Theme	Sub-Theme 1	Sub-Theme 2	Sub-Theme 3
Mining, Refining & Recycling: “Develop refining and recycling techniques to maximise W circularity”	**Mining:** “Identify and develop W-containing deposits to maximise extraction efficiency”	**Refining:** “Develop refining technology to reduce energy consumption and maximise purity of W extracted”	**Recycling:** “Develop capability to reprocess used W (inc. activated W) into new fusion feedstock”
Microstructural Design & Manufacture: “Develop microstructures for next-generation fusion systems (PFCs, Shielding & Coatings)”	**Plasma Facing Components:** “Develop manufacture techniques to produce improved microstructures resilient to thermal excursions”	**Neutron Shielding:** “Develop shielding materials and manufacturing processes to improve efficacy of neutron shielding (volume/weight reduction)”	**Protective Coatings:** “Develop manufacture methods of W and ceramic coatings to optimise microstructure for liquid metal coolants”
Operational Testing: “Quantify efficacy of microstructural strategies using international testing facilities”	**High Heat Flux & Plasma:** “Develop tiered testing strategy, to increase down-selection efficacy to determine successful microstructure-manufacture combinations”	**Irradiation:** “Develop irradiation standard, to facilitate comparison between different irradiation campaigns/facilities. Assess neutron capture/resilience”	**Liquid Metal:** “Develop testing facilities and procedures representative of fusion environments, with standardised metrics for susceptibility to corrosion”
Characterisation & Properties: “Identify and understand successful microstructures to inform future developments of manufacturing strategy”	**Microscopy:** “Utilise existing expertise and develop new techniques to assess and screen microstructures”	**(Micro)mechanics:** “Establish high-throughput micromechanical testing methodologies to screen samples before and after irradiation” “Establish relevant testing standards for functional in-vessel components”	**Thermal Properties:** “Establish relevant testing standards for functional in-vessel components”
		“Produce material property handbook suitable for fusion machine design engineers for successful material-manufacture pairings”	
Component Engineering: “Establish rigorous engineering standards, with simple joining and remote maintenance instructions for engineers”	**Joining:** “Identify and develop joining methodologies for W to other relevant material systems: Cu-alloys, steel, SiC, V”	**Qualification:** “Establish relevant testing standards for functional in-vessel components” “Establish acceptance protocols for part manufacture and repair”	**Remote Maintenance:** “Develop in-situ NDT inspection techniques” “Develop in-situ tile stripping and replacement methodologies” “Establish acceptance protocols for part repair”
Hierarchical Modelling: “Develop existing modelling capability to predict lifetime performance and inform maintenance schedules of W components”	**Tritium Transport Modelling:** “Identify probable H^3 trapping sites in W microstructures” “Propose microstructural, processing and maintenance changes to reduce retention and improve release of H^3”	**Microstructural Stability:** “Identify relative stability under irradiation of proposed microstructures (matrix, precipitates, fibres, etc.)” “Inform microstructural development strategy”	**Multiscale Modelling:** “Establish multi-scale modelling to match micromechanical testing to bulk mechanical performance” “Predict and validate microstructural performance under irradiation”

General Programme (~30mins)

- How could the overall objective be improved?
- Are there any missing themes?
- Are there any themes that should be removed, changed or replaced?
- Is there a better way to structure the approach (e.g. component or facility focussed)?
- What is missing from theme objectives? Can they be improved or focussed?
- Are there any missing sub-themes?
- What are the key issues surrounding a UK tungsten supply chain?
- When do these need solving? (within 10 years, before 2040, after 2040)
- What projects could solve these, and what input is required?
- What is achievable in the next 5-10 years? Where should we focus?
- Is anyone (individual/group) missing today that should be included?

Theme Focussed (~60mins)

- What are the main challenges specific to this theme?
- When do they need to be overcome by?
- Do the sub-themes capture these challenges? What is missing?
- What is missing from this theme's main objective?
- What is missing from the sub-themes' objectives?
- Does scope accurately capture challenges? Is scope broad enough, or can it be focussed?
- What work needs to start in the next 3 years to be overcome challenges in time?
- What targets should be achieved in the next 5-10 years?
- What challenges/projects should be tackled with each of the other themes?
- What existing facilities can facilitate progress? What facilities are missing?
- What should be prioritised for different amounts of funding? E.g. £1m, £2m & £5m for each theme

WP2

- Limited testing facilities and techniques & time
  - Impact on downselection strategies
  - Downselection needed early on
- Isolate and focus on Unique Selling Point
  - Pump primers
  - Biggest plant risk & biggest output impact
- Promotion of spinoff opportunities
- Roadmap – capture relative maturity of challenges

WP5

- Qualification
- Target components
  - Don’t box in too early by codes and standards
- Embed circular economy throughout programme
- Rig development
- Modelling component history & downstream effects
- Joining & inspection
- Metrology for in-situ monitoring – model to link characterisation to this
- Agnostic design for proof of capability

WP4 & WP6 Thoughts & Feedback

- **General Feedback:**
  - **Critical to have open information flow – prevents 'chicken and egg'**
  - **Critical to establish what is <u>needed.</u> How much are we engineering? How much are we researching?**
    - **Tight focus drives collaboration**
    - **Costs likely too high-as is. Needs downselection.**
  - **Fundamentally, what are we looking to develop? What does that mean W samples look like? How to we then make them? Risk that these bottleneck project start.**
  - We like "pure W". What is (realistically), pure W?
  - What criteria can be relaxed? Low activity?
  - Important to have both a bottom-up (science) and top-down (engineering) approach
  - Can we "shuffle" components as pseudo-reuse?
  - Sub-themes are wildly different in size and scope (multiscale modelling could be half a dozen people). But estimating ~£1.5M per sub-theme (assuming no n).
- **Missing Themes (General)**
  - Dedicated RDM / Comms / Integration
    - Distillation of key needs / questions / results
  - Uncertainty / qualification / regulation / economics
    - Good initial research exercise -> Drives scoping and costs
  - Cross-industry learnings? What *isn't* exclusive to W? Or fusion?
  - Engineering scale development and design (enough detail on stresses? Defects? Repair?)
  - Redeposition / dust?

WP6 specific Thoughts & Feedback

- Agree on a certain grade/type of W from a manufacturer point of view – get the microstructure specifications as much as possible
  Build all models tailored towards that particular ‘agreed’ W microstructure for better comparison and validation of models
- Figure out main failure modes that will kill the material fastest
  (inter or intra granular? What about ppts?)
  - Focus models tailored towards that failure mode first
- Integrate between component engineering (even joining etc.) to heirarchical multi-scale modelling
- Multi-physics modelling in addition to multi-scale
- Digital twin set-ups?
- Missing things in WPs:
  - Oxidation modelling (surface oxides) (reaction modelling in addition to transport modelling)
  - Interface modelling (W/steel, W/liquids, W/CuCrZr etc)
  - Processability issues need to be modelled
  - UQ for different aspects, at different levels
  - Unification of codes (design codes)
  - FAIR data principles, data handling can be a manned job (Digilab for LIBRTI for example)

Extra WP4/6 General

- **Missing Sub-Themes (WP4)**
  - “Microscopy” should be “Microstructural Analysis” -> Cover diffraction, Elasticity, etc
  - Does WP4 need to be separate or is it integrated enough? Two hats?
  - Use of test houses? (Building UK capability)
  - Use of multiple techniques for characterisation (c.f. Felix’s talk on invisible defects)
- **Missing Sub-Themes (WP6)**
  - Surrogate (AI) models for scale-bridging
- **Missing People**
  - Funders: Investors / DESNZ
- **Potential sub-projects:**
  - Coupled microstructural modelling & characterisation & irradiation
  - Legislation / policies / data sharing
  - Multiscale modelling
- **Notes:**
  - Economics of recycling critical. Killed GEN IV fission. And 80% vs 100% recycling doesn’t fix supply chain.
  - We like pure W. But there’s a lot on pure W.
    - Avoid overlap with EUROFUSION.
    - If irradiated W is important then this is a huge bottleneck.
  - People aren’t widly fussed about W alloys in the same way NEURONE works. Important to establish grades. But again not much alloy dev.
  - DESNZ are big fans of staged funding. Could WISE-1 as ”alloy design” and WISE-2 with neutron irradiation
  - UKRI students **cannot** contribute to deliverables