Materials and PFCs TSG Update
Status from last PAC and latest discussions

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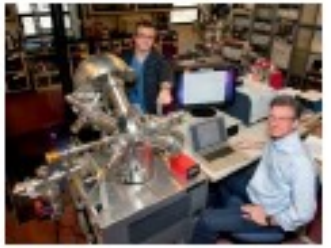
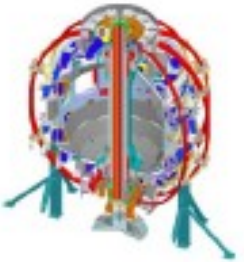
11/16/12

As of last PAC

Summary:

- Li PFCs have demonstrated promise for
  - Superior plasma performance
  - High heat flux handling
  - May solve PFC neutron damage and erosion issues in FNSF and demo.
- High confidence implementation requires R&D on:
  - Surface chemistry
  - Off-line heat flux tests of PFC prototypes
  - Tokamak integration
- Staged approach in place from atomistic simulations & lab experiments to test stands, LTX, EAST collaborations, leading to Li-PFC implementation in NSTX-U





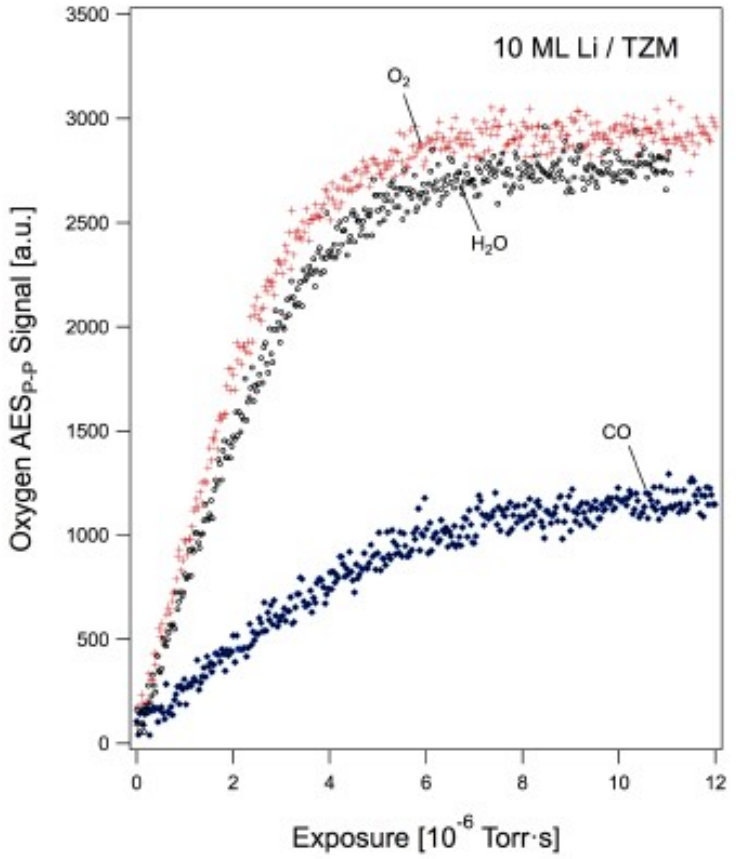
Last PAC 5-year outline

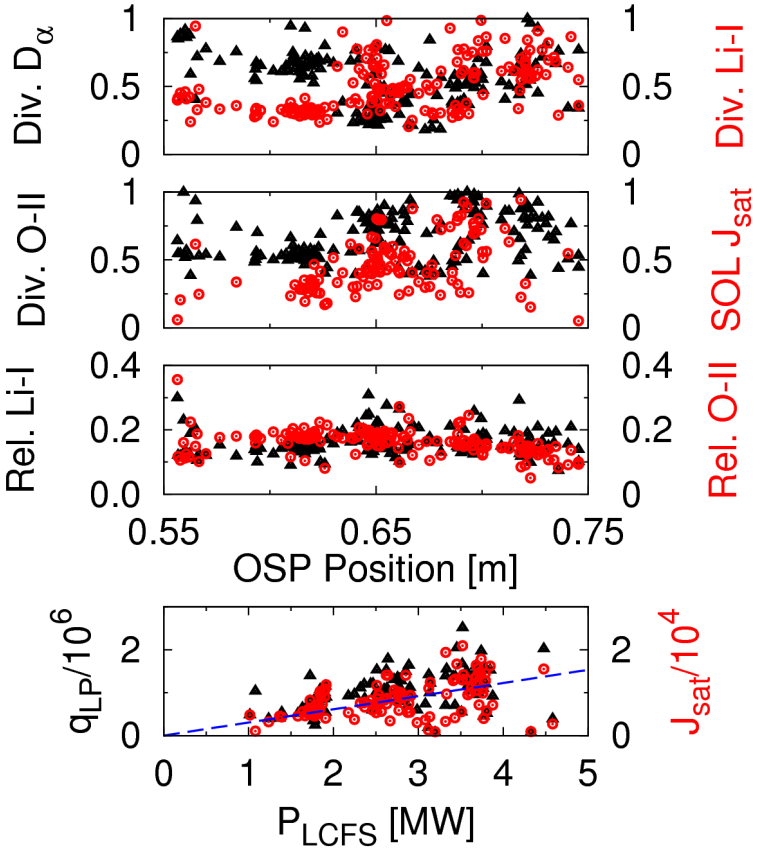
NSTX-U Plan for Years 1-5 of operation:

PAC29-5c
PAC29-18

- Year 1-2:
  - Test Li evaporation for pumping longer pulse duration NSTX-U plasmas.
  - Test Li evaporation to upper vessel by evaporator/injector, He diffusion, electrostatic sprayer.
  - Assess impact of full wall Li coverage on pumping, confinement
  - Test ELM control by midplane Li granule injector
  - Test Li-PFC prototypes on Magnum PSI and possibly LTX or EAST
- Year 2:
  - Down select to best flowing Li-PFC concepts
  - Test on Magnum PSI and LTX or EAST
- Year 3-5:
  - Test flowing Li-PFC on at least one toroidal sector of NSTX-U, possibly full toroidal coverage system, pending lab-based tests and modelling

Flowing system proposed to mitigate oxidation





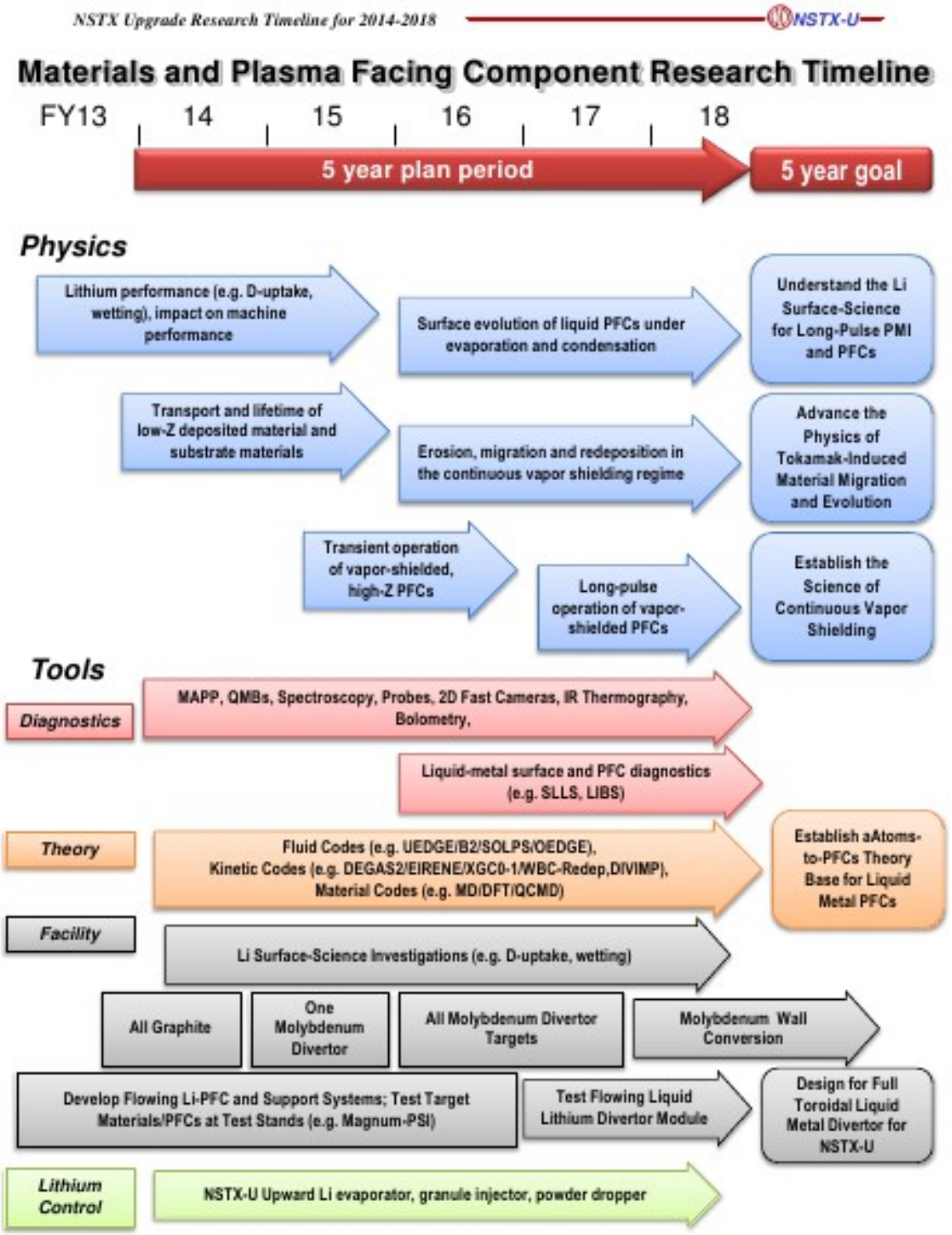
Oxidation rate measurements in surface-science laboratory (A. Capece, APS 2012)

LLD contamination by oxides likely due to vacuum conditions in machine – little effect on divertor emission, core plasma performance (Jaworski, IAEA 2012, APS)

Materials and PFCs TSG Discussions for the 5-year plan

- **Lithium surface-science for long-pulse PMI and PFCs**
  - Skinner, Capece, Roszell, Koel on-going lab experiments
  - Discharge performance with Li conditioning, extension to long-pulse, D-uptake/retention
- **The physics of tokamak-induced material migration and evolution**
  - Erosion of material, migration, redeposition (measure via QMB, marker tiles, etc.)
  - Magnum-PSI experiments on film lifetimes (Abrams APS) – near-surface transport of Li, O, B coatings on graphite and TZM
- **Establish the science of continuous vapor shielding**
  - Examine the interaction of high-temperature lithium surfaces with incident plasmas (Magnum-PSI experiments+, Jaworski, Rognlien, Stotler APS, corresponding modeling work)
  - Liquid-metal target system development to ensure replenishment for NSTX-U pulse lengths

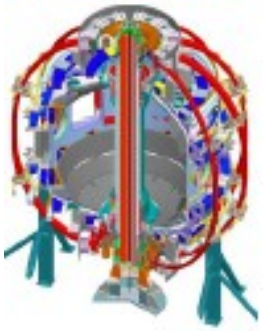
Assumed something like the incremental budget when originally created

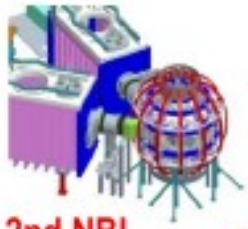


Incremental budget

Team developed comprehensive long-range plan supporting ITER, FNSF
Budget guess: requires 10-15% increment → must reduce scope up to 1/3

2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Upgrade Outage	1.5 → 2 MA, 1s → 5s				Advanced PFCs, 5s → 10-20s				





Start-up and ramp-up	0.3-0.5 MA CHI	0.5-1 MA CHI	0.2-0.4 MA plasma gun	up to 1 MA plasma gun	ECH/EBW	1MW → 2 MW	Extend NBI duration or implement 2-4 MW off-axis EBW H&CD		
Boundary physics	Divertor cryo-pump	Divertor Thomson	Diagnostics for high-Z wall studies						
Materials and PFCs	U or L Mo divertor	U + L Mo divertor	All High-Z PFCs	Hot High-Z FW PFCs					
Lithium	Li granule injector	Upward LiTER	Flowing Li divertor or limiter module	Full toroidal flowing Li divertor					
MHD	MGI disruption mitigation tests	Enhanced RFA/RWM sensors	NCC coils	NCC SPA upgrade					
Transport & turbulence	High k_θ	δB polarimetry	DBS	PCI or other intermediate-k					
Waves and Energetic Particles	HHFW feedthru & limiter upgrade	HHFW straps for EHO, *AE	Dedicated EHO or *AE antenna						
Scenarios and control	Rotation control	Snowflake control	Divertor radiation control	q_{min} control	Control integration				

U.S. FNSF conceptual design including aspect ratio and divertor optimization

Baseline budget

Strawman/draft upgrades to be in place by 2018 assuming base budget
(More work needed by Masa, myself, and you to better define schedule)

	2014	2015	2016- 2018					
	Upgrade Outage		1.5 → 2 MA, 1s → 5s					
New center-stack	Start-up and ramp-up		Upgraded CHI					
				ECH/EBW 1 MW				
	Boundary physics			Divertor cryo-pump				
	Materials and PFCs			U or L Mo divertor				
	Lithium			Li granule injector	Upward LiTER			
	MHD			MGI disruption mitigation tests	Enhanced RFA/RWM sensors			
	Transport & turbulence			High k_θ	Polarimetry and DBS			
2nd NBI	Waves and Energetic Particles			HHFW feedthru & limiter upgrade				
	Scenarios and control			Control: rotation, snowflake, divertor radiation, q_{min}