NSTX-DiMES PROJECT

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PROPOSAL

General Atomics (GA) and the Divertor Material Evaluation System (DiMES) team propose a collaborative project on the NSTX device to design, fabricate, and install a sample changer mechanism to insert plasma edge material samples and diagnostics, either flush with a lower divertor tile or into the plasma edge of NSTX.

GOAL

The NSTX-DIMES project is to develop the data-base for plasma facing materials. This goal directly supports the NSTX program by enabling two NSTX scientific objectives:

- **The investigation of plasma SOL properties for x-point divertor and natural divertor configurations**
- **The investigation of unique features in ST plasma edge and SOL under high power densities**

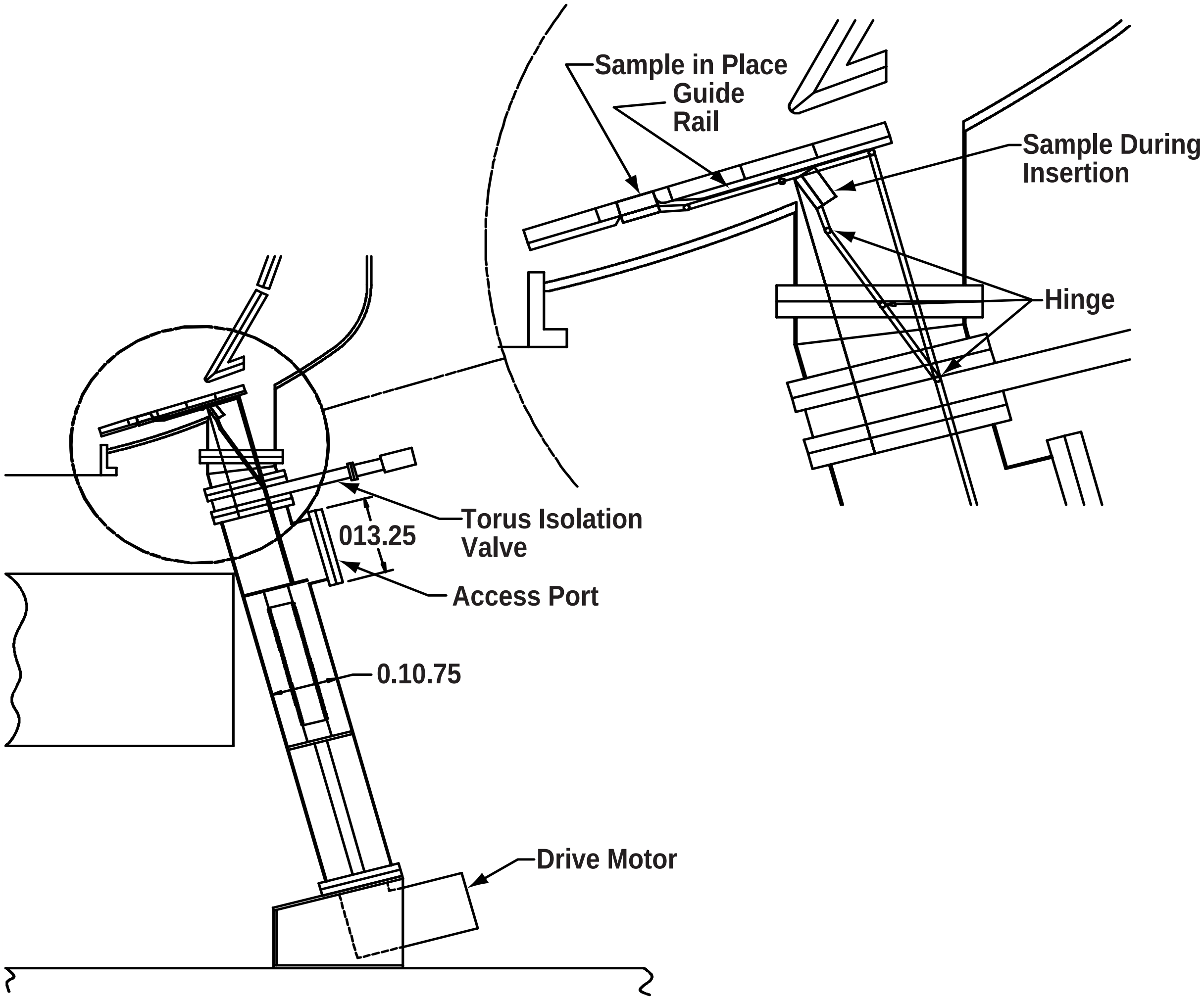
BENEFITS TO THE NSTX PROGRAM

- **Provide data on surface material erosion and tritium (deuterium) up-take**
- **Provide data on the effect on the core plasma from eroded material transport**
- **Evaluate surface effects from NSTX wall conditioning methods**
- **Provide the data for the selection of divertor plasma facing solid or liquid materials for NSTX, DTST and ST-VNS**
- **Support development of edge physics diagnostics**
- **Provide engineering for future, higher power NSTX operation, DTST and ST-VNS.**

In summary, the NSTX-DIMES project will address the key issues of NSTX divertor design and of impurity limits on plasma core performance, will provide additional, valuable scientific data, and will enable collaboration with four of the leading fusion institutions.

NSTX-DiMES EXPECTED RESULTS AND DELIVERABLES

- **Design, fabrication, testing and installation**
- **Experiments and data collection**
- **Modeling and analysis**
- **Diagnostics development**



Schematic of the NSTX-DiMES sample changer system concept (an example)

NSTX-DIMES INSTITUTIONAL ROLES

Institution	Role	Collaborators
GA	Coordinate design, fabrication, testing, installation, operations, maintenance, experiment selection, data collection, data analysis, data distribution.	Dr. C. Wong
PPPL	Provide NSTX access. Provide local monitoring and support.	Dr. H. W. Kugel
UCSD	Coordinate NSTX-DIMES experiments and analysis.	Dr. D. Whyte
ANL	Coordinate modeling tasks	Dr. J. Brooks
SNL	Support sample preparation and analysis, and provide diagnostics support	Dr. R. Bastasz, Dr. W. Wampler

NSTX-DiMES IMPACT ON NSTX

Material transport of the eroded material will constrain the performance of NSTX. The effects will likely be more severe than for conventional tokamaks because of the projected higher surface heat flux and particle flux at the strike point of the divertor, and because of the projected short connection length on the outboard side and high mirror ratio. The experimental data needed to understand, quantify and alleviate the constraints will be provided by NSTX-DIMES.

The operation of NSTX-DIMES as a user probe facility for the PSI community will stimulate noteworthy national and international interest in ST plasma edge materials research, and almost certainly will yield benefits to future NSTX upgrades or follow-on machines aspiring to higher performance regimes.

NSTX-DiMES ROLE IN ELUCIDATING ST PHYSICS

The NSTX-DiMES project staff will work closely with the NSTX Boundary Physics group to establish understanding of the ST plasma material interaction physics. In selecting NSTX-DIMES experiments, first priority is in addressing issues that are unique to NSTX. An example is the projected short connection length on the outboard side and high mirror ratio associated with the low aspect ratio of NSTX. This can lead to erosion and particle transport behavior, which is quite different from that of a conventional tokamak.

The NSTX-DIMES project is also a vehicle for the development of advanced in-situ diagnostics, which for providing hard-to obtain, real-time boundary physics data.

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SUMMARY OF KEY DIII-D DiMES RESULTS

Year	Experiments/Modeling	Significance
1992	8 month exposure of 12 graphite tiles	First measure of net erosion and redeposition for extended exposure
1995	Exposure of Be, W, V and Mo	First dedicated material exposure to controlled, characterized, divertor plasma
1996	Exposure of Be and W coatings	Measure erosion rate 10 times higher than predicted by ITER
1997	Exposure at high heat flux	Confirm erosion rate and deuterium up-take of long term exposure by short term exposure experiments
1997	Collection of carbon dust	First measurement of carbon dust under dedicated experiment
1998	Chemical sputtering	First measurement of chemical sputtering rate in detached plasma at low Ti
1999	Divertor surface erosion/redeposition	Confirmed similar D concentration pattern led to identification of similar lower divertor erosion/redeposition patterns on DIII-D, ASDEX and JET
2000	Chamber wall erosion	Confirmed chamber wall erosion has major contribution to the source of carbon
2001	Exposure of Li	Confirmed the significance of liquid–metal MHD effect during locked mode, ELMs and low power L-mode discharges, with the last case causing a disruption due to a massive injection of Li into the core

The inventory of tritium up-take for plasma facing component materials is another complicated phenomenon, and the tritium co-deposition with carbon in DTST or ST-VNS can represent a safety hazard as the tritium can be easily mobilized in the event of an accident. Tritium up-take can be measured with the proposed NSTX-DIMES experiment.

NSTX-DIMES EXPERIMENT AND ANALYSIS TASKS

The data base for plasma facing materials needs to be extended to the ST regime of higher heat flux, projected short connection length on the outboard side and high mirror ratio, all associated with the low aspect ratio of NSTX. The NSTX heat fluxes striking the plasma facing components are expected to be >10MW/m2 which is a factor of 5 higher than the average divertor heat flux of about 2 MW/m2 in DIII–D. Information on candi_date plasma facing materials is of primary importance in predicting the lifetime of NSTX components, evaluating NSTX core performance, and identifying suitable NSTX operat_ing modes for enhancing component longevity. Plasma facing materials being considered include C, Be, W, Mo and liquid lithium. Other promising materials are SiC-composites and special ceramics such as Ti3SiC2. In-situ exposure is required to couple erosion effects with the resulting material transport. Integrated testing will be essential to study the MHD effects with liquid lithium

The NSTX-DIMES system can be used as a test vehicle for plasma diagnostics develop_ment, and can be used as a carriage for unique plasma diagnostics that cannot be installed permanently inside NSTX.

EXPERIMENT AND ANALYSIS TASKS

Task	Why	How
Evaluate the integrated erosion and MHD effects of liquid lithium	Provide necessary data for the use of liquid lithium at the NSTX chamber surface	Expose lithium samples with temperature control to different plasma regimes and strike point locations.
Measure and model erosion and deposition	Extend data base to ST divertor plasma regime	Expose samples to well-characterized plasma. Model with ANL codes.
Measure and model deuterium up-take	Extend data base to ST divertor plasma regime	Measure deuterium content of exposed samples. Compare with previous measurements.
Evaluate and select divertor plasma facing materials	Extend data base to ST divertor plasma regime; accommodate the high divertor heat/particle fluxes	Expose and analyze material samples.
Study and model eroded material transport	Advance understanding of divertor/SOL tranport coupling	Simultaneous erosion and transport measurements.
Develop in-situ diagnostics*	Support in-situ measurements for all of above	Design, fab and test with NSTX-DIMES sample changer
High heat flux testing	Provide engineering data for future, higher power NSTX operation	Evaluate material damage under short-pulse, high heat flux operations.

*** A solid-state hydrogen sensor for the measurement of the flux and energy spectrum of plasma particles striking the walls could also be developed for the NSTX-DIMES project.**

PPPL Role

PPPL's role is to provide NSTX access, local monitoring and local support. Dr. Henry W. Kugel, NSTX contact for the scientific area of divertor, SOL, power and particle handling, will be the PPPL contact. PPPL will provide local support and will facilitate early installation. During the NSTX-DIMES user probe experimental phase, PPPL will monitor and support planning and execution of physics experiments and analysis.

Arrangements for Access to the NSTX Device

During the NSTX-DIMES design phase PPPL will assist in the design by providing NSTX engineering design details. Dr. Kugel has identified candidate lower ports with accessible floor space below the port (Sketch of the design is attached). Data acquisition and control room equipment are also available. The NSTX research team will be encouraged to participate in all aspects of NSTX research and will have full access to NSTX experimental data.

GA Role

GA will coordinate all phases of the NSTX-DIMES project. The Principle Investigator will be Dr. Clement P. C. Wong, currently the Principal Investigator for the DiMES program. Design, fabrication and initial testing of the sample changer will be done at GA and will be supported by the GA Fusion Group staff and facilities. Installation, operations and maintenance actitivies at PPPL will be coordinated by Dr. Wong with PPPL support as described above. During the user probe experimental phase, Dr. Wong will work with Dr. Kugel or designate to establish effective communications between NSTX staff, the NSTX-DIMES team and the user group. We anticipate that limited plasma discharge time will be available to perform dedicated experiments. Dr. Wong will be responsible for obtaining a NSTX/NXTS-DIMES/user group consensus on experiment selection and priority. He will also oversee data collection, data analysis and distribution of results.

UCSD Role

Dr. Dennis G. Whyte of UCSD, currently the Experimental Coordiantor for the DiMES program, will be the NSTX-DIMES Experimental Coordinator, responsible for the execution of experiments. He will work with the Principle Investigator to maintain the NSTX-DIMES sample changer system and to coordinate the exposure of samples. He will organize the divertor plasma characterization data collected from NSTX divertor diagnostics and distribute the data to the NSTX-DIMES team and users.

ANL Role

ANL will apply existing sputtered impurity transport and related modeling codes to analyze NSTX-DIMES probe data. Output of the analyses will include predictions of gross and net sputtering erosion rates, sputtered impurity near-surface densities, impurity flux to the core plasma, and photon emission. Code output will be compared with probe erosion/redeposition data, and photon and/or other relevant plasma diagnostic data. The analyses will (1) help plan experiments, (2) interpret data, (3) validate codes and models for NSTX plasma-surface interactions. Dr. Jeffrey N. Brooks, who currently provides these analyses for the DiMES program, will lead the modeling work.

SNL Role

SNL will be responsible for preparing and characterizing samples before and after exposure in NSTX, and for developing new measurement and diagnostic techniques. Sample characterization is done to determine changes in composition and microstructure of surfaces due to plasma exposure and wall conditioning, and to understand how these changes are related to corresponding changes in plasma conditions. They will develop new measurements. The SNL work will be led by Dr. W. R. Wampler of SNL-Albuquerque and Dr. Dr. R. Bastasz of SNL-Livermore, who have been supporting equiva_lent work for the DiMES program since 1992.

DESIGN, FABRICATION, TESTING AND INSTALLATION

We will do an NSTX-DIMES changer mechanical design, which will allow insertion of test materials and instrumented samples into the divertor plate region of NSTX without venting the machine. After discussion with NSTX stuff and considering mechanical design and configuration constrains, a mechanical insertion mechanism will be proposed. A bellows design will separate the insertion mechanism from the primary vacuum. The use of a dedicated vacuum pumping system will separate the motorized moving parts from the high vacuum of NSTX. Control of the sample movement and alignment with the surrounding tiles will be done from the NSTX control room. Allowances will be made from as many as 10 electrical leads to be connected to external instruments. With the sample changer in place, material samples can be exchanged overnight after as few as one plasma shot. Design concepts will be assessed, a candidate will be selected and refined at the beginning of the NSTX-DIMES project.

EXPERIMENTS AND DATA COLLECTION

The NSTX-DIMES team and user will select the sample to be exposed in the divertor of NSTX. These samples, possibly with depth marker and coated with relevant material, will be supplied by SNL-Livermore. The NSTX-DIMES experiment coordinator will work with the NSTX experimental planning group to identify the exposure of the sample under piggyback or dedicated exposure conditions, and then to select and set up the plasma discharges sample exposure. The data from available divertor and core diagnostics will be collected. These will become inputs for analysis and modeling. Experiments will include the characterization of transients associated with wall conditioning, start-up and plasma detachment, correlation of the particle energy spectrum with divertor radiated power, and the influence of gas puffing on the wall flux.

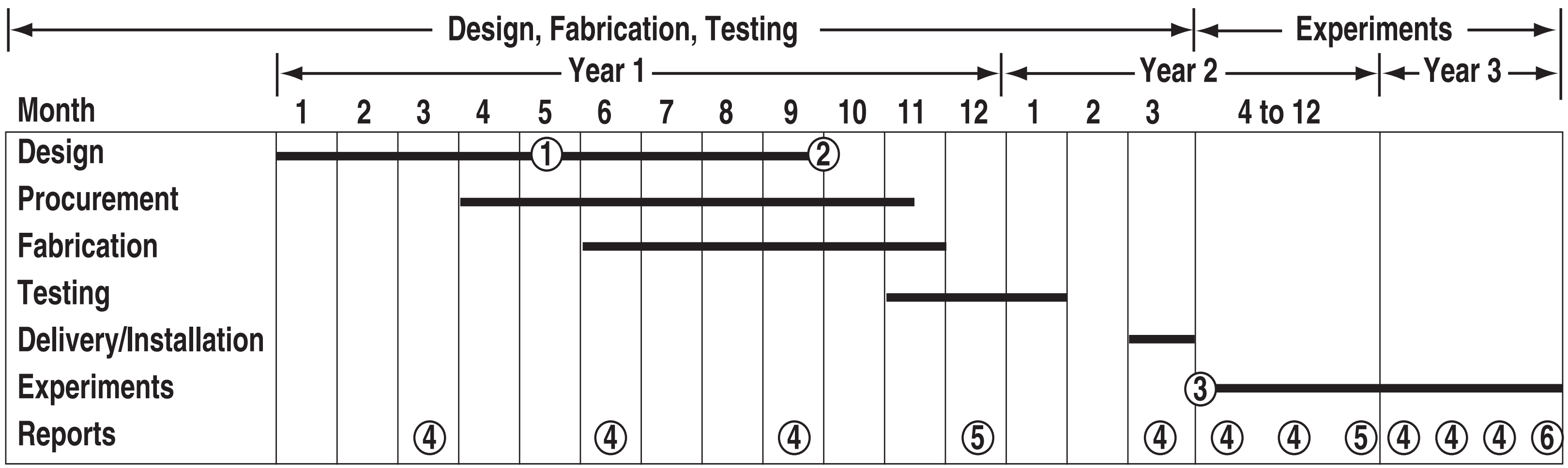
MODELING AND ANALYSIS

We will apply existing sputtered impurity transport and related codes to analyze NSTX-DIMES data. The results will be used to plan experiments, interpret experiments and validate codes/models for NSTX plasma-surface interactions. We will determine the sputtering, near-surface transport, and re-deposition of probe materials by using measured plasma parameters, near-surface data (i.e.,Ne, Te, particle and heat fluxes), and geometry/magnetic field data as input to the coupled WBC Monte Carlo and REDEP kinetic impurity transport codes and related codes (BPHI sheath code, ITMC and other sputtering codes). Output of the analyses will include predictions of gross and net sputtering erosion rates, near-surface sputtered impurity densities, and impurity flux to the core plasma, photon emission and particles transport. Code output will be compared with probe erosion/re-deposition data, and with photon and/or other relevant plasma diagnostic data.

DIAGNOSTICS DEVELOPMENT

The NSTX-DIMES system can be used as a test vehicle for plasma diagnostics development, and can be used as a carriage for unique plasma diagnostics that cannot be installed permanently inside NSTX. An in-situ measurement system equipped with remote control and data acquisition capabilities could be developed to increase the amount of information obtained from NSTX-DIMES. Data obtained from this diagnostic will enable assessment of coupling of plasma performance and surface material erosion.

NSTX-DIMES PROJECT SCHEDULE AND DELIVERABLES



① Preliminary Design Review (PDR)

② Final Design Review (FDR)

③ Initial Operation

④ Quarterly Report

⑤ Annual Report

⑥ Final Report

FACILITIES AND RESOURCES

Installation and subsequent operation of the NSTX-DIMES system will be done at PPPL, requiring facility support from PPPL. NSTX-DIMES design, fabrication, initial testing and all program coordination will be done at GA, utilizing the resources of the GA Fusion Group and the DIII–D National Fusion Facility, operated by GA for DOE.

NSTX-DIMES design, fabrication and testing activities will be done using the same infrastructure of laboratories, shops and technical support as was used for the similar, successful DiMES program. The NSTX-DIMES program will be supported in the areas of planning, scheduling, cost control, subcontracts, quality control, record management, accounting, computers, CAD, graphics and technical typing by the same organizational elements which supported the TPX PFC contract with PPPL, and which are a key factor in GA's continuing "superior" rating for DIII–D and related fusion activities.