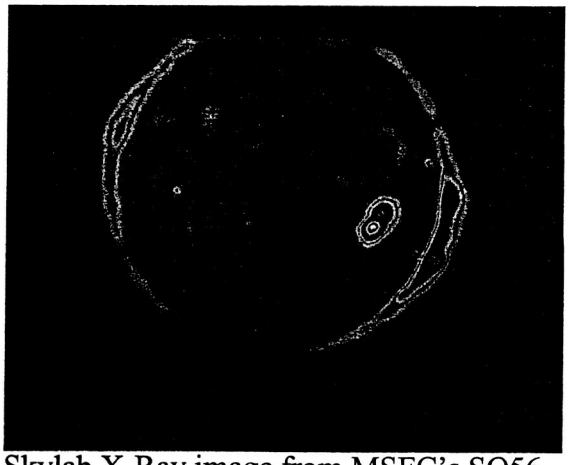
The NRC Research Associateship Program has Greatly Enhanced the Solar Research at Marshall Space Flight Center During the Last Quarter Century

Under the educational Resident Research Associateships (RRA) program, NASA Headquarters funds post-doctoral research scientists through a contract with the National Research Council (NRC). This short article reviews the important influence that the RRAs have had on solar research at NASA's Marshall Space Flight Center (MSFC). Through the RRA program the National Research Council under the National Academy of Sciences has provided the Marshall Space Flight Center's Solar Physics Group with 29 post-doctorial research associateships since 1975. This starting date corresponds with the increased research activity in solar physics at MSFC. A number of MSFC scientists had been working on and supporting NASA's Skylab Mission in operation from May 1973 until February 1974. This scientific effort included the development MSFC's X-ray telescope S056 and the development of the United States' first full-vector magnetograph. Numerous engineers and scientists at MSFC supported the development and operation of the cluster of solar telescopes on the Apollo Telescope Mount (ATM), a principal part of the Skylab orbiting workshop. With the enormous volume of new and exciting solar data of the solar corona, MSFC dedicated a group of scientists to analyze these data and develop new solar instruments and programs. With this new initiative, came the world-renowned solar prominence expert, Dr. Einar Tandberg-Hanssen, from the High Altitude Observatory in Boulder, Colorado and the support of the first two RRAs in support of solar physics research.

These first two associates were Dr. Hugh Comfort, who came from the University of Alabama in Huntsville (and was a student of Dr. S. T. Wu) and Dr. Ted Fay, who came from Indiana University at Bloomington (and was student of Dr. Howard R. Johnson). Because of the new view of the corona and the complex relation of these structures to the magnetic field, there was interest in detailed modeling of the coronal magnetic field. Dr. Comfort contributed to the modeling of nonforce-free magnetic fields in solar active regions supporting data analysis from the MSFC magnetograph and from Skylab. During this post-Skylab time frame, the magnetic field analysis was furthered by NRC associates Dr. B. C. Low, Dr. Nakagawa, and Dr. K. Krall. While a resident researcher at MSFC, Dr.



Skylab X-Ray image from MSFC's SO56 of a solar coronal hole. This image is shown in pseudo-color with the coronal hole open being the central black region. The magnetic field from this region opens directly to solar wind.

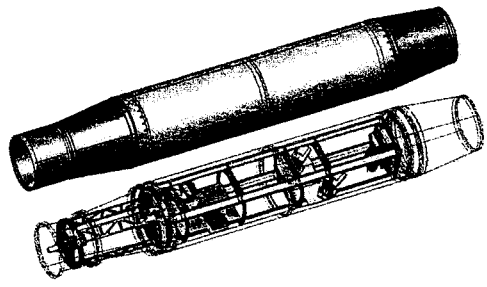
Nakagawa developed an analysis method for the MHD initial-boundary problem for evolution of nonforce-free fields based on the method of near characteristics. Dr. Low worked on the field and plasma configuration of a filament overlying a solar bipolar magnetic region. Working with Dr. Wu at UAH, Dr. Low wrote a paper on a class of analytic solutions for the thermally balanced magnetostatic prominence sheet. Dr. Krall studied the sheared photospheric velocity fields inferred from spot motions and compared the velocity shear with transverse magnetic field orientation changes observed with the MSFC vector magnetograph. During this time these associates helped develop solar science within the government facility and worked with the solar scientists at the University of Alabama in Huntsville to develop a new solar community.

During these post-Skylab years, as the space agency looked beyond the ATM solar success to new possible programs in solar physics (e.g., Photoheliograph, Solar Corona Explorer, and Advanced Solar Telescope), the agency selected a dedicated orbiting solar observatory. Dr. Tandberg-Hanssen became the principal investigator for the Ultraviolet Spectrometer and Polarimeter (UVSP) on this next important solar mission, the Solar Maximum Mission (SMM). SMM was launched February 14, 1980 and reentered the earth's atmosphere on December 2, 1989. During this time the operation of the MSFC Vector Magnetograph was in full operation and supported the Solar Maximum Mission. With the data from SMM and the MSFC magnetograms much of the research concentrated on relating the influence of magnetic field in the heating of the corona and the processes behind the production of solar flares. In this SMM era, the associates were Drs. Doug Rabin, Marcos Machado, Fukuo Nagai, Jason Porter, Chung-Hyuk An, and Juan Fontenla. These associates came from across the nation and around the world. During this period of time the Huntsville solar group was further stimulated with the arrival of Dr. Ernest Hildner (1982) from High Altitude Observatory to head the solar physics group at MSFC and Dr. Gordon Emslie (1981) from the University of Glasgow joined UAH, who in the 1990's would be interested in the imaging solar flares in hard X-rays using Fourier telescopes (which were precursor studies to RHESSI).

Working with MSFC's Dr. Ron Moore and Dr. Mona Haygard, Dr. Rabin studied the thermal conduction from the sides of coronal loops heated by the current dissipation with reference to the observed temperature distribution in the transition region. He also investigated submergence of the magnetic field in active regions. Another investigation which studied UVSP observations and MSFC magnetograms was undertaken by Dr. Jason Porter, who researched coronal heating in connecton with structure of the photospheric magnetic field. The research by Drs. An and Nagai centered on magnetohydrodynanic and magnetostatic models of filament eruption and flares. Dr. An working with Dr. Moore and Dr. Steve Suess of MSFC investigated Alfven wave propagation and trapping as a mechanism of solar heating. Dr. Machado working with MSFC and UAH scientists studied the magnetic energy release of hard X-rays during the impulsive phase of flares and studied the importance of magnetic separatrices as a site of energy release.

Associates that arrived later included Drs. K. S. Balasubramaniam, Zdzislaw Musielak, Parame Venkatakrishnan, Ashok Ambastha, Hirokazu Yoshimura, and Mukul Kundu.

These helped expand the solar research in magnetography and into other areas of solar physics in which new members of the MSFC scientific team were involved. With the arrival of Dr. David Hathaway from the National Solar Observatory, the MSFC solar group expanded its research interest into the solar interior. Dr. Yoshimura, working with Dr. Hathaway, investigated dynamo models to explain the 11-year solar cycle. Dr. Musielak as a RRA developed analytical solutions to the wave equations for steady vertical compression waves in an isothermal hydrostatic atmosphere. This wave study was a community interaction with Drs. An and Fontenla of NRC and Drs. Moore and Suess of MSFC. In 1986, Dr. John M. Davis came from American Science and Engineering and AS&E's solar X-ray program to become the leader of the solar group at MSFC. Working with Dr. Davis of MSFC, Dr. Fontenla of NRC conceived the idea of developing a magnetograph to observe the chromospheric magnetic Zeeman lines. From that initial idea, the MSFC solar group is now developing the SUMI (Solar Ultraviolet Magnetograph Investigation) rocket payload. The work of Drs. Balasubramaniam, Venkatakrishnan and Ambastha furthered the observation and analysis program for the MSFC Vector Magnetograph. This work included the exploration of the Stokes spectral profiles using a filter magnetograph, evaluation of magnetic shear in off-disk-center active regions, and magnetic shear variation in solar active regions with MSFC's Dr. Hagyard , Ed West and Dr. Gary.



The SUMI sub-orbital rocket instrument being built by MSFC solar physicists to study the chromospheric magnetic fields. The system composed of a new technology of self-filtering 30-cm telescope and ultraviolet toroidal grating spectrograph.

The next major era in solar physics was the launch of Yohkoh, a Japanese Solar mission with US and UK collaborators. It was launched into near-earth orbit in August of 1991 and was lost December 14, 2001. Over its lifetime, it has provided a complete solar cycle worth of valuable data about the Sun's corona and solar flares. During the 1990s the associates were Drs. Reiner Hammer, Steve Nerney, Silvano Fineschi, Ted LaRosa, Beverly Stark-Kublin, Debi Choudhary, Francis Fekel, David Falconer, Shyamsundar Parhi and Alphonse Sterling. The resulting research included a better understanding of the million degree coronal in terms of its heating, structure, and dynamics. Dr. Hammer and MSFC colleagues investigated the effects of thermal conduction on the heating and energy balance of open coronal regions. Investigating the magnetic field on the heliopause, Dr. Nerney of NRC and Dr. Steve Suess of MSFC described the heliospheric terminal shock and the morphology of the heliosteath. Dr. Parhi and Dr. Suess studied the associated instabilities occurring in the coronal plumes. Working with Dr. Hagyard, the magnetograph was supported with the work of Drs. Stark-Kublin and Choudhary in

quantifying active regions and their flare productivity. Dr. Fineschi studied ultraviolet impact line polarization expected in hot solar plasmas during solar flares.

During this period there were three additional important solar satellites providing new observations. These were the Transition Region and Coronal Explorer (TRACE) (launched April 1, 1998), the ESA/NASA Solar and Heliospheric Observatory (SOHO) (launched December 2, 1995) and the ESA/NASA Ulysses Mission (launched October 6, 1990) which explores the inner heliosphere over the Sun's north and south poles. Working with MSFC's Dr. Moore, Dr. Sterling, studied "EIT crinkles" (transient, localized brightenings in the images from the EUV Imaging Telescope) and morphologically homologous solar flares using X-ray observations from Yohkoh and ultraviolet observations from SOHO spacecraft. Working with SOHO, Yohkoh, and TRACE, and the MSFC vector magnetograph, Drs. Falconer of NRC and Moore have undertaken detailed investigations of the correlation of coronal mass ejections (CMEs) and coronal heating with magnetic shear measurements from the MSFC Vector Magnetograph. In 1994, Dr. James Miller joined Dr. Emslie at UAH. Working with Drs. Moore of MSFC, Emslie of UAH, and Miller of UAH, Dr. LaRosa studied electron bulk energization in solar flares and compared the Fermi acceleration of electrons and protons in reconnection-driven magnetohydrodynamic turbulence.

Recently, the Reuven Ramaty High-Energy Solar Spectroscopic Imager (RHESSI) was launched on February 5, 2002, with Dr. Emslie and Miller studying this data. The NRC associates at MSFC since 2000 have been Drs. Hori, Yohei Yamauchi, and the return of Dr. Choudhary. Dr. Choudhary returned to MSFC as a senior NRC associates and is working with Dr. Gary in developing a chromospheric-photospheric study of the magnetic field to explore with observations the three-dimensional structure of the solar atmosphere. Dr. Yamauchi with Dr. Suess is studying electron heat flux in pressure balance structures (PBS) as observed by Ulysses. They have concluded that PBSs are generated due to network activity at the base of polar plumes and that their magnetic structures are like current sheets or plasmoids.

In the near future, three new solar satellites, STEREO (2005), Solar-B (2006), and Solar Dynamics Observatory (2007) will be launched into orbit, and MSFC's sub-orbital Solar Ultraviolet Magnetograph Investigation (SUMI) will be flown. With this important new era of solar stereography, chromospheric magnetographs, and high-resolution observations, the future associates will continue to provide a stimulating interaction for the Huntsville solar community. The Solar Ultraviolet Magnetograph Investigation (SUMI), which was initially conceived by an NRC associate, will be flown in ~2005 and this data and future extensions of this program should provide useful portals for future RRAs. In 2001, the MSFC solar group moved into the newly established National Space Science and Technology Center (NSSTC) on the campus of UAH. The NSSTC is a collaborative research and education initiative focused on selected key scientific disciplines. In part, it consists of researchers and resources from MSFC and UAH that enables cutting edge basic and applied research and fosters education of the next generation of scientists and engineers. As such it provides a closer solar community in

Huntsville and allows student and post-doctoral associateships to participate fully in the associated activities. Looking backwards, the table below lists the full 29 RRA/NRC associateships that have enhanced the solar research at MSFC and show its success. This list also gives their current location which points out the extended influence of this program throughout the national and international solar community.

NASA's Resident Research Associateship Program is a NASA Education program managed by the National Research Council. This program has provided MSFC and the associates with a productive scientific platform which has successfully enriched the productivity of the Huntsville solar community. It has provided cross-fertilization of theorists, observers, and instrumentalists.

The NRC Associates at the MSFC in Solar Physics
during the last quarter century
showing dates at MSFC and Current Position

Ashok K. Ambastha (1989, 1992): Solar Physicist at Udaipur Solar Observatory
Chang-Hyuk An (1984-1986): Physicist at Photon Research Associates, Inc, Huntsville.
K. S. Balasubramaniam (1989-1990): Solar Astronomer at National Solar Observatory
D. P. Choudhary (1997-1998, 2003): NRC Associate at MSFC
R. Hugh Comfort (1975): Physics Professor at University of Alabama in Huntsville
David A. Falconer (1995-1998) Solar Physicist at University of Alabama in Huntsville
Theodore D. Fay, Jr. (1975): Physicist at PHI Applied Physical Science, Mission Viejo, CA
Francis C. Fekel (1992): Physics Professor at Tennessee State University
Silvano Fineschi (1998-1991): Astrophysics Professr at Universita di Torino, Italy
Juan M. Fontenla (1986-1988): Solar Physicist at Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder
Reiner G. Hammer (1991-1992): Solar Physicist at Kiepenheuer-Instituts fur Sonnenphsik, Germany
Kuniko Hori (2002) Solar Physicist at the Solar Terrestrial Research Center, Japan
Kenneth R. Krall (1977): Physicist at Kaman Sciences Corp., Colorado Springs
Mukul R. Kundu (1986): Radio Astronomer at Professor University of Maryland
Theodore N. LaRosa (1991-1993): Physics Professor at Kennesaw State University, Georgia
Boon Chye Low (1980-1981): Astrophysicist at High Altitude Observatory, Boulder
Marcos E. Machado (1985-1986): Director at Comisión Nacional de Actividades Espaciales Buenos Aires, Argentina
Zdzislaw E. Musielak (1986-1988): Physics Professor at the University of Texas in Arlington
Fukuo Nagai (1981-1983): Solar Physicist at Chiba Institute of Technology, Japan
Yishinari Nakagawa (1978-1980): Retired professor form Chiba Institute of Technology, Japan
Steven F. Nerney (1992-1994): Physics Professor at Ohio University –Lancaster
Shyamsundar Parhi (1997-1999): Physicist at Bartol Research Institute, University of Delaware
Jason G. Porter (1984-1986): Solar Physicist at MSFC/NASA
Douglas M. Rabin (1982-1984): Head of the Solar Physics Branch at GSFC/NASA
Beverly A. Stark-Kublin (1995-1996): Engineer at Nichols Research Corp., Huntsville
Alphonse C. Sterling (1999-2001): Solar Physicist at United Applied Technology, Huntsville
Parame Venkatakrishana (1987-1988): Head of the Udaipur Solar Observatory, India
Yohei Yamauchi (2002-2003): NRC Associate at MSFC
Hirokazu Yoshimura (1986-1988): Astrophysicist at the University of Tokyo, Japan