JET timeline update and future post mortem analysis opportunities

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JET

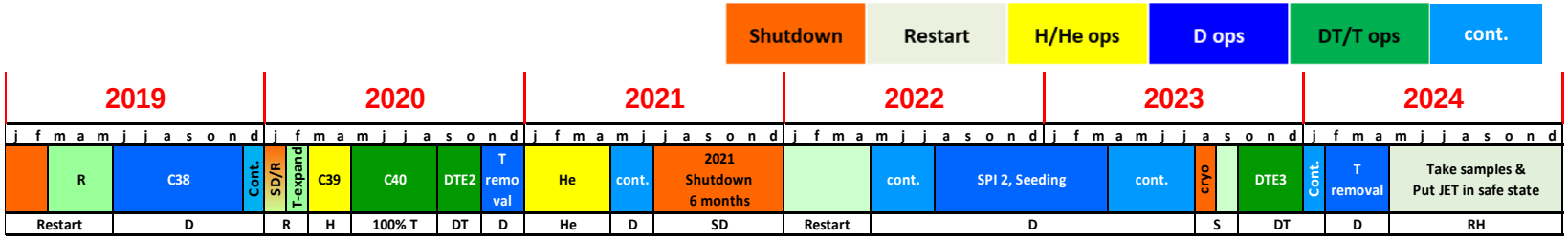
This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Outline

- Update on JET timeline
- Implications for availability of new samples from JET post DTE
- Review and retention of available materials from JET

Shown at 2019 annual meeting….

JET24 - Proposal for extension of JET to 2024 supported by UK government to deliver upgrades and enhancements. BUT where are we now…?



Programme elements ≈fixed

SPI, RH, mirrors, diagnostics ready

AGHS ready for N_2

DTE2: With 14 MeV neutron budget of $3x10^{20}$ (≈ 10 pulses at 10-15MW/5s)

He for ITER (H-mode, ILW)
- LIDS (ITER Cat A)
- Contingency for Seeding (I)

6-month shutdown:
- SPI2 (ITER Cat A)
- ITER mirrors (ITER Cat A)
- Take samples from ILW

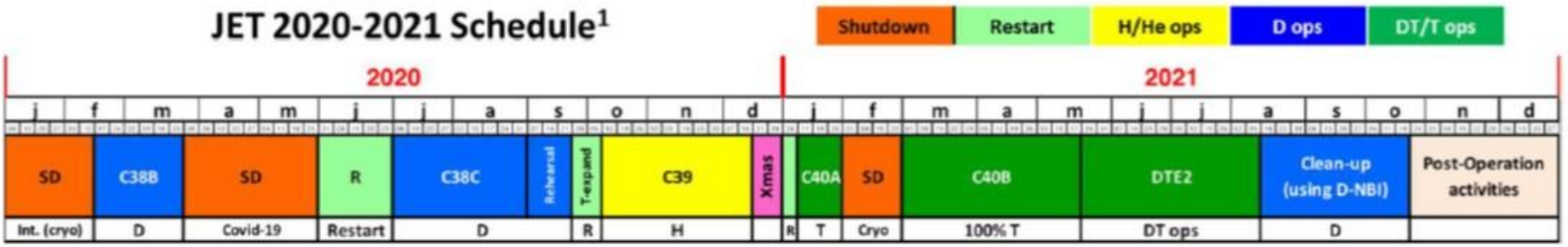
ITER disruption studies:
- with 2nd SPI (ITER Cat A)

ITER like operations
- Seeding with ILW, q_{95}≈3

DTE3 & T removal:
- N_2 seeding, LIDS (ITER Cat A)
- Budget: $13x10^{20}$ 14MeV

Put JET in safe-state:
- Remove ITER mirrors (ITER Cat A)
- LIBS (ITER Cat A)
- Diagnostic calibrations
- Take samples from ILW

Current JET timeline to end 2021

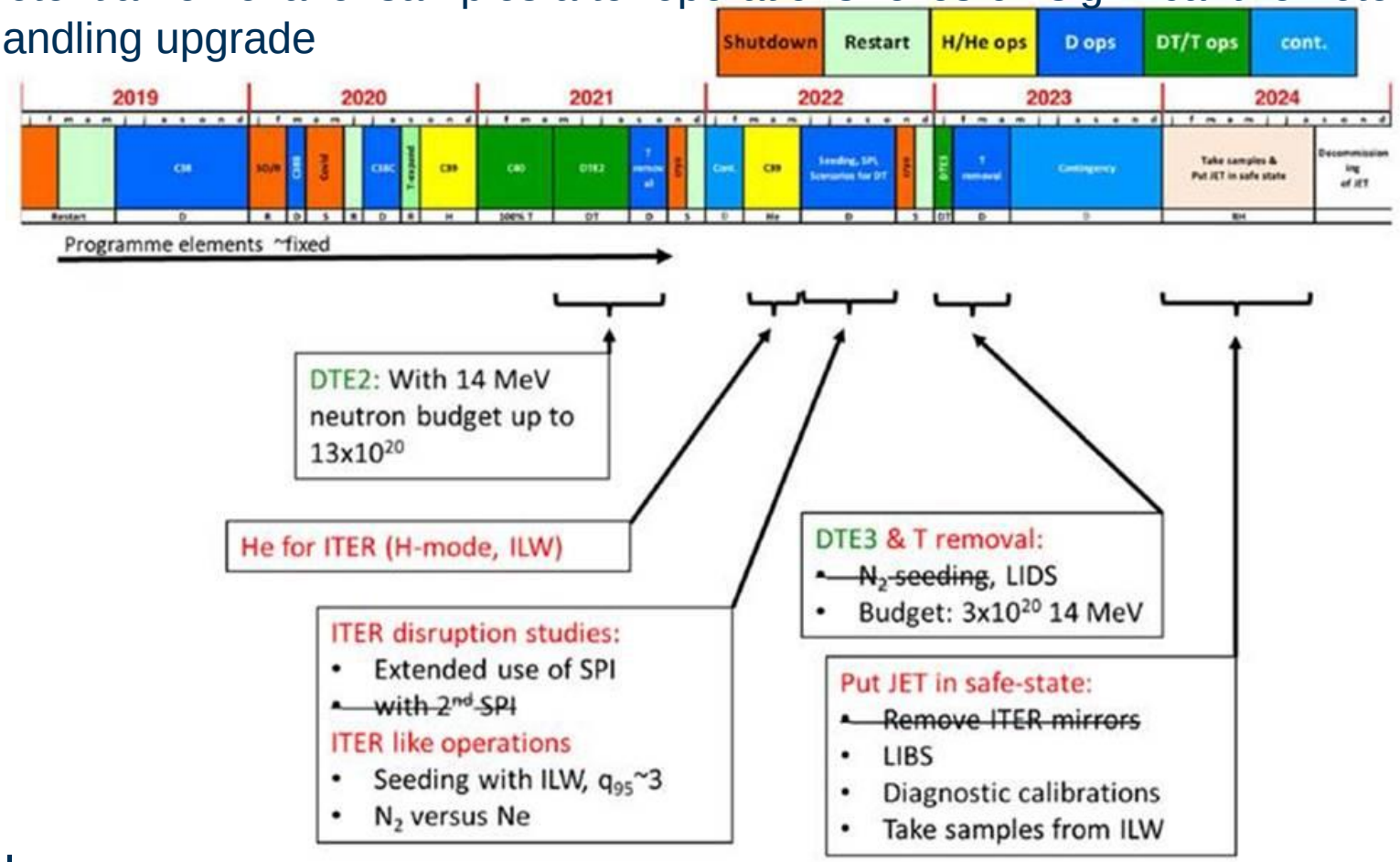


[1]presented at the EUROfusion General Assembly 6-7 July 2020

- Proposals for JET experiments to end of DTE2
- No enhancements
- No in-vessel activities (i.e., no sample removal)
- Move to decommissioning in 2022

Revised JET extended timeline to 2024

- Proposal supported by UK government
- Endorsement from EUROfusion at GA in July 2020 – NOT agreed
- Reduced scope to JET24 upgrades & enhancements
- No in-vessel activities planned during operations
- Potential removal of samples after operations relies on significant remote handling upgrade



Changes to JET24 planned upgrades

Discussion with EUROFusion/proposed at GA – **NOT agreed**

red - cannot proceed orange – reduced scope

No in-vessel activities before end of operations

1. SPI2 enhancements

- SPI2
- SPI2 Knock on
- SPI2 Support - Bolometry
- SPI2 Support – Cameras

2. LIBS/LIDS enhancements

- LID-QMS delivering LIDS capability to JET
- LIBS/LIDS Phase 2 - Heated Tiles
- LIBS/LIDS Phase 3 - Deployment by RH

3. AGHS refurbishment

- AGHS update for N compatibility

4. RHSME refurbishment

- Remote Handling System upgrade

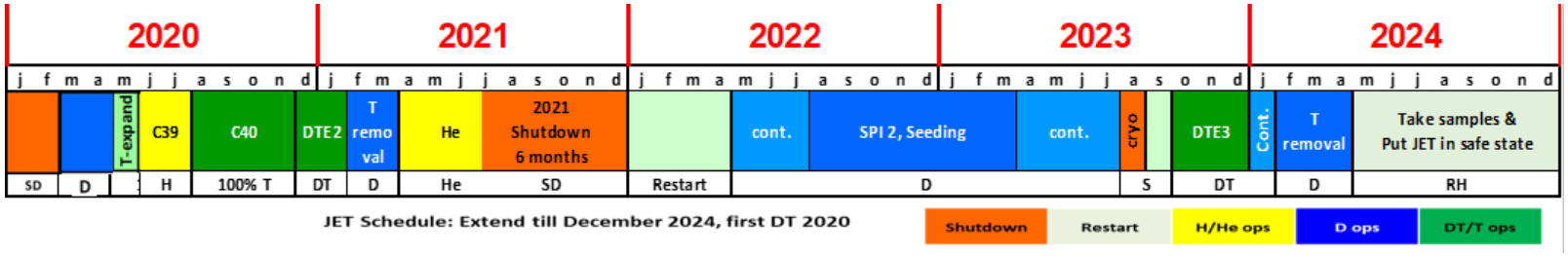
5. Integrated Upgrades for refurbishment….

- Asset Management
- Building and infrastructure
- CODAS
- Cooling systems
- Diagnostics (following DTE2)
- ICRH systems
- NBI systems
- 36kV distribution
- Tokamak power supplies
- Vacuum systems

…. and diagnostics enhancements

- ITER mirrors
- Black Calibration Tile
- SXR with thinner filters (now software)
- Divertor pressure gauges
- Divertor spectroscopy upgrades

UK government and UKAEA look to commit funds to reintroduce SPI2



- UK recognise the importance of SPI2 as expressed by ITER STAC
- UK are prepared to proceed at risk on everything controlled at UKAEA to keep open the option of a shutdown and enhancements including SPI2
- This would move JET24 back to something like the original schedule, but with a ≈ 5 month shift in DTE2 and the following timeline

NOTE: Shown timeline is illustrative of proposed operations – exact dates have shifted + 6 months. Operations would still end at end of 20204.

Changes to the planned upgrades

Early discussions with Eurofusion -**NOT agreed**

UK Atomic Energy Authority

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Looking to reintroduce

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JET Sample Removal

- **JET 2020 timeline does not include sample recovery**
- **Extended JET 2024 programme will not include in-vessel access**
- **Sample removal <u>may</u> only occur after JET operations completed**
  - Availability of remote handling
    - Significant upgrade foreseen in JET24 programme
    - Also needed for LIBS – deployment by remote handling
  - Capability for handling, preparing and analysing activated, tritiated, beryllium containing samples at laboratories
  - Cost analysis of retrieval and scientific output

What *could* be removed for analysis?

Removal of tiles would depend on availability of spares (new or used) or firm decision on end of life

- HFGC used as LID-QMS target & HFGC for comparison – validation
- Tile used for LIBS deployed by remote handling (future JET24 project) – validation

Diagnostics installed in 2017: **VOLUNTARY** (VR, CCFE, IPP, FZJ)

Outer wall:

- Mo irradiated mirrors – Fuel retention in damaged surfaces
- Rotating collector – time resolved deposition in DT
- Dust collectors – Dust & deposition

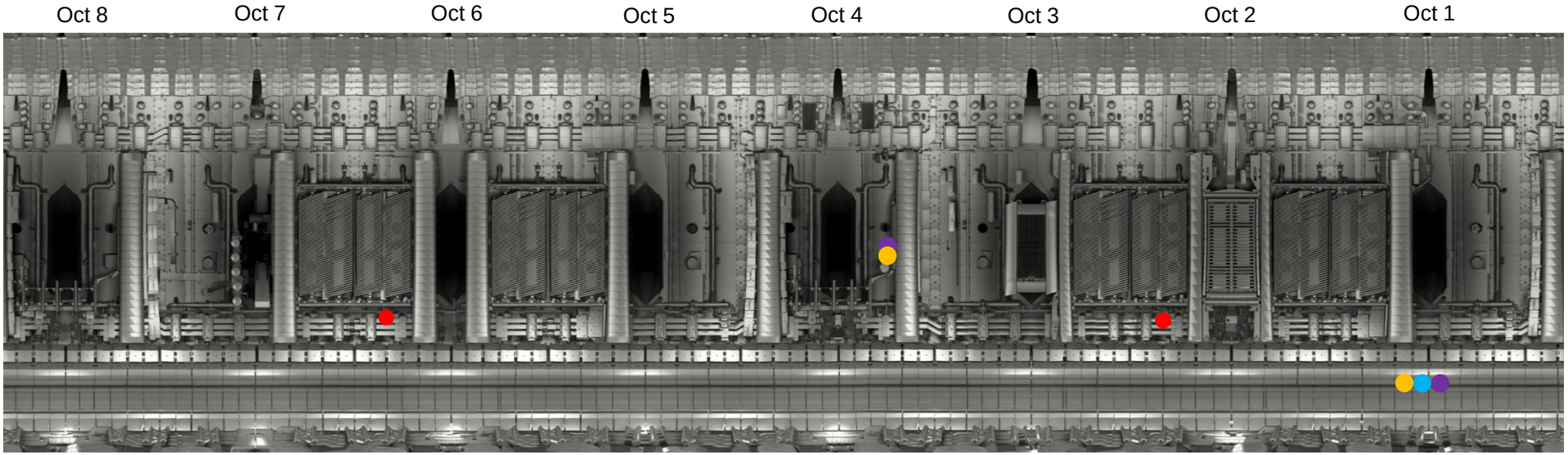
Inner wall:

- Inner wall cladding inserts W:Be - Erosion and retention in DT operations
- W Sticking monitors – Deposition/sticking on W surface, dust
- Dust collectors – Dust & deposition

Inner & outer divertor: Migration and retention in remote areas in DT

- Mirror-like deposition monitors (steel) - splashes & dust
- QMB covers - deposition monitors, splashes & dust
- Rotating collectors – time resolved deposition in DT

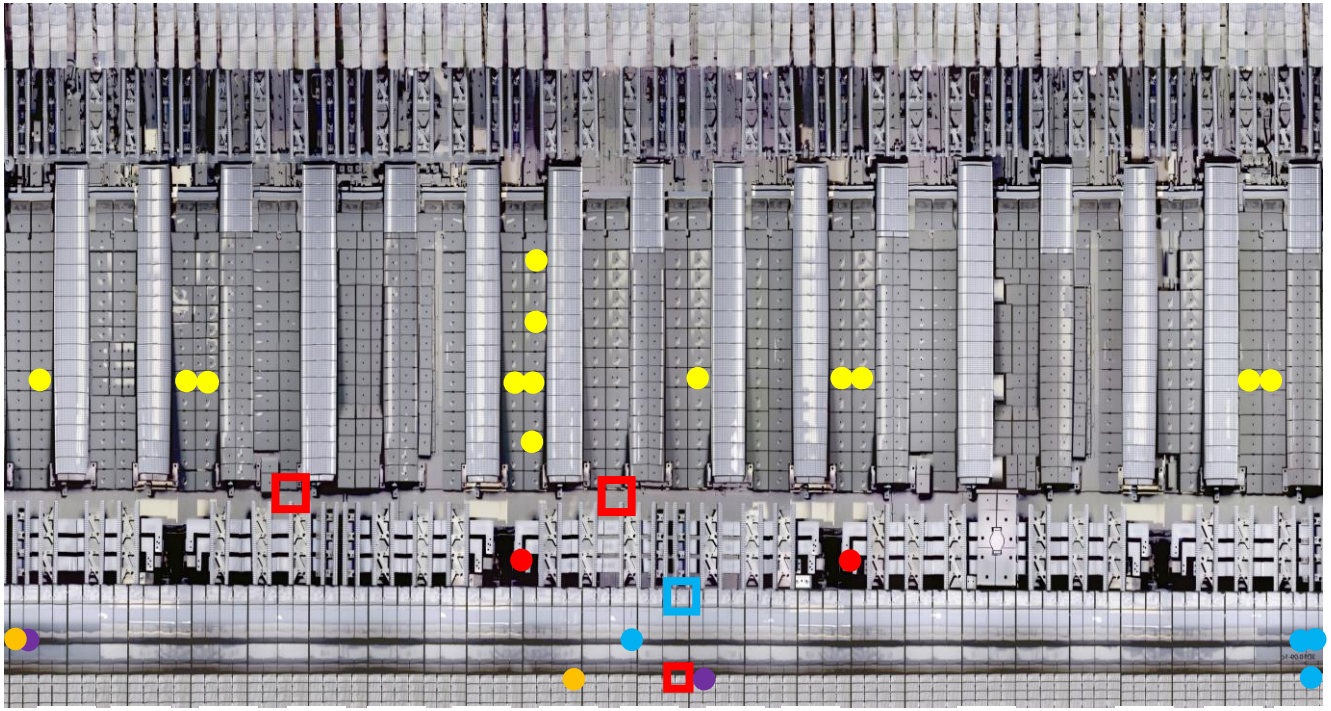
Erosion/deposition diagnostics: Outer wall & divertor



- Mirrors - (divertor deposition monitors, outer wall damaged/non-damaged)
- Rotating collectors
- QMB 5 (cover = deposition monitors)
- Dust collectors

Rendered image – NOT photograph

Erosion/deposition diagnostics: Inner wall & divertor

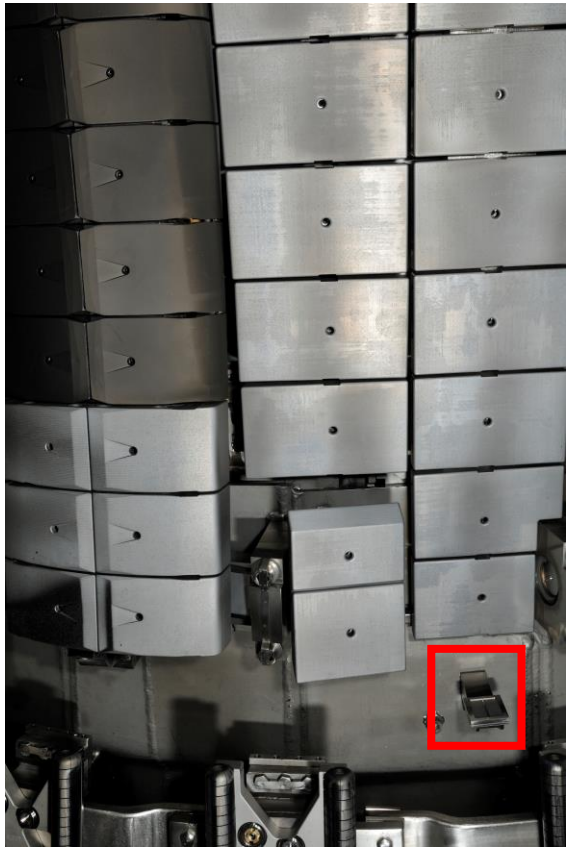


- Mirrors (deposition monitors)
- Rotating collector
- QMB 1, 2, 3, 4 (covers = deposition monitors)
- Inner wall cladding inserts 50:50 W:Be
- Tungsten sticking monitors
- Dust collectors
- HFGC tile – target for LID-QMS

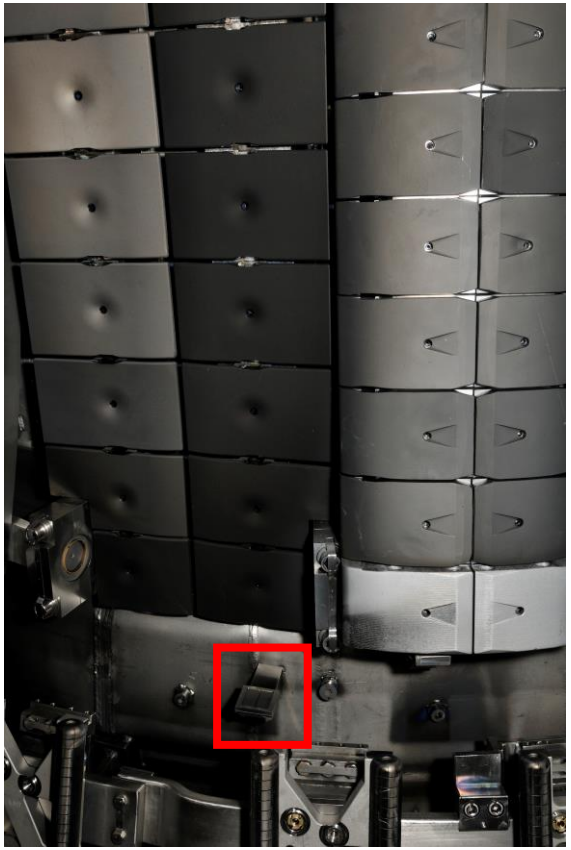
Rendered image – NOT photograph

Sticking monitors – inner wall

OCT3

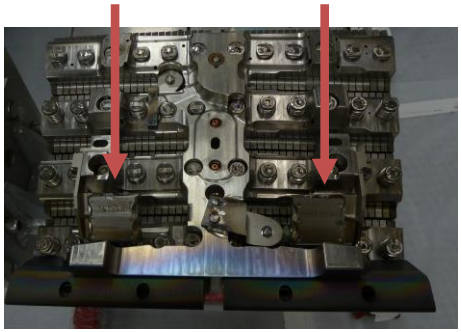


OCT5

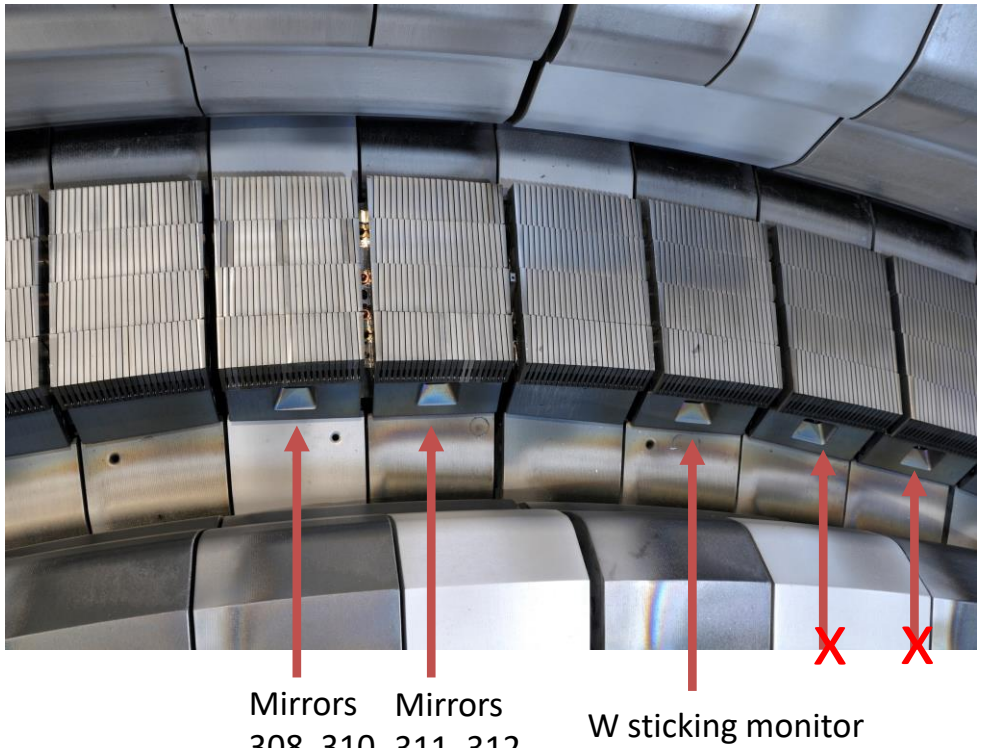


Sticking monitor and mirrors: Tile 5

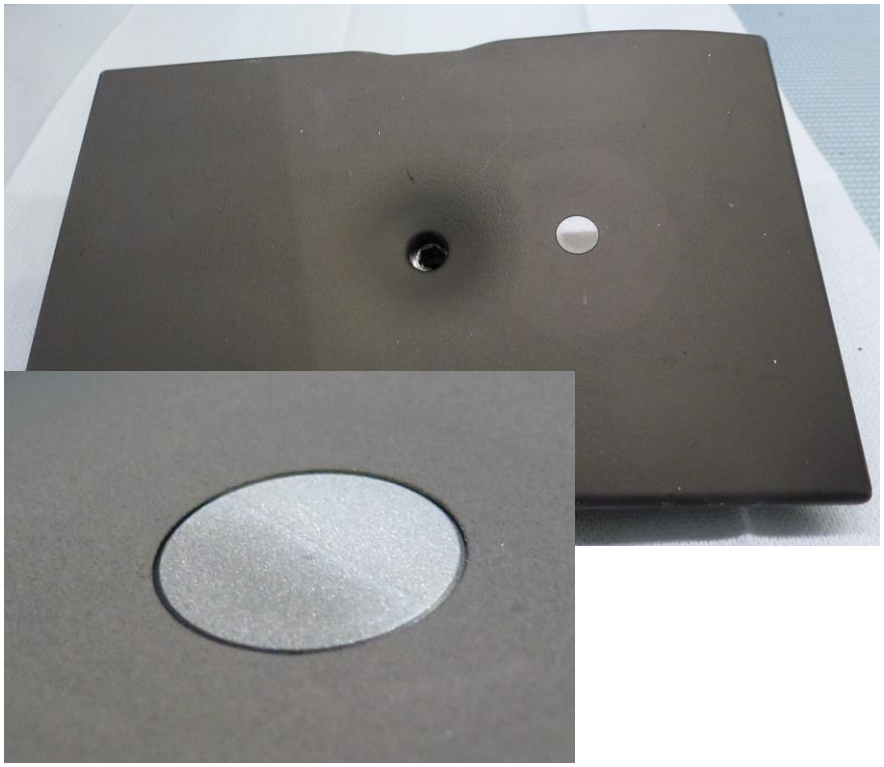
Photograph showing location of W-sticking monitor on 14W tile 5
Photograph from 2014 installation

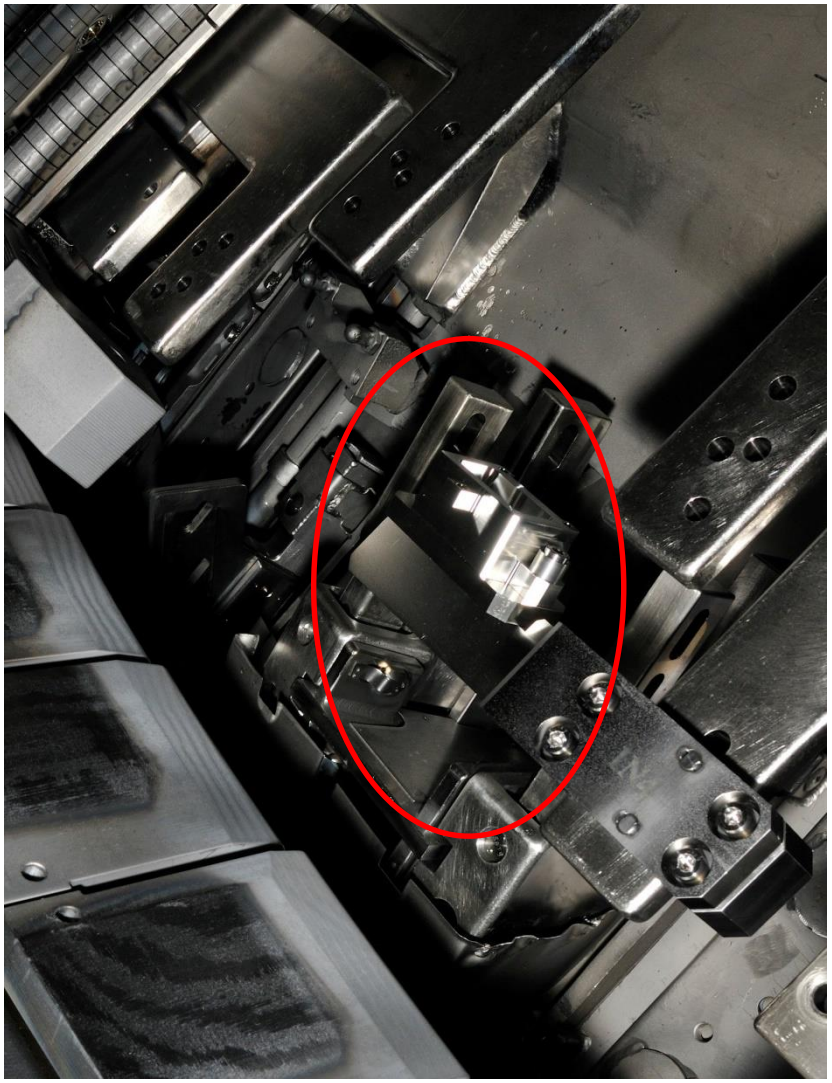


Photograph showing location mirrors 14N tile 5 installed in 2017



IWC insert & inner wall dust collector





Retention of JET tiles and samples

Return of samples and tiles is extended to end March 2021

- Research institutes may elect to keep samples, but need to demonstrate disposal route
- Don't delay – please send samples now in no longer needed

Review of all tiles, samples and diagnostics for retention at CCFE underway

- Any item not designated for retention will go in to waste stream and will no longer be available for analysis
- Whole tiles (W-CFC, W, Be, Be-Inconel) to be kept as potential "hot/used" spares for JET
- Selection of W-CFC cores and partially cored tiles cut at VTT have been selected for retention – complete JET-ILW divertor cross section, few MkIIa
- Be castellation samples and tile pieces (except marker coated) to be retained
- W lamellae samples (except marker coated) to be retained
- Mirror samples
- Langmuir probes (tungsten) removed in 2014 after damage – melting & cracking
- Remaining diagnostics to be reviewed

Samples still to be distributed for WPJET2

Be castellation samples from tiles in-vessel ILW1-3

- WPL 4D15 and IWGL 2XR11
- Samples at CCFE and will be shipped in November 2020 [Be-D-65]
- Research units to receive samples: IAP, VR, FZJ, VTT, UoL, CCFE
- Delayed deliverables to 2021 Be-D-66, Be-D-67, Be-D-68, DG-01, DG-03, DG-04, DG-05

Cores from HFGC in-vessel ILW1-3

- Final few TDS measurements [WC-D-49] and SEM surface/dust characterisation [WC-D-48]

Sample of beryllium filter in JET exhaust ventilation system

- Continued delay at CCF due to resource and access to BeHF (coronavirus)
- Sample due to be sent to IPPLM for SEM/EDX
- Delayed deliverable to 2021 D-RH-04

Langmuir probe – non-exposed

- Sample due to be sent from CCFE to IPPLM for nanoindentation – delayed (coronavirus)
- Comparison with data from exposed sample
- Delayed deliverable to 2021 MT-03