White Paper for *Frontiers of Plasma Science Panel*

Date of Submission:	***6/17/2015***

Indicate the primary area this white paper addresses by placing "P" in right column.
Indicate secondary area or areas by placing "S" in right column

	"P", "S"
• Plasma Atomic physics and the interface with chemistry and biology	
• Turbulence and transport	P
• Interactions of plasmas and waves	P
• Plasma self-organization	
• Statistical mechanics of plasmas	S

Indicate type of presentation desired at Town Hall Meeting.

	"X"
Oral	
Poster	
Either Oral or Poster	
Will not attend	X

Title:	Laboratory Simulation of Space Plasmas
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(Limit text to 3-pages including this form. Font Times Roman size 11.
1 page of references and 1 page of figures may also be included. *Submit in PDF format*.)

- ***Describe the research frontier* and importance of the scientific challenge.**

The dynamic behavior of the near-Earth space environment plays an increasingly critical role of all aspects of modern life. Critical communications, navigation, and surveillance rely on uninterrupted satellite links. The wide variability in geospace conditions, or space weather, is driven by varying solar inputs. The effects of solar storms on the magnetosphere and ionosphere can have dramatic direct consequences not only on space assets, but also on terrestrial systems such as power grids.

The increasing reliance on space for everyday activities underscores the critical need for understanding of the complex interactions connecting the Sun and Earth. While much has been learned from *in situ* space investigations, satellite data is inherently statistical in nature and subject to the vagaries of the uncontrolled environment. Laboratory experiments specifically designed to recreate properly scaled space plasma conditions offer an important, cost-effective complement to space experimentation.

Laboratory simulation of space plasma offers many advantages. Plasma sources with variable density and temperature ranges, coupled with flexibility in magnetic field strength and configuration, allow for sufficient tenability of key dimensionless plasma parameters, which control the underlying physics, to conduct experiments relevant to the phenomena under investigation. Laboratory experiments have the distinct advantage of knowing and controlling the initial conditions and boundary conditions. Unlike the

natural environment, these conditions can be reproduced on demand, allowing for detailed investigations using a wider selection of diagnostic tools, techniques, and data acquisition specifications than are typically available to *in situ* experimentalists. Such experiments are a critical element in the validation of theoretical and computational models, allowing the models to be applied with confidence to space data.

Numerous plasma phenomena relevant to both space and fusion plasmas are of particular interest, including:

- turbulence
- waves & instabilities
- wave-particle interactions
- plasma energization and transport
- radiation belt dynamics (energetic particle interactions)

- ***Describe the approach to advancing the frontier and indicate if new research tools or capabilities are required.***

Key to advancing the laboratory investigation of space plasma phenomena is the availability of facilities with sufficient flexibility in plasma parameters, magnetic field strength, and plasma species selection to allow proper scaling to important dimensionless parameters. Plasmas large enough to support the long transverse and magnetic-field-aligned wavelengths that characterize space plasma waves, while also allowing sufficient vacuum gap between the plasma and chamber walls to minimize boundary effects are required. Facilities such as the NRL Space Physics Simulation Chamber[1-6], the UCLA LArge Plasma Device (LAPD)[7,8], and the West Virginia University Large Experiment on Instabilities and Anisotropy (LEIA)[9,10] already exist that meet many of these requirements.

Each of these devices possesses unique capabilities that may be leveraged in collaborative partnerships. Taking advantage of established facilities would allow for extension of device capabilities in strategic ways for specific experimental requirements. Investment could be targeted for hardware acquisition, instrument development, experimental time, and data analysis.

- ***Describe the impact of this research on plasma science and related disciplines and any potential for societal benefit***.

Given the ever increasing reliance on satellite accessibility for everything from DoD operations to GPS navigation to space weather effects on terrestrial power systems, improved understanding of space physics is of tremendous societal benefit. Laboratory experimentation plays a critical role in developing this understanding by bridging the gap between theory/computation and space observations. Laboratory validation builds confidence in theoretical models building toward the development of predictive capabilities for space weather conditions.

Laboratory investigations often lead to the development of new diagnostic tools to be used in the space environment and lead to new insights and understanding of phenomena such as solar wind turbulence, electrostatic and electromagnetic wave generation and propagation, wave-particle interactions and plasma energization, radiation belt dynamics, scintillations affecting communications, and the couplings of the ionosphere and atmosphere, magnetosphere and ionosphere, and the Sun-Earth system.

References (Maximum 1 page)

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2. "Spontaneous electromagnetic emission from a strongly localized plasma flow", E. M. Tejero, W. E. Amatucci, G. Ganguli, C. D. Cothran, C. Crabtree, and E. Thomas, *Phys. Rev. Lett.*, **106**, Art. No. 185001 (2011).

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4. "Exploiting laboratory and heliophysics plasma synergies", J. Dahlburg, W. E. Amatucci, *et al.*, *Energies*, **3**, 1014-1048 (2010).

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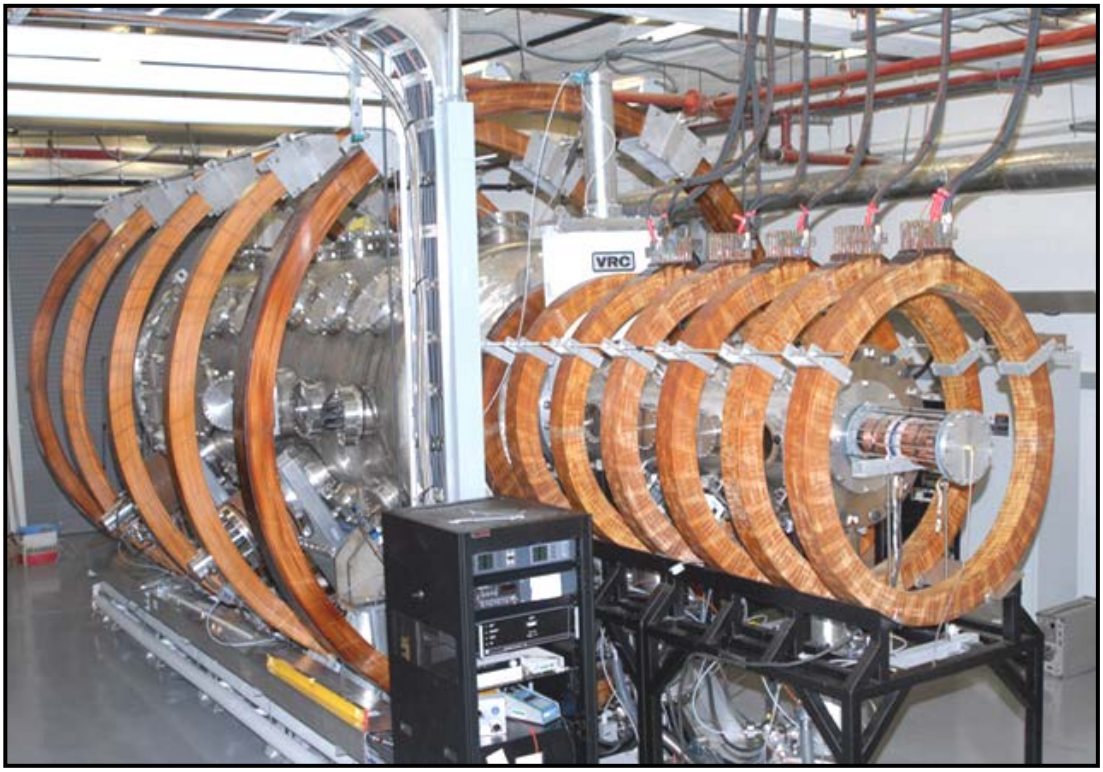
9. "The hot hELicon eXperiment (HELIX) and the large experiment on instabilities and anisotropy", *J. Plasma Phys.*, **81**, Art. no. 345810103 (2015).

10. "Spontaneous ion beam formation in the laboratory, space, and simulation", J. Carr Jr, *et al.*, *Phys. Plasmas*, **20**, 072118 (2013).

Figures (maximum 1 page)



Photograph of the Naval Research Laboratory Space Physics Simulation Chamber. The Space Chamber is a large volume plasma device dedicated to the investigation of plasma processes relevant to the geospace environment. Large-volume plasmas are created with dimensionless parameters scaled to ionospheric or magnetospheric regions of interest.