NSTX Research Forum March 2011

MAST Status, Plans & Collaboration Opportunities

Brian Lloyd

EURATOM / CCFE Fusion Association

CCFE is the fusion research arm of the **United Kingdom Atomic Energy Authority**

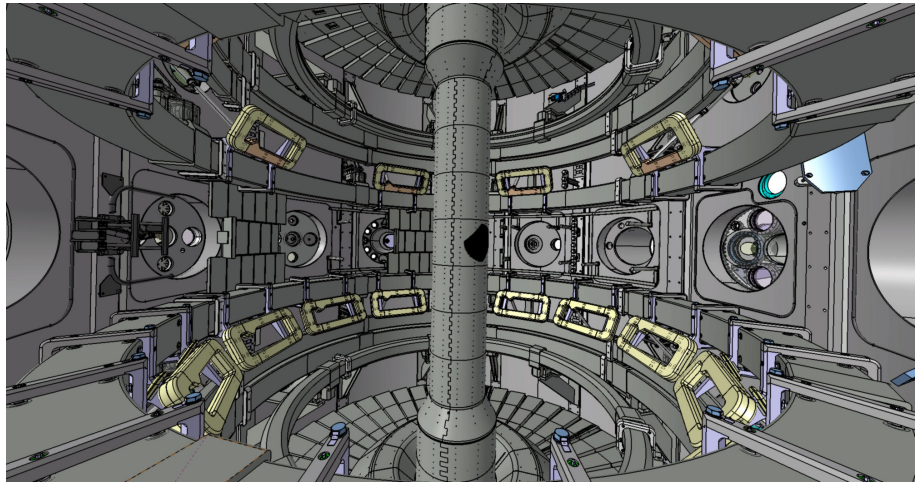
Jointly funded by EURATOM & RCUK Energy Programme

Outline

- MAST status
- Operating schedule (provisional)
- MAST programme
- Collaboration opportunities
- MAST Upgrade status

MAST status

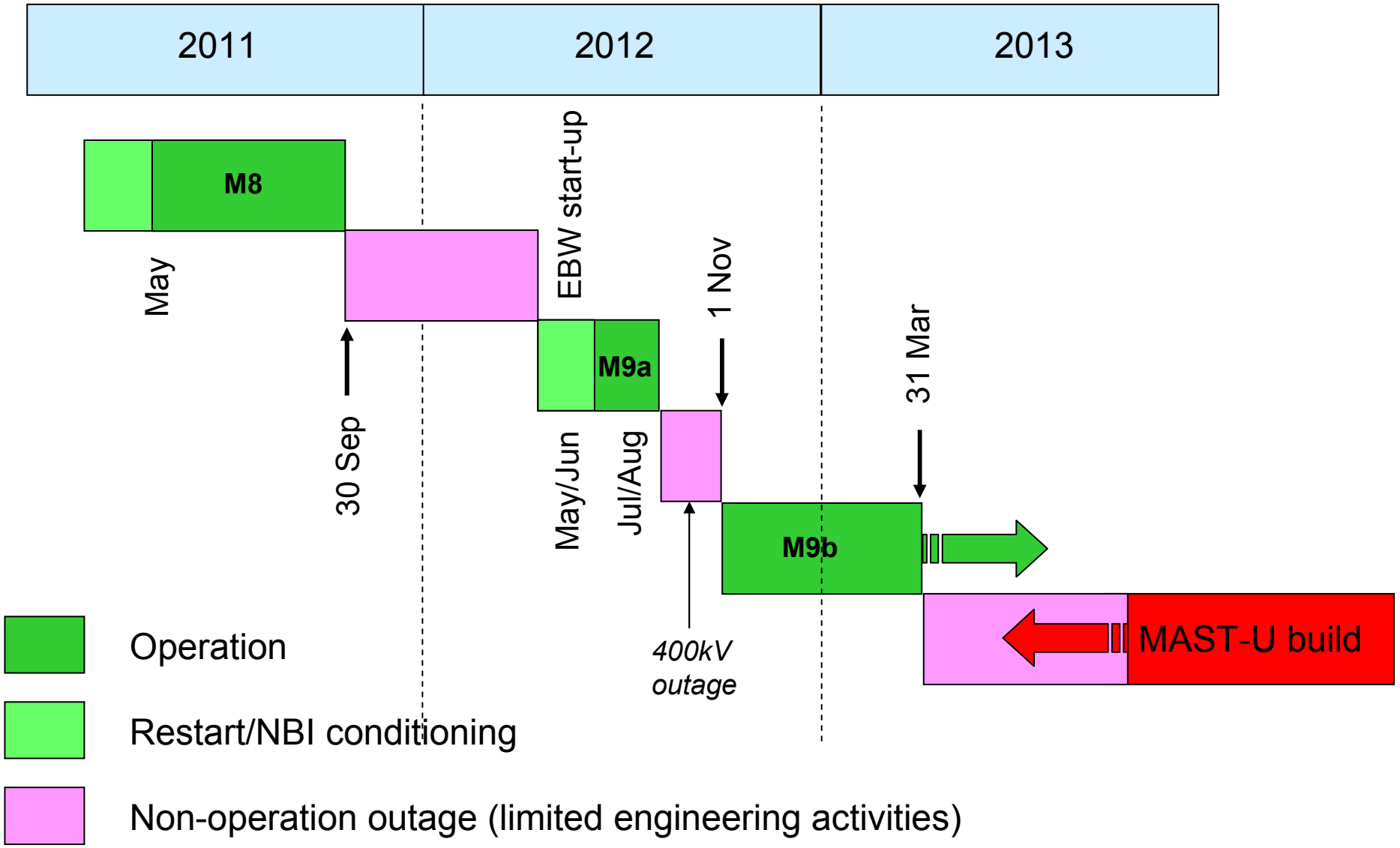
- In-vessel engineering break activities completed, vessel pumped and baked Nov 2010
  - additional ELM coils



- All major power supplies commissioned
- Major new diagnostic developments
  - 2D BES
  - FIDA
  - EBW imaging
  - Retarding Field Analyzer(s)
  - enhancements to edge Doppler spectroscopy and collimated neutron detector
- Controllable HFS fuelling
- PCS upgrade
- NBI control system upgrade – commissioning in progress

MAST operating schedule

(Provisional)



Engineering activities

- Focus on essential maintenance and engineering activities in support of MAST-U

  - new TF sliding joint tests

  - fast amplifier tests (vertical position control)

  - datacq developments for long pulse operation

  - NBI system developments (e.g. arc voltage ripple reduction, gettering tests, etc)

  - HVPS-5 (high voltage power supply) commissioning

  - ……..etc

Tokamak Science Programme

- Five new Tokamak Science Programme Leaders (3-years to March 2014) reporting to William Morris (Chief Scientist):
  - Integrated Plasma Scenarios: C. Challis (*Dep. M. Romanelli*)
  - Core plasma: I. Chapman, S. Pinches, D. McDonald (*Dep. M. Valovic*)
  - SOL and Divertor: W. Fundamenski
- Facilities/Infrastructure managers (FMs)
  - MAST – B. Lloyd
  - Theory and Modelling – T. Hender
  - JET participation – A. W. Morris

Elsewhere: MAST-U project, ITER systems, materials, technology (incl. DEMO, CTF engineering design), JOC.

Tokamak Science Goals

3-yr programme based on 4 high level goals:

- Predictable integrated plasma scenarios for ITER, CTF, DEMO — Clive Challis
- High performance core plasmas with tolerable instabilities — Ian Chapman, Darren McDonald, Simon Pinches
- An effective edge pedestal — Ian Chapman, Darren McDonald, Simon Pinches
- Predictive capability to design credible exhaust systems for ITER, CTF, DEMO — Wojtek Fundamenski

Integrated plasma scenarios

MAST:

Clive Challis

- Develop robust ELMy H-mode for MAST and MAST-U
  - Provide workhorse plasma for other MAST experiments
  - Develop ramp-up phase to envisaged MAST-U stationary conditions
    - plasma initiation without merging/compression
    - current ramp-up to elevated $q_{minimum}$ (>1.3) for plasma stability
    - plasma shaping for high elongation
    - access to good confinement (e.g. H-mode)

- Prepare basis for MAST-U steady-state operation
  - low flux consumption start-up/ramp-up (e.g. NBI assisted)
  - ramp-up phase to envisaged q-profile ($q_{minimum}$~2) at high elongation
  - off-axis beam driven current (new diagnostics: neutron camera, FIDA…)

Preparation of ramp-up phase to MAST-U scenarios will expand high κ / low l_i dataset and provide basis for model validation

Core: Stability

Ian Chapman

MAST:

- ELM control by RMPs (highest priority)
  - exploit new ELM coils
- NTM physics
  - measure critical island widths (Univ. of York)
- Effects of flows and fast ions on MHD stability
- Disruption mitigation by MGI (2011)

Core: Fast particle physics

MAST:

Simon Pinches

Increased focus of resources on fast particle physics:
- fast particle stability and fast ion losses/redistribution

- Quantify redistribution on MAST with new diagnostics
  Fast ions: FIDA, collimated neutron detector (Uppsala Univ.)
  Fluctuations: BES (RMKI Hungary)

- Measure and interpret spectrum of stable modes in MAST
  Specifically, demonstrate disappearance of AE gap modes at high β using TAE antenna (with increased drive)

- Further development of theoretical tools
  e.g. incorporation of drag, synthetic diagnostics etc.

Core: transport & confinement

MAST:

Darren McDonald

- Characterise turbulence fluctuations (BES) in MAST and compare with models.
- Confinement scaling
- Pedestal physics
  - test L-H transition models
  - long term aim is to develop a model for the complete ELM cycle
- Pellet fuelling
  - interaction with RMPs for ELM control, validation of deposition models

UK universities provide substantial theory & modelling support

Divertor & SOL

Wojtek Fundamenski

MAST:

- SOL transport in L- and H-mode (inter-ELM and ELM phases)
- Divertor heat loads in L- and H-mode, between and during ELMs, including effect of ELM mitigation
- Divertor detachment & density limit studies

Commitments

Near-term MAST programme is partially constrained by existing commitments e.g.

- EFDA Tasks
- Co-ordinated IEA-ITPA experiments
- Euratom programme (CoA)
- Collaborations & university commitments (PhD students, EPSRC grants etc)
- MAST PAC recommendations

MAST PAC advice (Sep 2010)

- Focus on:-
  - ELM physics & control
  - LH transition (incl. impact of connection length) & pedestal physics
  - First wall and divertor loads (incl. mid-plane SOL widths; deposition profiles of energy, particles, fast particles; toroidal asymmetries)
  - Fast-ion loss and re-distribution (impact on off-axis NBCD & potential for q(r) control)
  - Physics & control of NTMs

- Lower priority (can be studied better in MAST-U):-
  - confinement scaling
  - pellet fuelling
  - beta limit studies

- Other points:-
  - exploit open divertor structure while we can
  - study impact of flow shear on ITG modes
  - prioritise studies in support of MAST-U (e.g. low l_i, high κ scenarios)

Likely elements of 2011 programme

- Physics of ELMs & their control by RMPs (incl. effects on pedestal transport, plasma screening effects etc..).
  New ELMs coils

- L-H transition & pedestal physics (focus on the underlying physics of the L-H transition, impact of connection length and pedestal properties)
  MSE, EBW imaging, ECELESTE upgrade

- First wall/divertor heat loads (incl. toroidal asymmetries; effects of ELM control and disruption mitigation by massive gas injection; SOL width scaling; SOL T_i measurements)
  DMV, LWIR, Retarding Field Analyzers

- Transport studies – impact of q(r) and flow shear on low-k turbulence
  2D BES

- High beta macroscopic stability incl. NTM physics (e.g. critical island widths)
  TS upgrade, 'smart' triggering system

- Fast particle instabilities (e.g. TAE damping), Fast ion losses/redistribution and impact on plasma performance (e,g, energy confinement, q(r) control by NBCD etc).
  TAE coils, FIDA, neutron camera

NB. May be modified/extended by new PLs

Collaboration opportunities

Discussions with Jon Menard September 2010

Two main thrusts for MAST-NSTX collaboration (see J. Menard presentation to OFES Oct 2010):

1. ST-based FNSF/CTF

2. Physics topics important to ST, FNSF/CTF, ITER and DEMO

   - Steady-state, high performance scenarios
     - Turbulent ion and electron transport
     - Longer term – advanced divertors
   - Energetic particle physics
     - NBI current redistribution
   - 3D physics
     - Perturbed 3D equilibria

Collaboration on all elements of the MAST programme welcome

Collaboration opportunities

Fast ion loss/redistribution

MAST & NSTX are both well-equipped (diagnostics & codes) to study fast ion losses/redistribution, impact on NBCD etc. Both have FIDA as well as other diagnostics (NPA, collimated neutron detectors etc)

Turbulent transport

- both NSTX and MAST are now equipped with BES systems
- transport modelling

ELM control

Physics of ELM control by RMPs (improved plasma response models)

First wall & divertor heat loads

Mitigated/unmitigated transients (ELMs, disruptions)
Advanced divertors (snowflake, super-X)

Scenario development/operational experience

IEA-IA on Spherical Tori

Two new annexes being developed:

Co-ordination of activities and exchange of technical information relating to future ST applications

- Focussed on technical challenges common to a range of future STs (e.g. central solenoid, exhaust concepts etc)

- Sharing of information on, & assessment of, technical & physics design assumptions etc

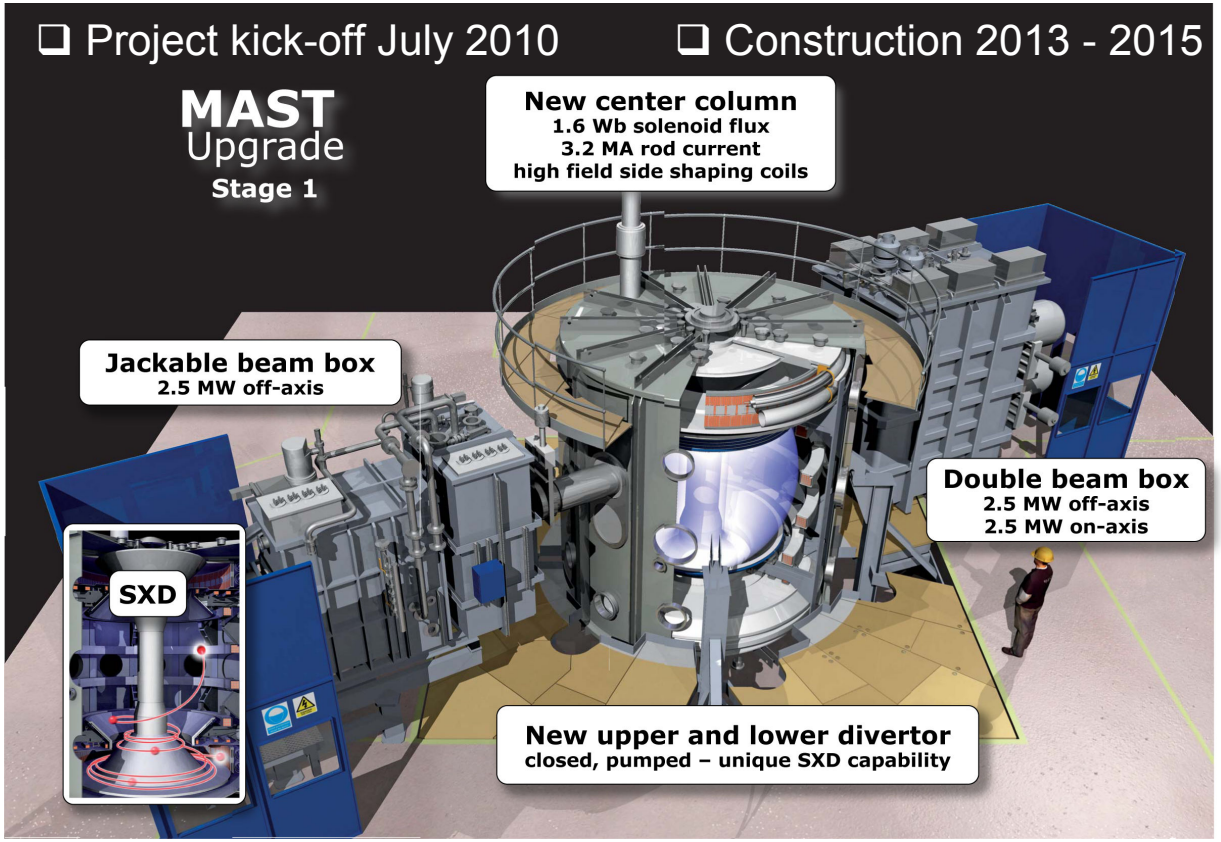
- Not focussed on any specific device or design

Steady state operation

Response to proposal for a cross-cutting initiative by O Motojima & J Jacquinot

Timely development :
- Upgrades to NSTX & MAST will enable fully non-inductive stationary (on a current diffusion timescale) operation

MAST Upgrade status



- ❑ Physics proposal was reviewed by the MAST PAC Sep 2010
- ❑ Team/structure set up and first Project Board held in December 2010.
- ❑ UK Government Gateway Review stages 1 & 2 were passed successfully in February 2011
- ❑ Technical proposal will be reviewed by the MAST PAC 14-15 April 2011