I. Summary

An internationally-recognized consortium of five major research universities, (New Jersey Institute of Technology (NJIT), University of Maryland (UM), University of New Hampshire (UNH), California Institute of Technology (Caltech), and University of Alabama in Huntsville (UAH), plus an industrial laboratory (Lucent Technologies) and two government laboratories (Naval Research Laboratory and Air Force Phillips Research Laboratory), are proposing a comprehensive and unique suite of solar-terrestrial measurements and modeling that will significantly advance the state of knowledge of the nature of space weather. Space weather can significantly, and negatively impact, DoD operations, as defined in the FY 2001 MURI Topic #29. Our team has unique observational capabilities with dedicated state-of-art solar optical and radio telescopes. Our unique U.S. solar observational resources will be combined with measurements from additional instruments (associated with consortium members and other groups) that are flying in the heliosphere and in the earth's magnetosphere. The data that will be acquired will be analyzed and interpreted, and used in models of consortium members who number among the most internationally-recognized space plasma theorists. The central theme of our proposal is to use our unique solar data, along with space-based solar and heliospheric data to forecast and predict the initiation of space weather events, follow their propagation and development in the heliosphere, and predict their likely impact on the near-earth environment.

We propose to utilize NJIT's existing, unique optical and radio observing facilities at Big Bear Solar Observatory (BBSO) including our various magnetographs, and our global H-alpha network, and Owens Valley Radio Observatory (OVRO) solar array for microwave radio imaging spectrometry. We also propose to further extend these in two key areas – microwave radio spectrometry and optical vector magnetograpy – with world-wide networks capable of 24-h coverage of the sun. For heliospheric observations, we will rely on spacecraft data from SOHO, Wind, and ACE

Using the expertise of our team, we will emphasize: (1) 3-D magnetic structure before and after major events from observation and modeling, (2) the physical cause of and correlations among different types of solar activity (flares, filament eruptions, and Coronal Mass Ejections (CMEs), (3) prediction and/or forecasting of solar activity, (4) real-time prediction of properties of magnetic clouds resulting from CMEs, (5) study and, perhaps, forecast of >10 MeV proton (SEP) events, and (6) prediction of likelihood and magnitude of geomagnetic storms. As an independent check of the particular models of filament eruptions, we will also include a laboratory component to simulate filament eruptions. The laboratory "data" will be closely compared with the results of observations and models. The above components will enable to understand the underlined physics of CMEs, and provide tools to predict geomagnetic disturbances and SEP events.

II. The Science Team

1) From NJIT, which operates BBSO and the Solar Array at OVRO, the members are Phil Goode, Director, BBBSO, Distinguished Professor of Physics; Haimin Wang, Associate Director, BBSO, Associate Professor of Physics; and Dale Gary, Director, Solar Radio Array, Associate Professor of Physics

2) Paul Bellan, Professor of Applied Physics at Caltech does laboratory modeling and theory of filament destabilization.

3) Terry Forbes, Research Professor at UNH does MHD Modeling of filament eruptions, flares, and magnetic reconnection

4) Profs. Stephen White and Mukul Kundu, UM, do radio observations, modeling, and interpretation of radio data

5) S.T. Wu, Director, CSPAR, Distinguished Professor, UAH, does modeling of CMEs and the solar wind.

6) Dr. James Chen, Research Physicist (NRL), does CME modeling, magnetic cloud modeling, and the prediction of geomagnetic storms.

7) Dr. Don Neidig, Title? Air Force Phillips Lab, Principal Investigator of ISOON

8) Dr. Louis J.Lanzerotti, Distinguished Member of Technical Staff, Lucent Technologies does heliospheric research.

9) International Partners (we are currently negotiating with other possible partners for radio and magnetograph sites) in Kanzelhohe Solar Observatory in Austria, Beijing Observatory and Yunnan Observatory in China.

III. Instruments

1. Halpha Network

Based on our successful experience in making high resolution full disk Halpha observations at BBSO, and the urgent need to monitor the evolution of the solar chromosphere continuously during the solar maximum, we have deployed a network for Halpha full disk observations utilizing existing facilities at BBSO in California, Kanzelhohe Solar Observatory (KSO) in Austria, and Yunnan Observatory (YO) in China. Each of these observatories has over 300 sunny days a year, good seeing conditions, competent observing staffs, and well-established Halpha telescope systems. With this network, we can monitor solar chromospheric activity with $1''$ pixel resolution and one minute cadence round-the-clock for most of the year, with the best available data quality. The network is operating normally.

2. Vector Magnetograph Network

BBSO and Huairou Observing Station (HSO) of Beijing Observatory have collaborated in round-the-clock vector magnetograph observations since 1988. Our night gap is 4-8 hours. Both stations have cadence of about 5 minutes and spatial resolution of about 1 aresec. We are currently seeking a third partner to form a 3-station vector magnetograph network.

3. Radio Network (DALE: COULD YOU CONDENSE THIS PART)

We are currently building at NJIT, for Lucent Technologies, a small (2 meter diameter) radio telescope for monitoring solar bursts, called the Solar Radio SpectroPolarimeter (SRSP). This telescope is highly automated, based on a similar system being deployed by the US Air Force, called the Solar Radio Burst Locator (SRBL–see the web page at http://srblserver.caltech.edu/). The telescope that we are building, the SRSP, is somewhat different from SRBL, in that improves on sensitivity to weaker bursts by replacing the spiral feed with a linear one. The trade-off is that it does not have the capability to locate bursts on the disk, but the linear, dual-polarized feed allows a continuous recording of the full burst spectrum from 1-18 GHz in two polarizations. Thus, it is complementary to the Air Force SRBL system, but is superior for the studies of space weather that we propose. The system is designed for unattended operation for up to weeks at a time, with the data being taken in a single, standard mode that does not normally require intervention. It has an automatic warning system when it detects a flare.

As an equipment procurement associated with this proposal, we propose to build two additional dishes to be placed in strategic locations, at existing radio sites, one in Europe and one in the Asia/Pacific region, to provide continuous 24-hour coverage of solar bursts.

4. Space Data

The combination of surface data discussed above with the data directly image CMEs is an unique aspect of the proposal. The most important data set will be LASCO coronagraph data which observe CMEs. The STEREO will certain extend and improve LASCO. In addition, EIT will provide EUV imaging of low corona eruptions. MDI will provide continuous monitoring of photospheric magnetic fields of the whole Sun.

Two kinds of data from Wind and ACE will be used: the magnetometer and particle detectors. These data provide in-situ measurements of structure magnetic clouds and particle properties.

IV. Scientific Objectives

Our scientific objectives are to forecast and predict the initiation of space weather events, follow their propagation and development in the heliosphere, and predict their likely impact on the near-earth environment. We divide them into two related parts: study of geo-effective CMEs and studies of SEP events.

IV.A Study of Geo-effective CMEs

1. We will use combined, high-resolution vector magnetograph data from BBSO and HSO (and possibly that from a third station) to observe the magnetic structure of solar active regions almost continuously. With the observed vector magnetic fields as boundary conditions, we propose to carry out force-free extrapolations to obtain the 3-D magnetic configuration before and after major events that produce geo-effective CMEs. Based on the results of studying many events, we will develop tools to predict eruptions from continuous monitoring of magnetic fields. At the same time, we will learn the underline physics of the events.

Different models will be tested and compared with observations. These include erupting flux model (Chen), MHD model (Wu) and Hybrid model (Forbes). HERE NEEDS TO BE EXPANDED BY THEORISTS

As a test of how filament eruption occur, Prof. Bellan (Caltech) can produce filaments in the laboratory replicating the complexity of what happens on the sun. We intend to use the observational results to guide laboratory studies and vice-versa. Also, the output of the theoretical modeling of filaments and CMEs will be tested in the laboratory.

2. We will use the data from Hα network to provide real-time reports of all flux emergences, filament disappearances and flares. When a major event occurs, the morphology (such as the extent of flux emergence, the filament helicity) will be used as boundary conditions in models, to predict the propagation of CME in heliosphere. The predictions will include the speed of the CME and magnetic structure of consequent magnetic clouds. The predictions will be checked by the magnetic cloud data observed by ACE and Wind. The large number of events will provide a useful tool to sort out which kind of flare/filament eruptions may have associated geo-effective events. The result will certainly be used as a forecast tool. The software that we develop will be coordinated with the ISOON team for use in their planned network coverage of Hα observations.

THE REST OF THIS NEEDS TO BE CONSIDERABLY SHORTENED.

3. More subtle characteristics of radio phenomena, such as spatial characteristics of interacting magnetic loops, will be studied with the multi-frequency imaging data available with the Owens Valley Solar Array (OVSA), to shed light on the development of instabilities in the solar atmosphere that lead to interplanetary events. The goal is to understand these interactions and recognize the important pre-event geometries that signal the likelihood of activity.

4. Assuming that our proposed world-wide radio network is available, we will compare the 1-18 GHz spectral characteristics of solar bursts with the metric radio events that are observed in Europe and the Asia/Pacific region. There are presently no meter-wave spectrographs in North or South America with which to compare, so without the network this aspect will not be possible. With the network, we will be able to link solar radio events near the surface with type II/IV events seen in ground-based metric spectrographs that are clearly associated with CMEs and interplanetary shocks. We will also follow these events into interplanetary space when they are observed with the radio spectrograph on the Wind spacecraft. We will seek signatures in such events, as well as magnetic geometries predicted by our heliospheric modeling, that are predictive of highly geo-effective CMEs and interplanetary shocks. We will incorporate any observable parameters into a prediction model that can be used to give real-time forecasts and warnings of impending activity.

IV.B Study of SEP Events

1. SEPs must be accelerated by evolving magnetic fields evolve. Observations of the evolution of solar surface vector magnetic fields and 3-D modeling will enable us to understand the acceleration processes of these particles. Are these particles accelerated during the reconnection process, or by shock waves? These can be tested by the models. The results from the models will be compared with observations from in-situ particle instruments in ACE and Wind, as well as radio observations.

2. The microwave spectral data will pertain to the high-energy component of solar flares, and diagnostics of the energy release region such as magnetic field and plasma parameters. We will use the microwave spectroscopic data to do a correlation analysis of microwave spectral characteristics with other characteristics such as optical, hard X-ray, and heliospheric (SEP) events. Successful correlation of robust characteristics in the radio spectra (e.g. spectral hardening through the burst, or the presence of highly polarized, coherent emission in the spectrum) with later production of interplanetary protons will allow us to forecast when such damaging radiation may occur near the Earth. We anticipate that with a world-wide network we can give a warning tens of minutes to hours ahead of the arrival of these particles.