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ANNUAL PROGRESS REPORT FOR
"SPACE RESEARCH, EDUCATION, AND RELATED ACTIVITIES
IN THE SPACE SCIENCES"

Cooperative Agreement #NCC 5 - 356

For the period October 1, 1999 - September 30, 2000

Submitted To:

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From:

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A handwritten signature in black ink, which appears to read "David Holdridge", is written over a horizontal line. A long, thin stroke extends from the end of the signature to the right.

Mr. David Holdridge
Program Director

INTRODUCTION:

The Universities Space Research Association received an award of Cooperative Agreement #NCC 5 - 356 on September 29, 1998. The mission of this activity, known as the Cooperative Program in Space Sciences (CPSS), is to conduct space science research and leading-edge instrumentation and technology development, enable research by the space sciences communities, and to expedite the effective dissemination of space science research, technology, data, and information to the educational community and the general public.

To fulfill this mission, USRA recruits and maintains a staff of scientific researchers, operates a series of guest investigator facilities, organizes scientific meetings and workshops, and encourages various interactions with students and university faculty members.

ACCOMPLISHMENTS:

Scientific Research and Instrument Development:

What follows is a brief sample of scientific investigations and instrument development projects, in which USRA staff members are currently engaged, and/or planning for, that directly contribute to the National Space Astronomy and Astrophysics priorities and the mission of the GSFC Space Sciences Directorate.

1. Detection of gamma-ray burst (GRB) counterparts in recent years confirm the large distances to the sources and suggest their potential use as probes of the large-scale structure of the universe. However, without a much greater understanding of the large diversity in observed GRB properties, such efforts are likely to be hampered. Recent studies, in which USRA scientists have participated, have, for example, demonstrated that among the small sample of GRBs at known redshift, about 15, there is a correlation between the time lag between signal pulses in separate energy channels and the burst luminosity. There is also a correlation between GRB brightness and a parameterization of degree of variability. More recently, it has been demonstrated that "dim" GRBs may form a separate subclass, allowing for further refinement to statistical studies. These findings offer the intriguing possibility of calibrating the GRB luminosity function. Since GRBs probably extend to the largest observable redshifts (other than the cosmic microwave background itself), and since they appear to be associated with star formation, they become a powerful tracer of the star formation history of the universe.

2. New model for the emergent spectra from accreting black holes. USRA researchers have applied data obtained from the Compton Gamma Ray Observatory and the Rossi X-Ray Timing Explorer to carry out tests of a novel new model. The basic idea is that the unique properties of accreting black holes, the free-falling matter accelerated to velocities approaching the speed of light in

the vicinity of the black-hole event horizons, lead to a generic spectroscopic signature in the X- and gamma-ray energy domains. These ideas have been tested against the data over the last several years with encouraging results. Now, some relationships between spectral and temporal properties are being explored within this framework. For example, the well known empirical trends of increasing quasi-periodic oscillations (QPO) amplitude with energy, and the decrease of hard-soft signal coherence are explained in a natural manner. Detailed Monte-Carlo simulations are being developed to better quantify this picture.

3. The extragalactic, diffuse high-energy background now seems to be well understood in the X-ray domain, and is reasonably well understood in the high-energy gamma-ray domain. In each case, separate subclasses of unresolved active galactic nuclei (AGN) are believed to be the dominant source. At lower-energy gamma rays, however, the measurements are limited by the internal backgrounds of the instruments flown to date. There does appear to be a significant diffuse component, and it is considered unlikely to be dominated by AGN as in the other high-energy spectral domains. A more likely source is the integrated signal of type Ia supernovae events in star-forming regions of galaxies out to redshifts of ~ 3 . USRA researchers have undertaken an effort to construct a highly detailed instrumental background study for the Transient Gamma-Ray Spectrometer experiment (TGRS). This involves the development of new software to numerically simulate the detailed nuclear decay chains of activation within the detector and spacecraft materials. If successful, this will allow utilization of the large amount of data collected from that instrument to be applied to the most sensitive measurement to date of the diffuse background

4. The X-ray Optics group at Goddard, in which USRA scientists play important roles, is currently focused on four major developments:

- rebuild of the lost Astro-E telescopes while improving their angular resolution (~ 1 arcmin),
- research on the Constellation-X large aperture (1.6m) and high-resolution (1/4 arcmin) optics,
- extend the effective energy band up to 80keV by using multi-layer coatings on the reflecting surface (Infocus, a high altitude balloon experiment, will be the first verification of such technology), and
- ultra-high resolution X-ray interferometry (to 10^{-6} arcsec).

The first three developments are the continuation of a long and successful effort with segmented X-ray mirror technology that was pioneered by the GSFC X-ray Optics group. A thin but strong substrate with a smoothly coated surface (to few Angstroms rms. below the spatial wavelength of millimeters) of epoxy provides the reflecting surface necessary to produce a sub-arcmin X-ray image. The two major design objectives for future X-ray imaging detectors are to minimize weight and maximize the collecting area. With a further improved angular resolution and extension of the energy band, the astrophysical community would

have acquired a powerful spectroscopic instrument to study detailed celestial X-ray sources, thus to understand the nature of emission processes and the underlying physics of the objects.

5. The Rossi X-ray Timing Explorer (RXTE) spacecraft has provided solid evidence to indicate that one of the Milky Way Galaxy's largest stars, Eta Carinae, may in fact be a double star system. The research team bases its conclusions on unusual variations in the intensity of X-rays emitted by hot gas near Eta Carinae, which is located about 7,500 light years from Earth. They believe that the variations are caused by the presence of a massive companion star in orbit around Eta Carinae. The work offers insight into the origin and evolution of a class of stars called luminous blue variables, which are the most massive stars known.

6. A RXTE monitoring program, which a USRA scientist is leading, has been extremely successful. The results from RXTE and other satellites show that the Small Magellanic Cloud (SMC) contains many more transient Be star X-ray pulsars than would be expected based on a simple scaling from the number of such sources in the Milky Way and the relative masses of the two galaxies. One speculation is that there has been a relatively recent burst of star formation in the SMC triggered by a tidal interaction with the Milky Way. These SMC observations are thus providing extensive information on star formation and evolution in both the SMC and the Milky Way galaxies. Recent highlights of the RXTE monitoring program include the discovery of pulsations from SMC X-2 -- a transient source discovered back in the 1970s. However, since the 1970s SMC X-2 has exhibited little activity and pulsations (although expected) had never been found. Evidence from the analysis of the ASM light curve showed that SMC X-2 might be in outburst. Following this up with Target of Opportunity pointed observations with RXTE it appears that an outburst was actually occurring and that pulsations were present at the relatively short period of 2.4 seconds. In addition, yet another new source was found -- XTE J0052-723, which is a 4.78 s pulsar, for which a possible optical counterpart was identified.

One of the more significant discoveries enabled by the RXTE satellite has been the detection of extremely rapid variability from low-mass X-ray binaries. LMXBs consist of a neutron star orbiting so close to a small, cool K or M-type star that material is pulled from the cool star and accreted onto the neutron star's surface, often with explosive results. During thermonuclear bursts, an extremely sharp periodic signal has been seen by RXTE from five different neutron star systems, with typical periods of 2.7 to 3.6 milliseconds, or up to 360 times a second. In addition, quasi-periodic signals are seen at up to 1200 times a second from globs of material rotating extremely rapidly, within a few miles of the neutron star surface. It has long been surmised that millisecond radio pulsars are formed by the recycling of old neutron stars within low mass X-ray binaries; these new observations confirm this hypothesis, and in addition allow scientists to make direct measurements of the mass and radius of the neutron stars, and probe the extreme gravitational and thermal conditions around these sources.

7. Constraints on neutron stars from burst data. RXTE also provides spectroscopic information, with high time resolution, during bursts. USRA

researchers are using the data obtained from very energetic bursts to probe the physics of neutron stars from a different angle. Spectral fits have been performed to a series of very energetic bursts in which the radius of the neutron star photosphere expands due to the radiation pressure of the thermonuclear flash. These LMXBs are in globular clusters, ensuring an unusually accurate knowledge of the source distance, and thus their luminosities. From the luminosity-temperature diagram, workers can study the variation of the Eddington luminosity, as measured by a distant observer at different photospheric radii, during the expansion and contraction phases and thus obtain the gravitational redshift factor. A full general relativistic calculation then results in redshift-corrected estimates for the neutron star mass and radius.

8. Spectroscopy of dip sources. Around a dozen low-mass X-ray binaries show broad and deep dips in their light curves, defining the orbital periods of the systems. The dips are caused by azimuthal structure on the accretion disk, kicked up at the impact point of the accretion stream on the disk. The depth, duration, and spectral evolution in dipping vary considerably between dippers. USRA researchers are analyzing the X-ray spectra obtained with the RXTE PCA during such dips to deconvolve the physics of the emitting regions. In the most luminous, longest-period, dipper, X1624-490 (21 hrs), they have performed simultaneous fits to spectra selected by intensity during dip episodes. These spectra can be well fit with a two-component model consisting of a point-like blackbody from the neutron star and progressive covering of an extended Comptonized region, presumably an accretion disk corona (ADC), corrected for photons scattered into and out of the X-ray beam by an interstellar dust halo. In this description, the absorber on the outer edge of the accretion disk moves progressively across the emission regions. Thus, at any stage, part of the Comptonized emission is absorbed and part is not, giving rise to the observed unabsorbed component. As a point source, the blackbody is rapidly absorbed once the envelope of the absorber reaches the neutron star. The large collecting area of the RXTE PCA provides the high signal-to-noise spectra with high time resolution required to perform this kind of data analysis. Further projects are currently underway with the shorter-period dippers.

9. The Advanced Satellite for Cosmology and Astrophysics (ASCA), even though the mission has ended, continues to yield excellent science, both by the original PIs and by archival researchers. One recent example involves an observation of a high Galactic latitude X-ray source, which has been known as a 111-min binary system. The analysis of the ASCA data, by a group involving USRA scientists, suggest this is a dipping and bursting low-mass X-ray binary (LMXB), presumably at a luminosity similar to other known dipping, bursting LMXBs (10^{36} ergs/s). This puts the source at an extraordinary distance of over 50 kpc, in the outer halo of the Galaxy. This group suggests the possible connection with a globular cluster, Palomar 14, in a similar direction, and at an estimated distance of 74 kpc. If true, this system is the most distant "Galactic" LMXB known.

10. X-ray diffuse emission near the Galactic plane, in a narrow ridge, was discovered with HEAO-1 about 20 years ago. Many subsequent observations have failed to clarify its origin. A group led by a USRA scientist has obtained a deep Chandra exposure in a region of the Galactic plane free of bright discrete sources, capable of detecting sources as faint as 6×10^{31} ergs/s at 10 kpc. Analysis to date suggests that most of the point sources detected in this observation may be extragalactic (primarily AGN). This favors the diffuse origin for the Galactic Ridge X-ray emission, although contributions from fainter individual sources are still possible.

11. In cataclysmic variables (CVs), matter accreting onto a white dwarf is heated to X-ray temperatures, cools via X-ray emission, and then settles onto the white dwarf surface. Using the High Energy Transmission Grating (HETG) instrument on-board Chandra, a group led by a USRA scientist is studying the spectra of several CVs in unprecedented detail. The two systems observed so far with HETG by this group have revealed many lines in the 0.5-3 keV range where this instrument excels. One early surprise has been the difference between the two systems in their Fe-L strength: one system has a rich forest of Fe-L lines, while the other has very little. It is thought that the thermal emission from the cooling plasma is suppressed in the latter system due to optical depth effects, leaving emission from photo-ionized plasma to supply the other (non Fe-L) lines.

12. The Advanced Composition Explorer (ACE) has been on station at the L1 Earth-Sun libration point for over three years. It is the premier satellite for measuring galactic cosmic rays, anomalous cosmic rays, and solar energetic particles and will be for many years to come. Teams, which include USRA researchers are analyzing these data to help explain the differences in evolution from three distinct sources of matter: the Sun, the nearby interstellar gas, and the distant Galaxy.

13. The Heavy Nuclei eXplorer (HNX) is a Small Explorer that will detect cosmic rays that are composed of the heaviest, rarest elements – Iron through Plutonium. HNX will be released by the shuttle and recovered a few years later. Its two instruments will span a region of the periodic table that is poorly studied, and will measure abundances of many elements that have not been previously observed in the cosmic radiation. HNX is currently selected as a SMEX Stage 1 study.

14. The Orbiting Wide-Field Light-Collector (OWL) satellite mission, under study by a GSFC-led team, will measure the energy, arrival direction, and interaction characteristics of the highest energy ($>10^{20}$ eV) individual particles yet observed. While a few particles at these energies have been detected by ground-based extensive-air-shower arrays, their origin and nature are poorly understood and OWL will yield crucial insights into the fundamental physics of the astrophysical processes in which these particles are produced or accelerated. Because the particle flux at these energies is on the order of one per square kilometer per millennium, OWL makes use of the Earth's atmosphere as a huge calorimeter with an active area of about a million square kilometers. OWL does this by observing particle showers produced by the interaction of ultra-high-

energy particles with the atmosphere. The UV fluorescence of atmospheric nitrogen excited the passage of the shower will be measured by a (binocular) pair of satellites to accurately plot the arrival direction of the incident particle and its interaction depth in the atmosphere. On each satellite an optical system with several square meters aperture will be viewed by about one million sensitive photon detector pixels to record the intensity of the shower as well as its spatial and temporal development. A USRA scientist is playing a leading role in developing the science simulations and, ultimately, the scientific justification for the OWL mission.

As part of the OWL study, a balloon instrument known as Nightglow will be flown around the world to observe the ultraviolet background against which the OWL measurements will be made. The ultraviolet glow from reflected starlight, clouds, man-made objects, etc. is poorly understood, but is required to properly design OWL.

15. Studies of the interstellar medium in the Milky Way and of external galaxies are being pursued using data collected by the operating Chandra and XMM-Newton observatories as well as through the use of archived data from the ROSAT mission. The structure and extent of the hot gas in a galaxy is directly linked to its evolution of both discrete sources and diffuse material. The nearby face-on spiral M101 provides an analog of the Milky Way which allows the examination of the central regions of a galaxy similar to our own without the absorption which obscures our view. A deep Chandra observation of M101 provides both the exposure and angular resolution to examine many interesting issues.

XMM-Newton observations of the Galactic X-ray bulge will allow for the parameterization of the extensive hot plasma. This additional information about the ionization states and metallicity of the gas will provide insight into the nature and origin of the material. For instance, is it infalling from a Galactic halo or outflowing as a Galactic wind. The issue of whether the Milky Way has an X-ray emitting halo has not been decided.

16. Shadowing studies of the Magellanic Bridge using XMM-Newton observations will provide interesting limits on the intensity of the cosmological X-ray background of a diffuse origin. Since current cosmological models predict that a significant fraction of the baryons in the universe are tied up in gas at X-ray emitting temperatures, such limits will add significant constraints to these models.

17. A Micro-well gas proportional imager, on which a USRA scientist has played a key role, is under development to perform large-format, high-resolution imaging for X-ray and gamma-ray astronomy. Micro-well detectors are a type of "micropattern" detector, a new, finely segmented, post-microstrip generation of gas proportional counters that exploit narrow-gap electrodes on fine pitch, rather than narrow anodes, to achieve gas amplification. In an application of this technology, LHEA is developing X-ray imagers for the focal plane detector of Lobster-ISS, a soft X-ray all-sky monitor mission that is to fly as an attached payload on the International Space Station. Selected this year for Phase A

development by ESA, Lobster-ISS is targeted for launch in 2008. Lobster will realize an order-of-magnitude sensitivity increase compared to any previous ASM (reaching a flux sensitivity of 1×10^{-12} ergs $\text{cm}^{-2}\text{s}^{-1}$ for one day of observation), provide an unbiased survey of virtually the entire sky, and develop a source catalog three times deeper than the ROSAT All-Sky Survey. Lobster-ISS requires six $20 \times 20 \text{ cm}^2$ focal plane detectors, each with $250 \mu\text{m}$ fwhm imaging resolution and 0.2-3.5 keV bandpass. Already, micro-well detectors exceed the Lobster-ISS resolution requirement. Currently, USRA researchers are designing readout electronics for the large-area Lobster detectors, and developing silicon nitride pressure windows with very high X-ray transmission, especially at the low end of the bandpass, and extremely low permeation rates.

In a related area, the LHEA micropattern detector group is also developing an electron track imager for the Next Generation High Energy Gamma Ray Mission, which has a design goal of a 5-10 fold improvement in angular resolution over GLAST. USRA scientists are developing active matrix readout arrays, based on thin-film transistors (TFTs) built on plastic substrates, for micro-pattern detectors with collaborators at the Center for Thin Film Devices at Penn State. TFT active matrices are the same basic technology used for active matrix displays, and can be made on increasingly large panels. A micro-well detector read out with this technique will demonstrate a large area, low density, fully active volume with high spatial resolution tracking.

The micropattern group also plans to leverage its experience with micro-well detectors and thin pixelized readout systems to construct an X-ray polarimeter for the 3-10 keV band. It has long been recognized that the linear polarization of X-rays contains important, perhaps unique information about compact astrophysical objects. In particular, X-ray polarization may provide the most unambiguous signature of a black hole. A group at the Istituto Nazionale di Fisica Nucleare-Sezione di Pisa recently demonstrated a breakthrough in polarimeter, based on a micropattern detector, that has high modulation below 10 keV, low systematics, and is relatively simple (Nature 411, 662-665 [7 June 2001]). While this recent development appears to be truly revolutionary, further significant improvements are both possible and highly desirable. To fully exploit the scientific information contained in X-ray polarization, sensitive measurements must be made across a large bandwidth. USRA scientists are investigating designs based on the TFT readout that would greatly extend the bandwidth of this exciting new detector technology.

18. The Solar and Heliospheric observatory (SOHO) is one of the most successful missions of the last decade. SOHO allows scientists to investigate 24 hours a day the structure of the heliosphere from the center of the sun to the interplanetary medium. The SOHO data set now covers more than half a solar cycle and, with extended funding, SOHO is on its way to complete one full cycle. It will be the first time that a full solar cycle is studied with such details. Several long-term analyses are ongoing, in which a USRA scientist is heavily involved, and promise to lead to a better understanding of the solar variability. The Extreme-ultraviolet Imaging Telescope (EIT) on board SOHO proved to be most

valuable in the study of Coronal Mass Ejections (CMEs) and discovered a new type of wave event, christened "EIT waves". The EIT also offers the unique opportunity to observe the 304 A resonance line of HeII. This capability of probing helium is of major importance since helium is the most abundant element after hydrogen. The extreme image stability of the EIT led to the discovery of the unexpected prolate shape of the solar limb at 304 A. Also, recent work showed that by using observations at this wavelength, it is possible to extend to helium the powerful diagnostics routinely performed today for hydrogen.

19. Magnetospheric physics modeling and forecasting is another activity involving USRA scientists. Solar wind-magnetosphere coupling issues have been quantified in terms of nonlinear low-order models and nonlinear filters. These systems, driven by the solar wind and/or magnetospheric activity indices, are used to forecast the surface magnetic field in short time-scales. The forecast website is being moved to a new server at the time of this writing, but will be accessible at <http://lep694.gsfc.nasa.gov/RTSM/>

A different modeling project was initiated last year: high-energy electrons in the inner magnetosphere are coupled to solar wind speed variations. The electron fluxes are measured by SAMPEX at a wide range of L shell distances, so that spatio-temporal (L vs. T) maps of activity can be constructed. The electrons are seen to respond systematically to solar wind speed and density variations measured by ACE. Based on these correlations, the temporal and spatial variability of the electron flux is reproduced (currently only at a moderate level of accuracy) by linear systems. This type of research is continuing.

Papers Published:

The USRA scientific staff maintained a high level of scientific productivity during the year. Collectively, we had a total of 129 papers accepted for publication in refereed scientific journals (counting only once papers with multiple CPSS staff co-authors). A summary of the publication citations is attached to this report.

Proposals Submitted & Accepted:

As part of the normal scientific research activities, the CPSS staff is heavily involved in writing proposals - primarily to obtain observing time on space-borne instruments. Over the reporting year, CPSS staff members submitted 120 research proposals - either as principal investigator or as a co-investigator. Indicative of the high level of community action, 89 of these submitted proposals were made in conjunction with a university-based collaborator.

Over the same period, (although, due to the time lag, not always for the same proposals submitted) CPSS staff member received 37 peer-reviewed research awards. The funding associated with these successful proposals totaled \$1,256,116* plus observing time. (*This amount included \$508,417 on an LTSA award that is being administered through the Co-operative Agreement.)

Support for Community Research:

The National Virtual Observatory, as an activity closely tied to the research endeavor, has become a major focus for USRA astronomers. During the past year, this effort has gone beyond abstract concepts with a number of prototype and early development efforts. The underlying goal of the NVO is to achieve the promise of the web to deliver to all astronomers the astounding data and analysis resources that are now being developed in a myriad of ongoing efforts – the SDSS, LSST, 2MASS, FIRST, GryPhyn,

While it is clear that an NVO will be created, USRA scientists have taken a leading role in shaping its growth. Like all great observatories, the NVO needs clear science goals. The adaptation of our experience in building physical observatories to an observatory based on software structures has mandated that we try several prototypes so that we can understand how our science goals can be addressed expeditiously. One major effort is building automated classifiers that use existing information to classify the bulk of unclassified X-ray sources. This effort exercises many of the key elements of the NVO: access to large quantities of distributed heterogeneous data, transformations of results from one representation to another, and large applications designed specifically to access data through the Web. The classifier itself is a substantial advance. Rather than a single classifier, it will use a network of cascading classifiers to enable maximal use of whatever information is available for a given source.

The SkyView virtual telescope addresses another aspect of the NVO. Given the vast amounts of data that are now becoming available, how do we make sure that astronomers are able to navigate and use these resources? The traditional SkyView system has addressed this by extending some of the simplest paradigms that astronomers have – simple maps and images – to data in all wavelength regimes. In its next incarnations SkyView will extend this idea of using the concepts that astronomers are familiar with for datasets they may not have previously attempted, beyond simple imagery to spectra and time series data. SkyView can become the finder telescope for the NVO – allowing the astronomer to quickly locate and browse datasets that can later be used in a more detailed analysis.

Visitors & Consultants

CPSS experienced a continued high level of visitor and consultant activity during the period October 1999 through September 2000. There were a total of 132 visitors - mostly coming to visit GSFC. The average length of visitor stays was 12 days. Visitors may come for one-to two days to give a seminar, or to stay for a few months during the summer. Consultants, of which there were 41 over the reporting period, may be contracted over the full year, but may only work for 10-20 days out of the year.

Workshops & Meetings

CPSS organized, and/or participated in the running of the following meetings and workshops over the reporting period:

- ◆ 12/1-3/99 - Pamela Collaboration meeting; GSFC
- ◆ 12/14/99 - Structure & Evolution of the Universe (SEU) meeting; GSFC
- ◆ 2/25/00 - HEASARC User's Group (HUG) meeting; GSFC
- ◆ 3/20-22/00 - Gamma-Ray Large Area Space Telescope Mission (GLAST) meeting; GSFC
- ◆ 3/23-23/00 - Advanced Cosmic-Ray Composition Experiment for the Space Station (ACCESS) Working Group meeting; GSFC
- ◆ 5/25-26/00 - GLAST Science Working Group meeting; GSFC
- ◆ 6/19-20/00 - Constellation-X Facility Science Team meeting; GSFC
- ◆ 7/19/00 - Compton Gamma Ray Observatory 1-day Symposia "Celebrating GRO;" GSFC
- ◆ 9/22-23/00 - GLAST Science Working Group meeting; GSFC

Space Science Education and Outreach:

USRA scientists team-taught a course, Astronomy 191, at GWU in Washington DC in the Spring, 2000.

A LHEA group led by Dr. Jim Lochner have continued to develop a series of mission learning centers; they re-vamped the "Imagine the Universe!" www site; and they conducted numerous public and education outreach workshops, e.g., "Information Technology in the Service of Education," April 13-14, 2000.

Student Activities

The CPSS Graduate Student Research Opportunities program placed eight students this year with LHEA and CPSS researchers who mentored them for approximately 10 weeks as they participated in various research projects at GSFC.

PROGRESS RELATED TO GOALS:

No explicit program-wide goals were established relative to the activities undertaken within the CPSS. However, from a staffing and financial standpoint, everything appears nominal. As of September 30, 2000, 24 months (and 57%) into the 42 month cooperative agreement, USRA had expended \$10,144,898 or 53% of the Co-op Agreement total value. At the end of the reporting period, USRA employed a total of 40 scientific staff.

PROBLEMS EXPERIENCED:

None





**COOPERATIVE PROGRAM IN SPACE
SCIENCE
(CPSS)**

**NASA COOPERATIVE AGREEMENT
NCC 5 – 356**

**Publications Listing
1999 through 2000**

**UNIVERSITIES SPACE RESEARCH ASSOCIATION
(USRA)**

**David V. Holdridge
Program Manager**

USRA CPSS 1999-2000 Scientific Publications List

1. Adams, Mike, et al. (**Lienard, S.**); "Design and Flight Testing of an Inflatable Sunshield for the Next Generation Space Telescope (NGST);" April 2000, AIAA-2000-1797
2. Allen, G. E., **Digel, S. W.**, and Ormes, J. F.: "What Can Be Learned About Cosmic Rays with GLAST?" Proc. 26th Int. Cosmic Ray Conference (Utah), 3, 515.
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