical of the methods used to obtain the spectrum. Interestingly enough, the result has apparently withstood the test of time with many independent observers employing a diverse range of techniques (including our own HEAO 1 observation) confirming the Apollo results.

C. HEAO 1

The first High Energy Astrophysical Observatory (HEAO 1) carried the Hard X-Ray and Low Energy Gamma-Ray Experiment, an instrument based on balloon program concepts, the honeycomb phoswich detector system, and an evolutionary follow-on, the balloon gamma-ray telescope developed by J. Ling and D. Gruber for their Ph.D. thesis research. Data from this instrument are being analyzed in the study of spectra and variability of discrete and diffuse sources over the .010 to 10 MeV range.

D. Balloon Spectroscopy

UCSD has been selected as the lead institution in one of two consortiums selected by NASA to develop advanced instrumentation and observational techniques for high resolution γ -ray astronomy. The specific goal of the program is to design and build an array of twelve segmented high purity germanium detectors which will use pulse shape discrimination to suppress internal background. These low background detectors will be enclosed in a bismuth germanate shield and image a broad field of view using a coded "dynamic aperture

modulator." The concepts being developed here are expected to eventually be used in extended space missions, possibly on a Shuttle platform or a dedicated Explorer spacecraft. This program evolved directly from activities occurring in the latter stages of the original UCSD balloon grant.

E. XTE

UCSD has been selected to develop a high energy X-ray instrument for the X-ray Timing Explorer mission which is now planned for an early 1990's launch. The UCSD instrument will be a 2000 cm² array of twelve large area phoswich detectors. The design of these detectors is based entirely on developments pursued under this grant (see § IID above).

F. Long Duration Balloon Program

As a follow-on to the UCSD/UCB collaboration effort under this grant a separate program to pursue observations of solar and cosmic transient phenomena from long duration balloons is underway at UC San Diego and Berkeley. These observations will be done using a tandem instrument consisting of a 600 cm² array of phoswiches plus the planar germanium high resolution spectrometer. These instruments are mounted in a new gondola configured for essentially autonomous operation throughout a 15 to 20 day balloon flight. The system is presently scheduled for its first launch from Alice Springs, Australia in January, 1986.

IV. Personnel

This section briefly describes the impact that the subject grant has had in the training of new researchers and in the research activities of several established personnel.

A. Graduate Students

The majority of graduate students who have received their degrees under the X-ray and γ -ray astronomy program at UCSD were supported through some or all phases of their graduate studies by this grant. Their activities under this grant gave them opportunities for direct participation in the development of space instrumentation. Such opportunities are unfortunately now becoming less common as the magnitude, complexity, and formality of space projects grow. Below, we list these students in the chronological order of receipt of their Ph.D. degrees, which are listed in Appendix A. It is interesting to note that all of these people have developed their careers in various space science disciplines, involving NASA projects, and remain active in these disciplines to this day.

Allen Jacobson (1968) took a position at the Jet Propulsion Laboratory where he was Principal Investigator for the Gamma-Ray Spectrometer instrument on HEAO-3. He now leads the Gamma-Ray Astronomy group at JPL. in addition to leading the Gamma-Ray Astronomy group.

Daniel Schwartz (1969) was appointed as a National Research Council Fellow of Goddard Space Flight Center following completion of his degree at UCSD. He then took a permanent research position at the Center for Astrophysics, Harvard/Smithsonian, where he remains active in analysis of HEAO 1 data and

development of focal plane instrumentation for future NASA missions.

David McKenzie (1971) took a position at Aerospace Corporation in Los Angeles where he continues to be active in Solar Astrophysics with an emphasis on soft X-ray observations.

Michael Pelling (1971) remained at UC San Diego where he has continued to work on development of photometric, imaging and spectroscopic techniques for X-ray and γ -ray astronomy.

he assumed a major role in the development of the UCSD/MIT instrument on HEAO 1. He now serves as Principal Investigator for the UCSD Program for Development of Spectroscopic Techniques for Gamma-Ray Astronomy.

John Laros (1973) assumed a position at Los Alamos National Laboratory where he has worked on development of observational techniques and instrumentation for observation of transient X-ray and gamma-ray phenomena.

James Ling (1974) took a position at the Jet Propulsion Laboratory in Pasadena where he works toward observations and development of instrumental techniques for gamma-ray spectroscopy from satellites and balloons.

Duane Gruber (1974) has remained at UC San Diego where he has played a key role in the analysis and interpretation of HEAO 1 data.

William Wheaton (1976) took a position at the Massachusetts Institute of Technology where he participated in analysis of HEAO 1 data. He subsequently moved to the Jet Propulsion Laboratory in Pasadena where he remains today as Senior Staff Scientist working in gamma-ray astronomy.

Richard Mushotzky (1976) took a position at the Goddard Space Flight Center where he participated in analysis of HEAO 1 data, specializing in observations of extra-galactic objects. He remains at GSFC today and is active in development of instrumentation for the Advanced X-Ray Astronomy Facility.

William Paciesas (1978) accepted an appointment as National Research Council Fellow at Goddard Space Flight Center where he worked on Gamma-Ray Spectroscopic Observations from balloons. He has subsequently taken a research faculty position at the University of Alabama where he is assisting in the development of the Burst and Transient Source Experiment (BATSE) which will soon fly on the Gamma-Ray Observatory.

B) Research Personnel - This grant supported the activities of several young researchers. Below, we list them and briefly describe the directions their careers have taken them.

Laurence Peterson received the core support from this grant for his developing group in X-ray and gamma-ray astronomy. He now holds the position of Professor of Physics at UC San Diego. In the intervening years Professor Peterson has served as Principal Investigator for all the major space mission instrument developments discussed in section III. He has also served on planning, oversight and selection committees for NASA, NSF and NRC too numerous to list here.

Fredrick Gillette received his initial support for research in observational techniques for infrared astronomy under this grant. He now holds a faculty position at the University of Arizona where he has played a key role in the development of the Infrared Astronomy Satellite (IRAS) mission and analysis

and interpretation of its results.

Wayne Stein also received support for his research activities under this grant. He now holds joint appointments on the faculties of the University of California, San Diego and the University of Minnesota where he remains active in ground based infrared astronomy.

APPENDIX A

PUBLICATIONS, PRESENTATIONS, AND THESIS

The Early Years

L.E. Peterson, "Balloon and Satellite X-ray Astronomy", Colloquium at University of Maryland, College Park, Maryland, November 11, 1968.

D.A. Schwartz, H.S. Hudson, and L.E. Peterson, "Satellite Observation of Albedo X-rays Between 7.7 and 210 keV", American Geophysical Union, December 2-4, 1968, San Francisco, CA.

H.S. Hudson, D.A. Schwartz, L.E. Peterson (UCSD), H. Zirin and W.H. Ingham (Caltech), "X-ray Observations of Limb Flare", American Geophysical Union, December 2-4, 1968, San Francisco, CA. (attendance and presentation by H.S. Hudson and D.A. Schwartz)

L.E. Peterson and R.M. Pelling, "Upper Limits on CP 1919 Pulsed X-ray Emission", Fourth Texas Symposium on Relativistic Astrophysics, December 16-20, 1968, Dallas, Texas. (contributed paper)

L.E. Peterson, H.S. Hudson, D. McKenzie (UCSD); H. Zirin and W.H. Ingham (Caltech), "De-Occultation Event of December 2, 1967", American Astronomical Society, February 18-21, 1969, Pasadena, CA., (contributed paper by L.E. Peterson).

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L.E. Peterson, "Balloon and Satellite Observations of Cosmic X-Ray Sources", University of Chicago, April 16, 1969. Colloquium by Laurence E. Peterson.

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COORD. X-RAY AND GAMMA-RAY BALLOON FLIGHT SUMMARY

FLIGHT NO.	INVESTIGATOR	EQUIPMENT	OBJECTIVE	RESULTS	LAUNCH			FLIGHT			BALLOON		FLIGHT		RECOVERY AREA	
					SITE	DATE	TIME	TYPE	GLIDES PER HOUR	WIND VELOCITY	MALLOON TYPE	FLIGHT ALTITUDE FEET	FLIGHT DURATION	TEMPERATURE		BALLOON PERFORMANCE
1	Peterson	B-16 Detector	Measure B Egrd properties of COO-1 detector in flight configuration	None - cut down prematurely by faulty command Rx.	5-8-63	0710 MST	Dynastic	235	90	None 3008 -15 all poly.	53,000	90 mb	-8	5-8-63 0640 MST	Good	Chillevia, 7 mi
2	Peterson	B-15 Detector	"	None - cut down prematurely by faulty command Rx, also IIR antenna was broken	6-5-63	0630 MST	"	235	90	"	111,000	8-2 mb	1 hr	6-5-63 0903 MST	Good	Beckery, Arizone
3	Peterson	B-16 Detector	"	Good flights - found added later in isotropic and coincidence channels due to local matter compared with COO-1. X-rays observed on COO-1	6-26-63	0643 MST	"	235	90	"	103,000	9-8 mb	4 hr	6-26-63 1309:30 MST	Good	Santa Rosa Nevada, California
4	Peterson	Modified B-16 Detector	Measure B Egrd Properties of COO-1 detector with local matter removed	"	8-7-63	0707 MST	"	235	90	"	103,000	9-8 mb	2 hr 25 min	8-7-63 1016 MST	Patched small hole	Ocotillo Wells, California
5	Peterson	B-57 prototype Detector	Measure detector performance with different anti-coinc. configurations	All objectives met due to short flight counting statistics were less than desired.	"	"	"	270	105	"	"	"	"	"	Good	Thorsch, Arizone
6	Schwartz	3x3" NaI, with plastic shield, KMC analyzer	Measure 1-10 Mev atmospheric X-rays rejection.	Measured continuous, gain change measured spectrum. Obtained anti-coinc. anti-off comparisons.	10-4-64	0728 MST	Anchor Line	222	115	760 ft all	111,000	6. mb	4 hr	4-64 1419 MST	Good	Casal Dome Arizone
7	Schwartz	"	Measure atmospheric X-rays from 1-10 Mev. Look for lines from O, N, C	Measured continuous, 1-5 Mev. Did not see lines. Large gain change measured spectrum.	11-22-64	0737 CST	"	586	50-1	None 2 x 10 ⁶ 0.5 poly	130,700	3-04 mb	4 hr 47 min	0604 CST	Excellent (high values recorded in anti-coinc. configuration)	Salisbury, North Carolina
8	Peterson Sells Jard	NCA T265 Phototube 120 channel analyzer	Study effects of high energy radiations on noise pattern from phototube	Successful flight. Phototube and H.V. power supply cooperative at impact. No fluctuation during flight.	2-22-65	0651 CST	"	337	42	Waters 2.5 x 10 ⁵ 1.0 w poly	91,200	16.27 mb	1 hr 30 min	1005 CST	Very Good	Monroe, Louisiana
9	Jacobson	B-57 Detector	Measure the detector background and atmospheric background.	Successful flight to all respects.	4-16-65	0751 CST	"	344.5	85	None 3.6 x 10 ⁵ .75 all poly	96,500	12.9 mb	9 hr 10 min	1701 CST	Very Good	Waucho, Texas
10	Schwartz Peterson	3" x 3" NaI packed in Dunite	Search for X-ray lines in moonlike material	See 2:2 Mer line from detector information. No line characteristic of Dunite.	4-14-65	0705 CST	Upstate	572	212	Waters 2.5 x 10 ⁵	78,000	30-15 mb	8 hr 17 min	1552 CST	Good	Brack, Texas
11	Jacobson	B-57 Detector Servo goodie	To observe COO X-1	Servo problems, but source observation achieved	6-10-65	1853 CST	"	659	130	None 3 x 10 ⁶ .75 all poly	128,500	3-3 mb	9 hr 23 min	0600 CST	Good	Arizone, New Mexico

12	14-P	Schwartz, Lange	3' x 3' NaI plastic shield	Measurement of atmospheric gamma-rays from 100 Mev to 10 Mev, calibrating on 511 Mev atmospheric line	-	-	6-21-65	0016 CST	Anchor Line	70A	45	Barve 3 x 10 ⁶ -75 mil poly	126,000	3.6 mb	10 hr 31 min	1223 CST	Irregular descent and float	Pen Base, Texas
13	14c-P	Schwartz, Lange	-	Measured 1-10 Mev atmospheric spectrum. No lines found; upper limit below Arnold's estimate	-	-	6-24-65	0026 CST	-	59A	60	Barve 3 x 10 ⁶ -55 mil poly	129,000	3.17 mb	11 hr 30 min	1436 CST	Very good	Merford, Arizona
14	15-P	Jacobson	-	Balloon failure - Trap - 9977	-	-	9-13-65	N/A	Dynamic	72A	182	-	N/A	N/A	N/A	N/A	Balloon failure - Inflation tube tore	N/A
15	16-P	Jacobson	-	Equipment functioned properly. Source not observed.	-	-	9-14-65	0724 CST	-	1026	183	Waters 4 x 10 ⁶ 0.7 mil poly	124,000	3.05 mb	19 hr 35 min	0530 CST	214 not reached expected altitude	Douglas, Arizona
16	16-P	Jacobson, Peiling	-	Balloon failure.	-	-	9-22-65	2016 CST	-	662	139	Barve 3 x 10 ⁶ -55 mil poly	None	None	None	2126 CST	Failed to rise above 51,000 feet.	Neal, Texas
17	16-P	Jacobson, Peiling	-	Successful observation, terminated prematurely	-	-	9-23-65	2234 CST	-	679	141	-	126,000	3.6 mb	5 hr 20 min	0610 CST	Good	Bryan, Texas
18	17-P	Jacobson	-	Successful	-	-	9-28-65	0612 CST	-	660	129	-	129,000	3.17 mb	10 hr 48 min	1700 CST	Good	Lampasas, Texas
19	20-1P	Matteson	1. ERS-18 Prototype detector 2. Ball Bross. 3. Small grand- in X/TLS. am.	To search for isotropies in atmospheric background	-	-	2-12-66	0618 MST	-	845	450	Barve 1.5 x 10 ⁶ 2.5 mil poly	79,000	29 mb	8 hr 10 min	1615 MST	Good	Quemah, New Mexico
20	20-1P	Schwartz	3' x 3' NaI shield with plastic shield	Measure atmospheric gamma-rays, 1-10 Mev, search for solar X-rays and Crab Nebula gamma-rays	-	-	2-17-66	1859 MST	-	569	253	Barve 511-2201 3 x 10 ⁶ -55 mil. 2-128 poly	126,000	3.6 mb	11 hr 56 min	0940 MST	2,000 ft. below theoretical ceiling; no reliable depth measurement	Shreveport, Louisiana
21	20-1P	Peiling	1. ERS-18 Prototype detector 2. ERS-18 Analyt. 3. Air-As. gas- Sola served to contact ERS	Measure X-ray flux from quiet sun	-	-	2-18-66	0445 MST	-	640	168	Barve 3 x 10 ⁶ -55 mil	126,000	3.6 mb	8 hr 53 min.	1600 MST	Good	Crosbytown, Texas
22	20-1P	Matteson	Small grand- in with flight emulator	Check ERS-18 prototype gamma-ray detector with anti cm/off & al mass near & away from detector	-	-	2-25-66	0259 MST	-	247	130	Barve 8 x 10 ⁴ -75 mil poly	69,724	41-47 mb	9 hr 15 min	1450 MST	Good	Fort Sumner, New Mexico
23	23-P	Jacobson	5-57 detector Barve Gamma and XB-2	Observe gamma rays during EYE XB-1 Transit. no EYE XB-2 because of battery failure	-	Polistone, Texas	8-6-66	1650 CST	-	665	185	Barve 3 x 10 ⁶ -55 mil poly	124,800	3.8 mb	8 hr 24 min	0938 CST	Poor float. Lost altitude for 2 weeks	Carlsbad, New Mexico

UCSB X-RAY AND GAMMA-RAY BALLOON FLIGHT SUMMARY

FLIGHT NO.	UCSB CONTR.	INVESTIGATOR	EXPERIMENT			LAUNCH			BALLOON			FLIGHT			REMARKS
			SCHEMATIC	OBJECTIVE	RESULTS	DATE	TIME	TYPE	UCSB FLIGHT NUMBER	NATIONAL BALLOON NUMBER	FLYING ALTITUDE (ft)	FLYING ALTITUDE (m)	FLYING DURATION	TERMINATION	
24	241-P	Schwartz	Scintiscan Bal. Blocking Cryst. Small Bal. with filter.	Investigate background properties of honeycomb detector	Measured count rate spectrum with aperture blocked.	9-3-66	2030 CST	Dynamic	713	17A	None	None	None	Balloon full-up at launch	N/A
25	249-P	Schwartz	Scintiscan det. Small Bal. with filter.	Investigate background properties of honeycomb detector.	Measured count rate spectrum with aperture blocked.	9-3-66	1919 CST	-	707	17A	3-3 mb	10 hr 40 min	9-6-66 0727 CST	Somewhat variable flight day. No photocathode CRT.	College Station, Texas
26	250-P	Schwartz	"	Compare count rates with flight 25. Measure spectra of CYS XP-1 & CYS XP-3	Measured CYS XP-1 spectrum to 180 kev. Battery failure shortened flight.	9-13-66	1853 CST	-	729	18B	3-3 mb	5 hr 50 min	0936 CST	Percent	Waco, Texas
27	252-P	Jacobson	8-31 Detector servo gondola	Observe Tauros XP-1	Successful flight.	9-20-66	0113 CST	-	706	16B	3-3 mb	7 hr 36 min	1104 CST	Very Good	Porter, Texas
28	253-P	Schwartz	2" x 1" crystal in Bal well.	Study properties of shield in 1-10 Mev range.	Measured spectra in and out of well, 200 kev to 10 Mev. Estimated production in well. Studied fluxes vs. atm. depth.	9-21-66	1053 CST	-	794	155	3-3 mb	15 hr 0 min	9-22-66 1140 CST	Good	Oakville, Texas
29	261-P	Balcer	Scintiscan det. servo gondola	Observe Moon and NG1	Stuck in calib. moon eyes" tracked the balloon. Poor servo performance	2-27-66	2323 MST	-	1293	308	3-3 mb	6 hr 24 min	0800 MST	Very Good	Dome Creek, Colorado
30	262-P	McKenzie, Druber	Lead-plastic collimator, 2" x 1" NaI det., scintiscan monitor	Evaluate lead-plastic collimator. Determine background & count of well with anti on and off	Successful flight. No plastic design rejected.	3-1-67	0630 MST	-	764	15A	26.1 mb	5 hr 12 min	Cordova 1330 MST	Excellent	Merble Canyon Arizona
31	263-P	McKenzie	NaI well, 2x3 detector, anti on, anti off	Determine background properties of large NaI well with anti on and anti off	Balloon failure	3-1-67	0238 MST	-	703	157	None	None	0419 MST	Breaks at 571	Ogilby, New Mexico
32	308-P	McKenzie, Schwartz	NaI well, 2x3 detector	Observe Cygnus from 200 kev to 2 Mev	Anti-coincidence off during flight. Battery failure necessitated cut down	6-4-67	2009 CST	-	856	257	3.76 mb	12 hr 0 min	6-7-67 Cordova 1143 CST	Verticalized between 3:05 and 3:05 ab.	San Angelo, Texas
33	309-P	Jacobson, Laroc	OxLi solid state detector	Observe Tauros XP-1 looking for line emissions 20-250 kev	Balloon did not reach altitude.	6-7-67	0613 CST	-	1177	241	3-0 mb	6 hr 0 min	Cordova 1600 CST	Further poor	Abilene, Texas
34	313-P	Jacobson, Laroc	"	Observe 800 XP-1 for line emissions 20-150 kev	Leaking balloon	6-13-67	2030 CST	-	1707	107	N/A	N/A	Cordova 0600 CST	Leaking balloons	Waco, Texas

35	313-P	McKenzie	3M1 wall, 3M3 detector	Observe Crab and Cygnus from 200 kv to 2 kv	•	•	6-15-67	1912 CST	•	816	176	Wissam 2.94 x 10 ⁶ .6 ml poly	122,000	4.19 mb	16.2 hr	6-16-67 Caldwell 1130 CST	Poor - alt. varied from 2.9 to 1.2 mb.	Marfa, Texas
36	309-P	Jacobson, Laros	06A solid state detector	Observe Xaurus X-1 for line emissions, 20-280 kv	•	•	7-23-67	0511 CST	•	1264	322	Wissam 6.0 x 10 ⁶ .5 ml poly	129,000	3.17 mb	9.6 hr	Caldwell 1500 Impact 1602 CST	Excellent	Las Cruces, New Mexico
37	313-PA	Laros	"	Observe Scorpius X-1 for line emissions, 20-280 kv	•	Page, Arizona	1-9-68	0330 MST	•	1751	325	Wissam 10.6 x 10 ⁶ .5 ml poly	136,000	2.8 mb	7 hr	Caldwell 1413 Impact 1441 MST	Excellent	716 Twp, New Mexico
38	314-PA	Shaban	JTA experiment	Detector test	•	•	1-10-68	0638 MST	•	1092	160	Wissam 5.2 x 10 ⁶ .7 ml	130,000	2.05 mb	6 hr	Approx. 1600 MST	Good	Blaming, Utah
39	315-PA	Matteson, Pulling	3M1 wall, Cal homocycle, Cal detector, JTA servo system	Observe M-87 from 20-200 kv	•	•	1-13-68	2145 MST	•	140	140	"	116,000	5.35 mb	N/A	Approx. 0900 MST	Poor	Pierre Terry Arizone
40	317-PA	Laros	06A wall state detector	Observe Cygnus X-2 for lines, 20-280 kv	•	•	1-17-68	0424 MST	•	1340	335	Wissam 6.0 x 10 ⁶ .5 ml poly	130,000	3.0 mb	8.5 hr	Caldwell 1520 Impact 1516 MST	Excellent	Amarillo, Texas
41	317-P	Matteson, Pulling	Same as 317-PA except 3M1 detector	Simultaneous optical & X-ray observation of X-1 & Cygnus X-3. PCM dropout terminated Cygnus region 20-280 kv	•	•	5-21-68	2000 CST	•	1942	495	Wissam 10.6 x 10 ⁶ .5 ml poly	135,000	2.55 mb	11.8 hr	1100 CST	Excellent	Marfa, Texas
42	304-P	Matteson, Pulling	"	Observe M-87, M82 X-1, Pulser 1, 20-200 kv	•	•	6-9-68	1847 CST	•	1536	300	Wissam 6.0 x 10 ⁶ .5 ml poly	128,000	3.23 mb	10.7 hr	0728 CST	Good	Marfa, Texas
43	307-P	Matteson, Pulling	"	Simultaneous optical and X-ray observation of X-1, Cygnus region and X-2 X-1	•	•	6-27-68	1829 CST	•	1962	498	Wissam 10.6 x 10 ⁶ .5 ml poly	132,000	2.8 mb	8 hr	0145 CST	2.8 mb float	Marfa, Texas
44	307-P	Matteson, Pulling	Photovitch X-ray telescope 2.7 half angle and blocking X-ray	Determine background properties and test anti-coincidence schemes.	•	•	4-15-69	1720 CST	•	1315	300	Wissam 5.2 x 10 ⁶ .5 ml	129,000 not activated 018 mb 10,000	N/A	N/A	2110 CST	Failure at 19,000 feet	Marfa, Texas
45	309-P	Lind, Laros	3M1 X-ray shield	Measure atmospheric X-rays to 100 kv	•	•	4-23-69	1746 CST	•	962	205	Wissam 3 x 10 ⁶	120,000	4.55 mb	5.5 hr	0145 CST	Good	Gulf Port, Mississippi
46	301-P	Matteson, Pulling	Photovitch telescope & servo gondola	Simultaneous optical & X-ray observation of X-1, X-2. Observe X-2 X-1 & Cas A	•	•	6-9-69	2215 CST	•	2372	489	Wissam 11.5 x 10 ⁶ .7 ml	133,000	3.0 mb	7.7 hr	0732 CST	Good	Marfa, Texas

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UCSD I-RAY AND GAMMA-RAY BALLOON FLIGHT SUMMARY

FLIGHT NO.	UCSD COVER	INVESTIGATOR	EXPERIMENT		LAUNCH				BALLOON					PAYLOAD				RECOVER
			EQUIPMENT	OBJECTIVE	RESULTS	DATE	TIME	TITLE	GROSS WEIGHT	NET WEIGHT	BALLOON TYPE	FLYING ALTITUDE	FLYING DURATION	TERMINATION	BALLOON PERFORMANCE	AREA		
47	189-P	Mattison Pilling	Research Balloon Gondola	See Cygnus weight for 3 hrs. Data short look at Sec 2-1 when reach limit	Detector performance improved below 40 kv from 71. 46 kv still not good. Cygnus data should be good. Did not see top of beam of JAKE launch	9-16-69	0847 CST	Dynasize	2404	640	Wizara 10.6 x 10 ⁶ 0.75 mil	3-05 mb	6.8 hr	0600 CST	Good	Carlsbad, New Mexico		
48	225-B	McKenzie	OSO-B Solar Engineering Model. Test Gondola	Test engineering model of OSO-B solar. Make sure true detector background	High wind velocity at all flight duration barely enough to measure true detector background in three shield stages	1-26-70	0806 MST	-	1049	250	Wizara 2.58 x 10 ⁶ 0.7 mil	1.25 mb	3.8 hr	1401 CST	Good	Trinidad, Texas		
49	227-B	Larso	Test gondola w/OSO-B cosmic engineering model detector	Test operation of OSO-B cosmic detector. Observation of Cygnus region	Good	2-1-70	0901 MST	-	1298	335	Wizara 5.0 x 10 ⁶ 0.75 mil	3-51 mb	5.9 hr	1559.25 CST	Fair	M. Plaquemine, Texas		
50	279-P	Larso	OSO-B Gondola with honeycomb and Crab Meibels detector	Observe the Cygnus region. Ypsilon 61 and Crab Meibels 20-400 kv	Good	9-8-70	0953 CST	-	2463	645	Wizara 11.1 x 10 ⁶ 0.75 mil	3-05 mb 3-5	12.1 hr	1023 CST	Fairly Good	Louisburg, New Mexico		
51	383-P	Larso	-	Observe Cas A, the Crab Meibels, M31 20-400 kv	Good	9-24-70	1957 CST	-	2453	640	Wizara 10.6 x 10 ⁶ 0.75 mil	3-56 mb	12.9 hr	1130 CST	Fair	DeQuincy, Louisiana		
52	598-P	Larso	-	Observe M31, 3C 273 & recent supernova in M31 and Explains supernova	Good, but somewhat com- promised by a too short flight	10-20-70	1720 CST	-	3048	675	Wizara 15.0 x 10 ⁶ 0.7 mil	2-32 mb	6.4 hr	1613-30 CST	Good	Pine Mt., Georgia		
53	623-P	Gruber	Directional gamma detector	1) Crab Meibels obser- vation 0.3-10 MeV 2) OSO-B engineering data	Probably successful observations. Lots of engineering data	7-7-71	0641 CST	-	2147	500	Wizara 11.1 x 10 ⁶ 0.75 mil	2-01 mb	5-5 hr	1230 CST	Excellent	Sierra Blanca Texas		
54	628-P	Gruber	-	-	-	8-8-71	0403 CST	-	2149	485	Wizara 11.1 x 10 ⁶ 0.75 mil	2-50 mb	6.4 hr	1250 CST	Excellent	Carlsbad, New Mexico		
55	645-P	Ling Gruber	-	1) OSO-B. 0.3-10 MeV 7- 10 MeV 2) Crab Meibels 0.3-10 MeV 3) Crab Meibels 0.3-10 MeV pointing 90° & 180° from RAHEB	Balloon failures	10-25-71	1833 CST	-	2693	450	Wizara 15.5 x 10 ⁶ 0.75 mil	3/4	3/4	3/4	Falloon Failure	Jacksonville, Texas		
56	648-P	Ling Gruber	-	-	Successful	10-28-71	1818 CST	-	2232	450	Wizara 15.0 x 10 ⁶ 0.5 mil	2-15 mb	6.3 hr	0920 CST	Excellent	Monticello, Florida		
57	651-P	Ling Gruber	-	1) Atmos. 0.3-10 MeV 7- ray protzer max Tom 1 hr obser. w/det. point- ing 0.45, 90, 135, 180° 2) Atmos. 7-10 MeV 10-100 MeV 0.50, 1.50°	Successful	11-5-71	0648 CST	-	955	450	Wizara 0.175 x 10 ⁶ 1.5 mil	7.0 mb	8 hr	1800 CST	Excellent	Baytown, Louisiana		

58	65AP	Palling	Invert. of a 7-7R det. utilizing a combination of passive collimation & charged particle rejection over range 20 MSZ-30K4 SEAO STABU.		12-7-71	1722 CST		1574	506	Raven 5.0 x 10 ³ 0.75 mil	10	1000 mb	5 sec	1722.30 CST	N/A	Palestine, Texas
59	655P	Palling						1575	510	Raven 5.0 x 10 ³ 0.75 mil	117,000	5.1 mb	2 hr 40 min	2557 CST	Good	Bonaville, Alabama
60	680P	Pacifica Numbotz	Very observations of the spectrum and time variability.		6-10-72	1936 CST		2702	653	Winren 6 15 x 10 ⁶ .6 mil poly 2 x 0.6 mil poly caps	153,000 alt. to 121,000	2.70 to 4.40 mb	9.23 hr	0852 CST	Fair	Van Horn, Texas
61	68AP	Pacifica Numbotz	Observations of the spectrum and time variability of Cys X-1, Cys X-2, FR 1929-11 and 1935-11 simultaneous with OSB-7		6-22-72	2040 CST		6821	650	Raven 11.1 x 10 ⁶ .75 mil poly .75 mil poly cap	130,000	3.05 mb	7.39 hr	0649 CST	Excellent	Van Horn, Texas
62	723P	Palling	Two types of phoswich det's ground investigation with various collimators selected during flight.		12-1-71	441 CST		1460	370	Raven 5 x 10 ⁶ .75 mil poly	122,000	4.2 mb 3.85	4 hrs	1250 CST	Excellent	Montgomery, Alabama
63	815P	Palling Ogawa Miyamoto Numbotz Pacifera	MC. III servo, large area phoswich modulation collimator		4-5-74	1904.30 CST		3308	1371	Winren 10.4 x 10 ⁶ .5 mil poly .8 mil poly .8 mil cap	121,000	4.4 mb 3.9	5.4 hrs	4-4-74 0707 CST	Fair	Baselmont, Miss.
64	870P	Matteson Cruber	SEAO A-4 Basic detector array - spec test gondola		12-17-74	1701 CST		2376	1137	Winren 5.06 x 10 ⁶ .6 mil poly .8 mil cap	113,800	6 mb 5.5	8.4 hrs	12-18-74 0350 CST	Level float - did not make throat.	Monteville, Alabama
65	871P	Palling Numbotz Pacifera	MC. III, mod 2 servo, large area phoswich		1-4-75	1800 CST		3090	1241	Winren 5.9 mil poly .9 mil cap	N/A	N/A	N/A	N/A	Burst at 72,000	Cartersburg, Texas
66		Pacifica Numbotz	Spectrum + variability of Cys X-1, Cys X-2, FR 1929-11, also FR 1935-11 simultaneous back-ground dependence.		6/23/75			3172	1205	Winren 13 x 10 ⁶		2.85 mb	6.3 hrs	0615 CST	Fair	Sierra Blanca, Texas
67		Pacifica Numbotz	Spectrum + variability of Cys X-1 and Cys X-2		7/13/75	2108 CST		3220	1276	Winren 13 x 10 ⁶		2.9 mb	4.6 hrs	0608 CST	Fair	Pecos, Texas
68		Palling Ogawa Miyamoto Pacifera Sabal	Up Crab nebula with 10 arc sec resolution													Palestine, Texas
69		Palling Ogawa Miyamoto Pacifera Sabal	Up Crab nebula with 10 arc sec resolution		2/28/77	2036 CST		4180	1337	Winren 17 x 10 ⁶		2.75 mb	4.5 hrs	0014 CST		Marion, So. Carolina

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FLIGHT NO.	EXPERIMENT					LAUNCH				BALLOON				FLIGHT				RECOVERY
	CONTR.	INVESTIGATOR	EQUIPMENT	OBJECTIVE	RESULTS	SITE	DATE	TIME	TYPE	SPD'S WEIGHT	PART'D WEIGHT	BALLOON TYPE	FLIGHT ALTITUDE DEPTH	FLIGHT DURATION	TERMINATION	BALLOON PERFORMANCE	RECOVERY	
70	1055-9	Phillip Owens Miyamoto Pacienza Sobaj	NE 111 mod 2 x-ray photo modulator collimator	Map Crab	Obtained 10 arc sec map of Crab nebula in two dimensions.	Palestine, Texas	1/26/78	1600 CST	Dynamic	4693	1670	714000 23 x 10 ⁶	3.1 mb	5.6 hrs	0134 CST	Good	2nd 4900 ft	
71	1206-7	UCR/UCSD	4X Ge (upside down) UCSD scis.	Crab NE 451 CAS A	Measured nebula continuum and polar light curve - obtained upper limits on NE 451 and CAS A line emission.	"	Oct. 779	1600 launch	Dynamic.	4710	1600	450000	2.9 mb	13 hrs	0700 CST	Good	Yonoville, Tennessee	
72	1206-7	UCR/UCSD	4X Ge	SCM	Observed solar hard X-ray burst - discovered super burst component and microflares.	"	6/17/80	0722 CST	Dynamic	4747	1800	714000 23 x 10 ⁶	2.3 mb	10.3 hrs	1725 CST	Excellent	Van Horn, Texas	

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