

1. Science Concept

There is growing realization of the extent to which the sub-systems (the spheres) of terrestrial space science and the processes therein are interconnected, such that the composite of these regions, Geospace, acts as a coupled, complex system whose pieces and properties should not and cannot be studied in isolation. Whole-atmosphere models extending from interactions with the oceans and land masses below to the magnetosphere and solar drivers above are examples of the effort to understand the workings of the system as a whole. Individual features and research topics contribute to the composite picture, but a larger-perspective point of view is needed to begin to appreciate how these components work together to shape our space environment, its dynamics, and variability. At present, this larger-picture view of Geospace is extremely data deficient. Individual projects and missions address separate regions, topics and processes. Flexible, coordinated, cost-effective observations of Earth's space environment are needed to provide the wide range of measurements with the spatial distribution and temporal resolution needed to support Geospace monitoring, research, modeling, and predictive activities. An initiative to undertake a phased implementation of a program to field and coordinate Distributed Arrays of Scientific Instruments (DASI) is a much needed component of the Space Science research and development plan for the coming decade.

This white paper does not attempt to describe the final global network of next-generation instruments and data infrastructure which is the goal of the DASI initiative, but strives to express the need to take the first steps to structure and coordinate activities in the planning and utilization of space research instrument arrays in support of the broad needs of Geospace system research and to provide the real-time data and analysis capabilities needed for Space Weather modeling and predictive activities. DASI is already underway, with many regional arrays in place and operational. An initial effort to coordinate activities, facilitate data exchange and utilization, and to expand the data-user community within the North American region is suggested as a Phase I (developmental) implementation of DASI. Development of miniaturized instruments and efficient deployment strategies would lead to extended array coverage and capabilities while addressing cost efficiency - potentially during a DASI Phase II which would take increased funding and commitment. Incorporation of observations from small-satellite constellations, from extended ocean and remote-location instrument platforms, and strong international participation would be a goal for the implementation of DASI on the global scale needed to address the requirements of studying, understanding, and predicting Earth's coupled Geospace system.

2. DASI: Advancing space science and operational capabilities

The enhanced observational capability and ready data availability provided by DASI will enhance and extend the scientific activities of the owners and users of the contributing arrays by providing access to correlated data and contributing phenomena observed over an extended (global) spatial scale, providing contextual information with which to interpret localized phenomena (e.g. the system history and context of specific RBSP observations). Wide-ranging, readily-available data will support system-level research projects, extending the scope of research programs to incorporate Geospace system aspects and influences. For operational capabilities, the DASI concept addresses directly the needs of Space Weather research and operational products to have access to

global real-time observations of atmospheric and space characteristics and phenomena. DASI is a part of providing an integrated space situational awareness capability.

3. Cost estimates

Adopting a phased approach to DASI implementation would avoid the unrealistic task of trying to design, cost, and coordinate the needed global observational capability before further developing concepts, strategies, and instrument anointment based on the arrays and infrastructure already in place. Phase I - enhancing coordination and communication among existing regional arrays and users - would come at flexible, lower cost (and be classified as a Small Project) since the size and pace of this prototype regional program could be scaled to the amount of support available. A second Phase of enhanced instrument development and deployment would take appropriate levels of targeted funding. As the need and utility for DASI instrumentation becomes apparent as the program gains momentum, the scope of a global DASI Phase III and its final costs would scale with the priority given to such a program by the community.

It is worth noting that the NSF CEDAR research program began 25 years ago as a no-new-funding Phase 0 effort to coordinate separate research activities in a way which demonstrated the value-added having a common focus and goal. CEDAR Phases I, II, and III followed, each with enhanced levels of funding, community participation, and scientific contribution.

4. DASI: Specific Review Criteria:

a. Identified as a high priority in previous studies

A small instrument distributed ground-based network (DASI) was recommended as a Priority small program in the previous Solar and Space Physics Decadal Survey. Following the Survey recommendation, an NRC community workshop and report were organized to further explore the DASI concept (ref). The DASI report emphasized three recurrent themes: 1) the need to address Geospace as a system, 2) the need for real-time observations, and 3) the insufficiency of current observations (observational space physics is data starved).

b. Contribution to Panel themes;

The Scope of the Survey includes the physics associated with the magnetospheres, ionospheres, thermospheres, mesospheres, and upper atmospheres of the Earth and other planets. In many instances, these areas have been treated as separate 'spheres' and missions and programs have embraced a focus too narrow to explore the inter-sphere connections which are inherent in the Geospace system. By providing a growing observational framework and access to data from instruments addressing a wide spectrum of Geospace characteristics, DASI contributes to the better understanding of both the sub-system processes and the working of the Geospace system as a whole.

c. Contributes to important scientific questions

DASI by providing for a wide spectrum of inter-related geospace observations with good spatial and temporal resolution is a key element in addressing the coupled-system aspects of Geospace. The inter-relationship of thermosphere effects and variability to the characteristics and processes in Earth's magnetosphere are largely unexplored and thus not incorporated in descriptive or pre-

dictive models because of the lack of coordinated observations which could be used to address such system effects. An adequate observational base is needed to advance our understanding of all aspects of Geospace connections.

d. Contributes to applications and/or policy making

The development of a coordinated, readily-accessible network of distributed geospace observations directly supports the needs of Space Weather real-time monitoring and prediction activities. An operational DASI network will provide a robust framework for supporting the Space Weather requirements. This is particularly evident in that the specific processes and effects (e.g. ionospheric scintillations) of interest in the Space Weather arena are manifestations of the complex, coupled system which is Geospace, requiring distributed real-time observations for both monitoring and understanding.

e. Complements other observational systems or programs

The DASI concept- facilitating the acquisition, exchange, and multi-user access to distributed real-time geospace observations - directly complements existing and planned ground and space-based missions exploring the processes and interconnections of Earth's space and atmospheric environment. By combining resources addressing characteristics and processes in the different spheres of the geospace system, DASI supports the extension of the scientific value of such systems and missions by providing a ready means for exploring the linkages among the sub-systems of geospace. For example, RBSP (Radiation Belt Storm Probes) will provide in-situ probes of Earth's energetic particle environment. Processes investigated there depend on ambient conditions (e.g. cold plasma often of ionospheric origin and M-I coupling effects on the plasma waves which energize and scatter the radiation belt particles), which require a system understanding of conditions and processes occurring in the underlying ionosphere and thermosphere.

f. Is affordable (cost-benefit)

Initial aspects of DASI instruments and infrastructure already exist and are in operation supporting regional studies of aspects of the Geospace system. A cost-effective beginning for a more-extensive DASI program will be in supporting the scientific coordination and development of the infrastructure which will provide ready access to such existing data resources to an extended user community. Implementation of such efforts in a region which already has considerable observational resources and data dissemination networks (e.g. the North American sector) would make infrastructure development, testing, and initial coordination activities less costly. Major space research instruments including incoherent scatter radar facilities, portions of the high-latitude and new mid-latitude SuperDARN HF radar networks, THEMIS GBO optical and magnetic observatories, as well as numerous small -instrument arrays are in place in this region. As a coordinated system perspective of our space science activities gains emphasis, development of our existing instrument and coordination infrastructure capabilities will produce highly cost-effective returns.

g. Readiness

For a North American regional DASI, major space research instruments including incoherent scatter radar facilities, portions of the high-latitude and new mid-latitude SuperDARN HF radar networks, THEMIS GBO optical and magnetic observatories, as well as numerous small -instrument arrays are in place in this region. Joint US and Canadian activities (AMISR radars at Reso-

lute Bay, THEMIS GBO networks as well as a large body of active researchers addressing aspects of ground and space-based geospace research in the region speak to the readiness of this region to undertake an initial deployment of a regional DASI program.

The new AMISR ISRS (supported in past Survey) have been put into operation and their numbers are increasing with phased-array radars in place in Alaska and Resolute Bay with others underway in Argentina and a 2nd installation at Resolute Bay and proposed for Antarctica. Combined with existing dish ISRs at Sondrestrom, Millstone Hill, and Arecibo, the radars, whose operations are coordinated and data distributed to a broad user community via MADRIGAL, form a large-instrument backbone for a regional distributed-instrument capability for obtaining detailed real-time observations needed to address geospace science and space weather objectives.

h. National and international plans and activities.

Within the NSF research community, the GEO Division has issued a GeoVision plan which promotes the investigation of the Earth environment as a coupled system, with both the understanding of system processes and sub-system interconnections, and human-system interactions and effects (e.g. Space Weather and aspects of Climate Change) being important goals for GEO research. The DASI initiative addresses these cross-coupled objectives nicely in its objective to make space science observations readily available to the more-broad research, applications, and education communities. On a more-focused scale, a significant portion of ground-based space science research activities are supported by the Upper Atmosphere Research Section of the GEO Directorate's Division of Atmospheric and Geospace Sciences (AGS). Here, the CEDAR (Aeronomy/ITM) research community has put forward a new Strategic Plan which puts an emphasis on addressing the broader aspects of CEDAR research within the framework of Geospace system science. DASI, both with its instrument arrays and coordination and dissemination of data, can be envisioned as a major observational capability supporting the implementation of the new CEDAR plan.

References

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