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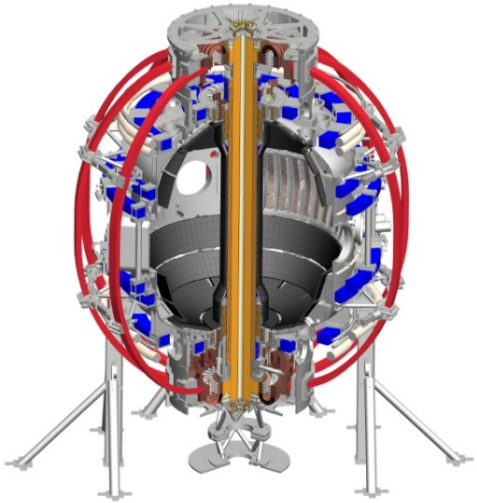
NSTX-U Program Update

J. Menard
For the NSTX-U Research Team

NSTX-U Team Meeting
PPPL LSB B318
December 4, 2014



Coll of Wm & Mary
Columbia U
CompX
General Atomics
FIU
INL
Johns Hopkins U
LANL
LLNL
Lodestar
MIT
Lehigh U
Nova Photonics
Old Dominion
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X Science LLC

Culham Sci Ctr
York U
Chubu U
Fukui U
Hiroshima U
Hyogo U
Kyoto U
Kyushu U
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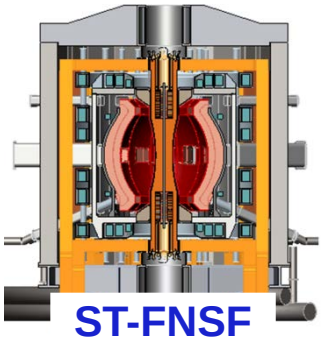
U Tokyo
JAEA
Inst for Nucl Res, Kiev
Ioffe Inst
TRINITI
Chonbuk Natl U
NFRI
KAIST
POSTECH
Seoul Natl U
ASIPP
CIEMAT
FOM Inst DIFFER
ENEA, Frascati
CEA, Cadarache
IPP, Jülich
IPP, Garching
ASCR, Czech Rep

Outline

- FESAC strategic planning update
- NSTX-U Organizational Structure
- Preparation for Research Forum

NSTX Upgrade mission elements

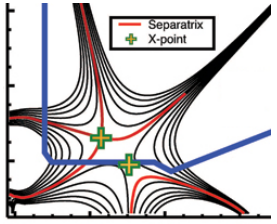
- Advance ST as candidate for Fusion Nuclear Science Facility (FNSF)



ST-FNSF

- Develop solutions for the plasma-material interface (PMI) challenge

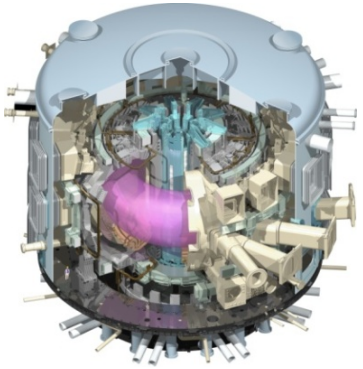
Liquid metals/Li



"Snowflake"

- Explore unique ST parameter regimes to advance predictive capability - for ITER and beyond

ITER



- Develop ST as fusion energy system

Thank you for your FESAC SPP presentations + white-papers - they did actually influence the FESAC report

FNSF

1. Menard, NSTX-U: ST research to accelerate fusion development
2. Majeski, LTX: Exploring the advantages of liquid lithium walls
3. Fonck, Initiatives in non-solenoidal startup and edge stability dynamics at near-unity aspect ratio in the PEGASUS experiment
4. Raman, Simplifying the ST & AT concepts (CT injection fueling/momentum + EBW)

PMI

5. Maingi, A liquid-metal plasma-facing-component initiative
6. Jaworski, Liquid metal plasma-material interaction science and component development toward integrated demonstration
7. Allain, Establishing the surface science and engineering of liquid-metal plasma--facing components

Burning plasmas, discovery science

8. Podestá, Development of tools for understanding, predicting and controlling fast-ion-driven instabilities in burning plasmas
9. Sabbagh, Critical need for disruption prediction, avoidance, mitigation in tokamaks
10. Crocker / Guttenfelder, Validating electromagnetic turbulence and transport effects for burning plasmas

NSTX-U missions aligned with FESAC SPP report

Quotes from the report:

- "The primary mission of the NSTX-U subprogram element is to evaluate the potential of the low-aspect ratio tokamak, or spherical torus, to achieve the sustained high performance required for a FNSF."
- "Innovative plasma-material-interaction (PMI) solutions are another important element of this program"
- "ITER-relevant research on NSTX-U includes energetic particle behavior and high-beta disruption control"
- "NSTX-U should primarily focus on resolving the technical issues underpinning the FNSF-ST design."
  - "Key issues: non-solenoidal startup, sustainment of the plasma current, and scaling of confinement with collisionality."
  - LTX, Pegasus: important support for PMI and current initiation

FESAC SPP Report Priorities:

Tier 1

- **Control of deleterious transient events:** This Initiative combines experimental, theoretical, and simulation research to understand highly damaging transients and minimize their occurrence in ITER-scale systems.
- **Taming the plasma-material interface:** This Initiative combines experimental, theoretical, and simulation research to understand and address the plasma-materials interaction (PMI) challenges associated with long-pulse burning plasma operation.

Tier 2

- **Experimentally validated integrated predictive capabilities:** This Initiative develops an integrated "whole-device" predictive capability, and will rely on data from existing and planned facilities for validation.
- **A fusion nuclear science subprogram and facility:** This Initiative will take an integrated approach to address the key scientific and technological issues for harnessing fusion power.

- Tier 1 Initiatives are higher priority than Tier 2 Initiatives. Within a tier, the priorities are equal.
- In concert with above Initiatives, Discovery Plasma Science will advance the frontiers of plasma knowledge to ensure continued U.S. leadership.

FES comments on FESAC SPP Report (1)

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Quick take on the Tier 1 & 2 recommendations

Recommendation	Comments
Control of deleterious transient events	Critical, show-stopper issue
Taming the plasma-material interface	Critical, show-stopper issue. Any new PMI facilities should serve the scientific needs.
Experimentally validated integrated predictive capabilities	Should be equally high priority, not Tier 2. It is critical for Transients and PMI, but more broadly as well
A fusion nuclear science subprogram and facility	Construction of an FNSF will not happen during the decade, due to budget pressures. Existing program of fusion nuclear science will be continued (not as a new subprogram), and should grow

From "FES Considerations for Strategic Planning" by Edmund Synakowski – Associate Director, Office of Science, Fusion Energy Sciences – UFA Meeting – October 27, 2014

FES comments on FESAC SPP Report (2)

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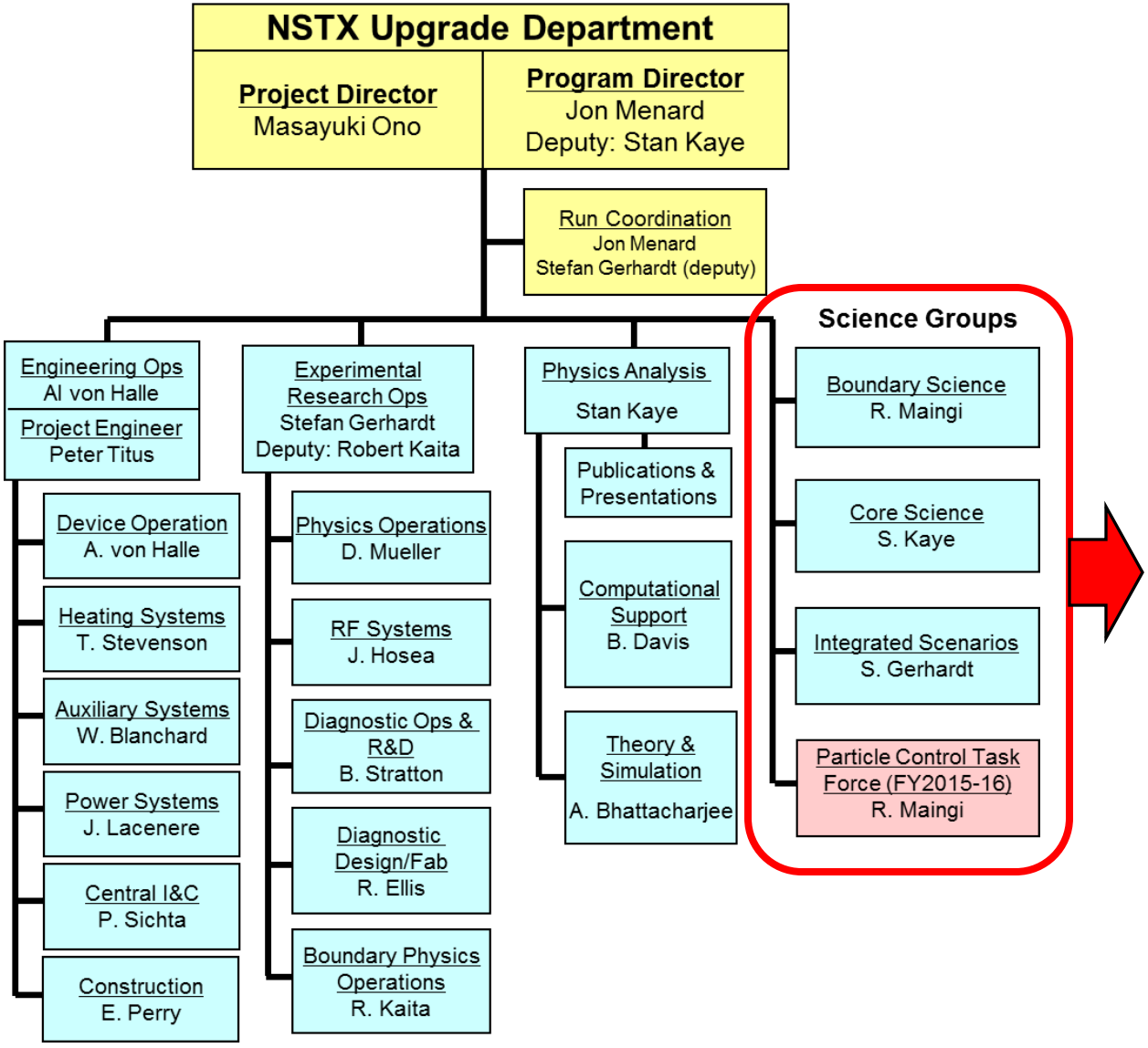
On other high-level specific facility recommendations of the report

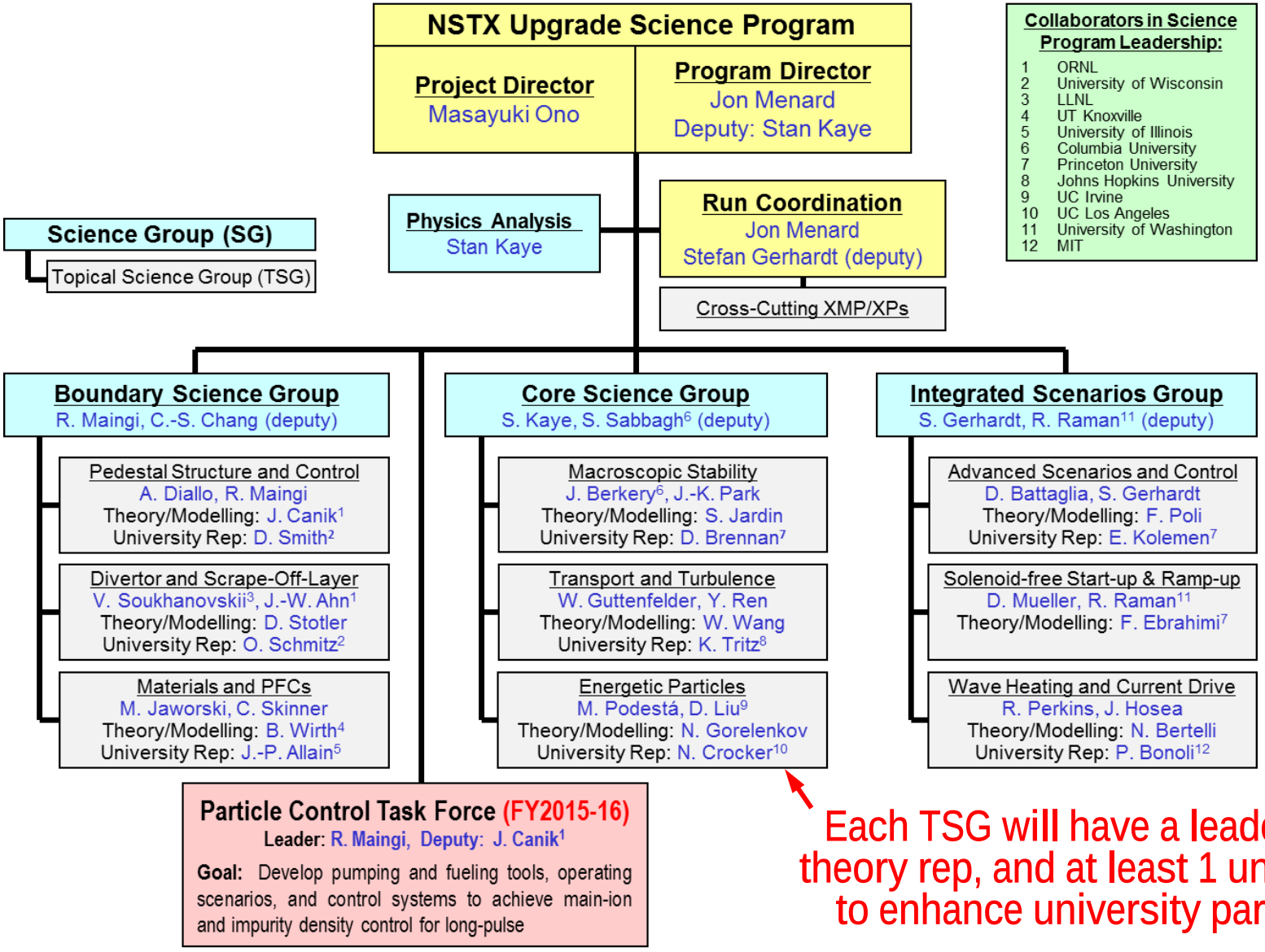
Item	Comment
C-Mod operations end	The plan will be consistent with the previously stated Administration position and recent House-Senate direction to operate Alcator C-Mod for FY 2015 and FY 2016.
Down-selection between DIII-D and NSTX in 5 years in some budget scenarios	DOE views this as premature in any case. In the Administration plan, any decision point will be later in the ten year period, regardless of budget scenario, and there will be more possible branching directions

From "FES Considerations for Strategic Planning" by Edmund Synakowski – Associate Director, Office of Science, Fusion Energy Sciences – UFA Meeting – October 27, 2014

NSTX-U Organization for FY2015



NSTX-U research program will be (re-)organized along 3 "Science Groups" starting with FY15 run



Each TSG will have a leader, deputy, theory rep, and at least 1 university rep to enhance university participation

Motivations for restructuring science program

- TSGs provide expertise in broad range of topics, but program would benefit from better coordination between TSGs
  - SG leader responsibility: Coordinate TSG physics research plans, experimental/shot plans, diagnostic coverage & usage
- Experiments that engage more than one TSG will receive increased priority for run-time
  - Example: experiment on 3D fields generating data for: plasma response, turbulence, energetic particle loss
- Efficient shot usage especially important during first run year (many systems need to be re-commissioned)
- Incorporate much wider set University researchers/PIs in planning + coordination of research program (FES/PPPL goal)
- NEW: Task-force for long-pulse particle control → cross-cutting goal supporting entire research program

Upcoming research planning/advisory activities

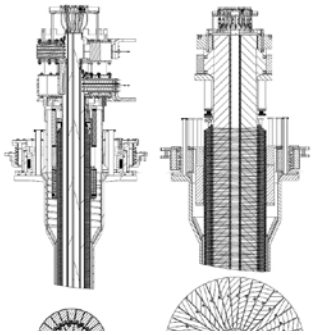
- Pre-forum meeting #1 – Mid Dec (~1 day) *(most likely Dec 16)*
  - Discuss new SG/TSG structure, roles, responsibilities, "other issues"
  - Discuss actions/experiments needed for restart, initial physics-ops
- Pre-forum meeting #2 – January 28-29, 2015 (Wed, Thu)
  - Goal: Provide up-to-date operations status to aid scheduling
  - Day 1: Diagnostics/operations readiness meeting
    - Status updates and projections for all systems needed for research ops
  - Day 2: Update from SG/TSGs on XMP/XP solicitations
- Research Forum – Feb 24-27th (Tue-Fri) at PPPL
  - Plenary session, TSG break-outs, SG sessions, team joint session, summary (also safety session and team photo)
- NSTX-U PAC-36 – Sept/Oct 2015 (end of/after FY15 run)

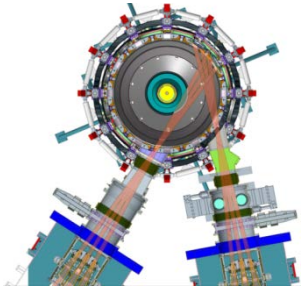
FY2015-16 research milestones target exploitation of new capabilities, exploration of new regimes

Incremental (full ops)

Expt. Run Weeks:

	FY2015	FY2016
	12 **14**	16 **20**
Boundary Science	R15-1: Assess H-mode confinement, pedestal, SOL characteristics at higher B_T, I_P, P_{NBI} Develop snowflake configuration, study edge and divertor properties	R16-1: Assess heat-flux mitigation and PFC response using advanced divertor configurations + radiation at high $q_{\|\|\text{-div}}$
Core Science	IR15-1 R15-2: Characterize effects of NBI injection angle on fast-ion distribution and NBI-CD profile	IR16-1: Assess confinement and local transport and turbulence at low ν^* with full range of B_T, I_P, and NBI power
Integrated Scenarios	R15-3: Develop physics+operational tools for high-performance discharges (κ, δ, β, EF/RWM)	R16-3: Develop high-non-inductive fraction NBI H-modes for ramp-up & sustainment R16-2: Assess fast-wave SOL losses and core thermal / fast ion interactions at increased B_T, I_P
FES 3 Facility Joint Research Target (JRT)	NSTX-U leads JRT: Quantify impact of broadened J(r) and p(r) on tokamak confinement and stability	C-Mod leads JRT: Assess disruption mitigation, initial tests of real-time warning and prediction techniques





Backup slides

Research Forum Overview

- Science groups will nominally follow priorities/detailed plans developed for 5 year plan (until they are obsolete…)
- Abbreviated eXperimental Proposals (XPs) (developed in Dec-Jan) will be presented at the forum
  - Motivation, goal, shot plan, # of run days, diagnostics, analysis…
- Prioritization carried out at forum using abbreviated XPs
- ~70-90% of prioritization completed by end of forum
  - Highest priority research in research milestones / task forces
  - Proposals that address milestones will receive the most run time
  - If abbreviated proposal idea is “priority 1”, the author is asked to develop full proposal for operational + program review/approval
- Expect ~1/3 of all XPs for year to be approved, ready at start of physics campaign (April 2015), then roll forward
  - Typically schedule XPs ~1-2 months in advance

Update on increasing University engagement in the NSTX-U program

- Increasing engagement was FY2014 “Notable Outcome”
- Previously developed ideas to enhance participation:
  - Expand Early Career Research (ECR) awards to University Scientists
    - No support within DoE Office of Science to extend this beyond tenure-track
  - Support students with coordinated senior projects and targeted run-time
    - Will consider once NSTX-U resumes routine/full operation (late FY15)
  - Implementing enhanced collaboration tools (remote control rooms)
    - Will engage NSTX-U Science Groups to determine optimal tools (during FY15)
  - Implement “NSTX-U Innovative Research Award (NIRA)” with funding targeting primarily university researchers
    - No FES funding available, consider funding from NSTX-U post-Upgrade
  - Consider direct financial support for start-up and initial salary for tenure-track professor positions (Same answer as previous question)
  - More strongly engage University Principal Investigators and researchers in the management of the NSTX-U scientific program
    - **Implementing this for FY2015 run**

NSTX-U 5 year goal: Establish ST-FNSF physics/scenarios

10 year goal: Integrate high-performance core + metal walls

Plan presented at FESAC:

2015-2019

Establish ST physics / scenarios:

- Non-inductive start-up, ramp-up
- Confinement vs. β , collisionality
- Sustain high β with advanced control
- Mitigate high heat fluxes
- Test high-Z divertor, Li vapor shielding

Inform choice of FNSF configuration:

- Lower A or higher A?
- Standard, snowflake, Super-X (MAST-U)?

2020-2024

High-performance + metal walls

- Convert all PFCs from C to high-Z
- Static → flowing Li divertor module(s), full toroidal flowing Li divertor, high T_{wall}
- 5s → 10-20s for PFC/LM equilibration
- Assess ST with high-Z, high-Z + Li

Inform choice of FNSF / DEMO plasma facing materials:

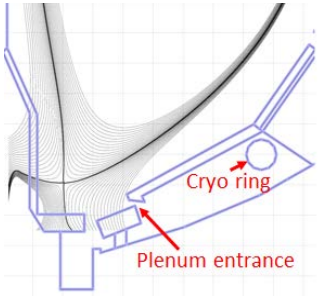
- High-Z acceptable? or need high-Z + Li?
- Assess for both divertor and first-wall

NSTX-U facility enhancements proposed for 5 year plan support FESAC Tiers/Priorities

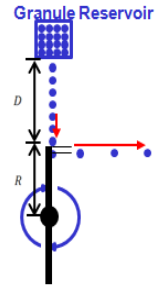
- Improved particle control tools
  - Control D inventory, rapidly trigger ELMs to expel impurities *(Transients, PMI)*
  - Low ν^* to understand ST confinement to support FNSF, validation *(FNSF, Predictive)*
- Disruption avoidance, mitigation *(Transients, Predictive)*
  - Massive gas injection, detect halos, disruptions, control v_ϕ, RWM, ELM
- ST start-up and ramp-up tools *(FNSF)*
  - ECH to raise start-up plasma T_e to enable FW + NBI + BS I_P ramp-up
  - Test EBW-CD start-up, sustainment
  - Start-up/ramp-up critical for ST-FNSF
- Begin transition to high-Z PFCs, assess flowing liquid metals *(PMI, FNSF)*
  - Plus divertor Thomson, spectroscopy

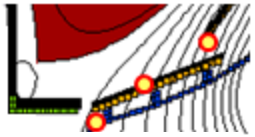
Upward Li evaporator

Divertor cryo-pump



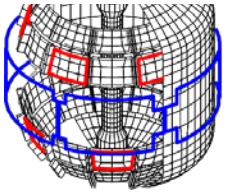
Li granule injector (LGI)

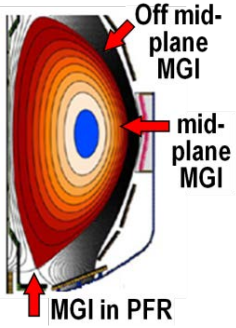




Extended low-f MHD sensor set

Midplane + off-midplane non-axisymmetric control coils (NCC)





1MW 28 GHz gyrotron

High-Z tiles

Actively-supplied, capillary-restrained, gas-cooled LM-PFC