STATUS OF THE MAST UPGRADE

Chris Llewellyn Smith

UKAEA Fusion Working in Europe

CONCLUSIONS

- **Assuming Euratom approval and funding, stage 1 of the upgrade of MAST will go ahead**
- The Challenge is to define a staged upgrade **within the available budget** that includes major base assembly work *and*
  - will provide a major step forward in ITER and ST/CTF physics, and
  - with a second (incremental?) stage allow us to meet the EFDA ten year milestone **"Completion of R&D on Spherical Tokamaks in preparation of decision making on CTF"**
- **The PAC's advice is now sought on**
  - what we propose including in our preferred version of stage 1
  - what could be dropped with least damage if sufficient funding is not available for our preferred stage 1
  - the proposed on-going MAST programme (which will inevitably have to be constrained to release funding for the upgrade, although benefiting for recent major hardware investments)
  - wisdom of seeking Euratom approval for whole project in one step?

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Meeting the EFDA Ten-year CTF milestone with an upgrade to MAST

Derek Stork

for the MAST and Upgrade Programme teams

(with special thanks to Richard Buttery, Glenn Counsell, Hendrik Meyer, Mark Shannon and Garry Voss)

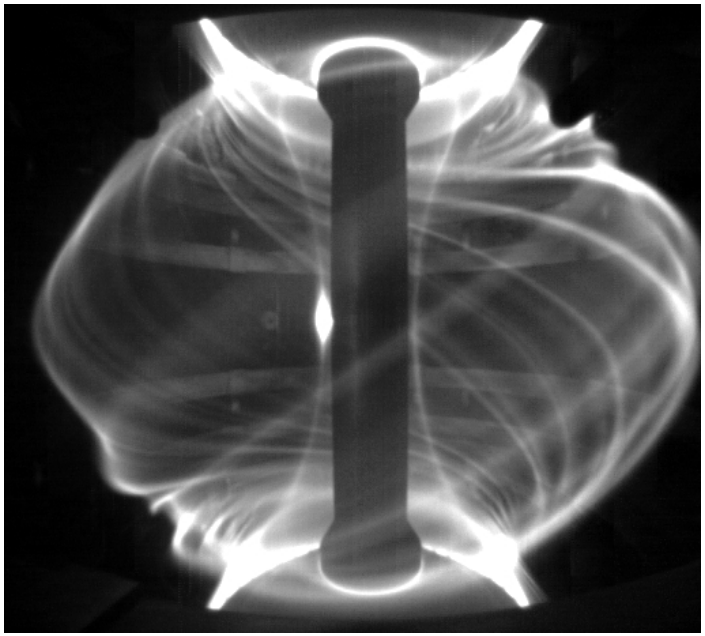
Euratom-UKAEA Fusion Association,
Culham Science Centre,
Abingdon, OX14 3DB,
England

UKAEA

Staging the Upgrade Programme (III)

- Stage 1 of the programme includes:
  - all changes to the Load Assembly
    - New CS; new Centre Rod; new Chiller system; new TF sliding joints; new divertor and inboard PF coils; new CFC divertor target; divertor cryopump; new gas introduction system;
  - New long-pulse TF and divertor coil power supplies;
  - LHe/LN_2 cryoplant and supply lines;
  - Increase in NBI power to 10MW, with 5 MW off-axis co-injection, 2.5 on-axis counter-injection capability; (includes new double-PINI NBI box);
  - Accompanying infrastructure changes/upgrades eg. neutron shielding, 36kV connections and Reactive Power Compensation.

2008 MAST Programme



Brian Lloyd

EURATOM/UKAEA Fusion Association
Culham Science Centre, Abingdon, UK

UKAEA Fusion Working in Europe

Outline

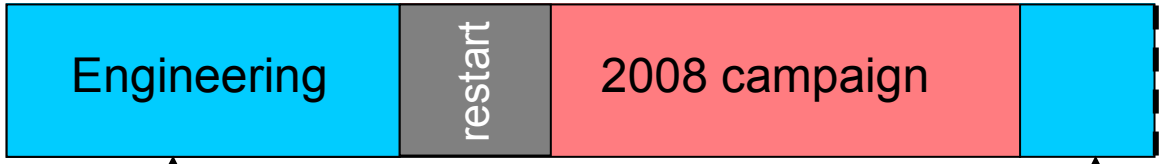
- Introduction
  - Status of MAST & operational schedule
- Technical developments
  - new capabilities and progress on major developments
  - investment plans
- Programme organisation & planning
- Programme plans
  - Performance optimisation
  - Stability
  - Exhaust

  (separate presentations on Confinement & Transport (M Valovic) and ELM Control (E Nardon)

MAST Status

- Following the engineering break (ELM coil installation, TAE antenna system, MSE) high temperature baking was completed on 15 Feb.
- ELM/TAE coils installed by Nov 2007 – 1 month ahead of schedule.
- Multi-chord MSE system installed by Mar 2008 – on schedule.
- Major TS upgrade on schedule – 8 lasers available by June (increased temporal resolution and burst mode capability)
- Power supply re-commissioning complete.
- Sliding joints tested and TF commissioned
- Magnetics calibrations complete.
- First plasma obtained 29th April 2008. Plasma conditioning now in parallel with NBI commissioning/conditioning
- S-NBI: Operation up to 51kV, 1MW established.
- SW-NBI: Mechanical installation of new PINI completed Jan 2007 – on schedule. HV testing into dummy load now being carried out. High power SW-NBI operation now expected August onwards.

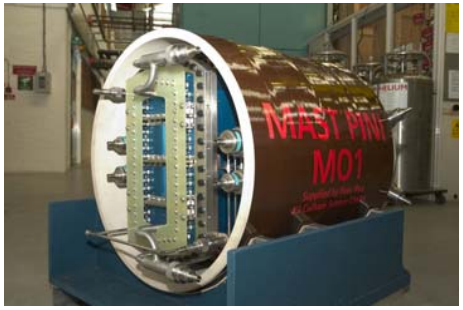
MAST forward schedule



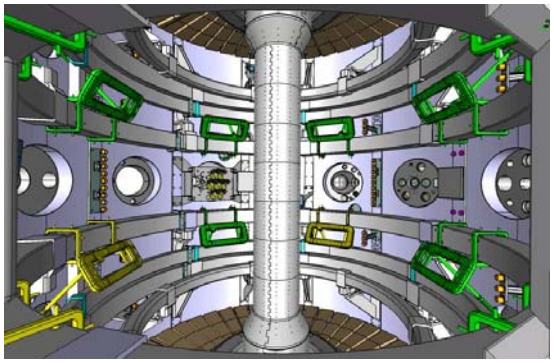
July Feb May ≥ Dec

ELM coils
2nd PINI
Multi-chord (>30) MSE
TS upgrade Phase I
(4 ⇒ 8 Nd:Yag lasers)

ELM coils Phase II (n=4, n=6)
TS upgrade Phase II
(19 ⇒ 120 core channels)
BES 2D turbulence imaging



MAST PINI



BES turbulence imaging

ELM/TAE coils
- *control of edge instabilities*
- *controlled excitation of fast particle driven instabilities*

MAST – new capabilities 2008-09

- Higher power long pulse NBI (2^{nd} PINI)
- ELM control/TAE coils: 6 + 6 internal array
- Nd:YAG TS upgrade: 4 → 8 lasers (2008), 19 → 120 core channels (2009)
  (high resolution edge TS and 300pt ruby TS single pulse system will be retained)
- Multi-channel MSE (installed Mar 2008)
  - 35 spatial channels, better than 3cm, 5ms resolution
- BES 2D turbulence imaging system (2009)
  - custom 8 x 4 channel, 1 MHz APD camera
- Improved imaging & spectroscopic capabilities
  - long wavelength IR camera, filtered fast camera, second filtered divertor camera, new spectrometers
- Divertor science facility
- Higher power (350kW), long pulse 28GHz gyrotron (on loan from ORNL)
- Disruption mitigation valve (FZJ/IPP collaboration)
- Centre column chiller system being developed, installation under consideration

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Other MAST developments

Improved remote participation and data display facilities

Control room refurbishment

New air conditioning system

- New MAST Central Control System implemented – PC-based SCADA package
- New dedicated error field compensation coil power supplies
- Digital plasma control system (PCS) being upgraded to a PC-based system (Dec 2008)
- Data acquisition system upgrades for long pulse operation (hardware replacement, network infrastructure improvements, increased data storage capacity etc.)

ELM/TAE coils

Installed Nov. 2007, 1 month ahead of schedule

6 + 6 internal array

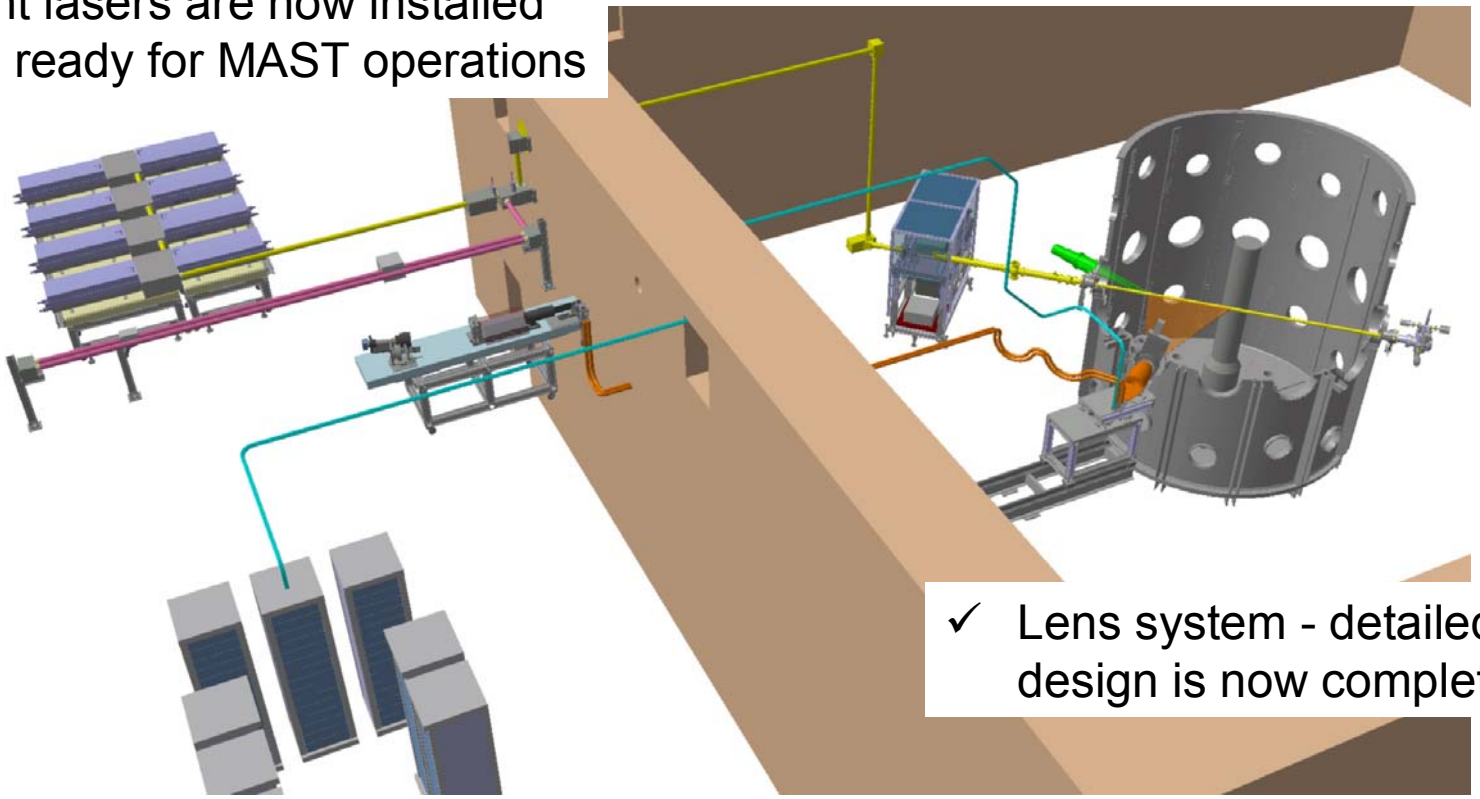
- ≤ 2kA, 4 turn coils for ELM control (n = 3). Additional 6 coils could be installed in 2009 to allow n = 4, n = 6
- 10A, 0.5MHz for TAE excitation

Outstanding C & I work etc. expected to be completed by end of May.

TS upgrade

- Part funded by York University
- Project on track (schedule & cost) – budget £2.024M, spent £1.3M, committed £135k
- Increased temporal resolution & burst mode capability with 'event triggering' 2008, increased spatial resolution (120pt, ~ 1cm resolution) 2009

✓ Eight lasers are now installed and ready for MAST operations



✓ Lens system - detailed design is now completed

✓ ADCs have been procured, beginning spectrometer assembly

TS upgrade

- Four additional new lasers have been installed
- Four existing lasers have been converted to higher energy
  - Combined 240Hz 1.6J laser capacity (previously 200Hz ~1J)
- Newly installed lasers are operating to specifications

MSE status

- System has now been constructed and installed, achieving milestone date of March 2008.
- External calibrations demonstrated the expected performance levels.
- Filters installed in 11 channels – remainder being delivered as they are manufactured.
- First beam light expected this month (May 2008).

Key parameters:

- 35 spatial channels
- R ~ 0.8 – 1.5 m
- Resolution:
  $\Delta R \sim 2.5$ cm
  $\Delta t \leq 5$ ms
  $\Delta\alpha \leq 0.5°$

On-going investments I

- To earmark funds for MAST-U, *discretionary* spend on MAST hardware cut back significantly - have so far allocated only £185k for Apr 2008 – Mar 09. Some funds held in reserve to cover unforeseen equipment failure.
- Operating costs (incl. maintenance, consumables, software licences, T & S, training, publication costs etc.) ~ £380k.
- Large *non-discretionary* spend (£875k), in 2008-09 only, to complete the following on-going projects:

  - TAE system
  - Divertor science facility
  - Long pulse datacq
  - MSE (temp. control)
  - BES (with HAS)
  - Disruption mitigation valve (with FZJ/IPP)
  - Fission chambers
  - New spectrometers

and for key spares/safety & reliability:

  - NBI components (DECEL p/s, bend magnets, crowbar)
  - CXRS CCD (single point failure)
  - Power supply components (MFPS replacement cards)
  - Remedial safety work (NBI cubicles)

On-going investments II

- MAST is in a strong position to exploit the major investments of the last few years viz., NBI upgrade, high resolution diagnostics (e.g. TS, CXRS, MSE), ELM/TAE coils, control & data acquisition etc.

- Commitment to completion of on-going projects, plus investment in key components, helps ensure that we fully exploit and benefit from our previous investments in the near-medium term.

- Nevertheless, the requirement to set aside money for MAST-U means that the following projects are unlikely to go ahead in the near term:

  - additional in-vessel ELM control coils
  - new pellet injector
  - high power (~ 1MW), low frequency (~ 18GHz) EBW system