Theme I: Achieving and Understanding the Burning Plasma State in ITER

Understanding alpha particle effects

Study alpha heating effects
Understand instabilities driven by alpha particles

Extending confinement to reactor conditions

Understand transport in the burning plasma regime
Control how the ITER plasma spins
Use transport barrier physics to achieve high gain
Achieve a sufficient edge pedestal for high gain
L-H transition and pedestal characterization
Sawtooth activity
Toroidal field ripple effects
Transport and confinement in transient phases

Creating a self-heated plasma

Startup, flat-top, and rampdown scenarios
Achieve high gain in ITER
Achieve modest gain steady-state capability
Optimize gain in non-inductive plasmas
Establish integrated simulation model
Achieve 100% non-inductive operation of ITER
Use RF systems to control ITER plasmas
Provide central fueling in ITER
Impacts of H-mode issues on operation and modifications
Impacts of wall interaction issues on operation and modifications
Error field correction
Breakdown
Ramp-Up
Flat-top
Termination
Impacts of scenario development issues on operation and modifications
Plasma facing materials - scenarios
Refined set of ITER reference plasma scenarios
Develop a comprehensive modeling capability
Execute necessary R&D to prepare for upgrades to H&CD
Handle unprecedented power exhaust challenge
Operate with sufficiently low tritium inventory
Tritium retention
Dust
PFC lifetime
Plasma facing materials - PWI
Assess the performance of power-plant-scale superconducting magnets

Theme I: Achieving and Understanding the Burning Plasma State in ITER

Controlling and sustaining a self-heated plasma

(Joint with Theme II Control panel)

- Control complex, burning plasmas
- Stability pressure-limiting instability
- Suppress confinement limiting instabilities in ITER
- Neoclassical tearing modes
- Resistive wall modes
- Error field effects
- Breakdown
- Define requirements for plasma control system
- Impacts of MHD stability control on operation and modifications

Mitigating transient events in a self-heated plasma

(Joint with Theme II Off-normal plasma events panel)

- Disruption/VDE/runaway mitigation
- Implement edge stability suppression in ITER
- ELM control/mitigation

Diagnosing a self-heated plasma

(Joint with Theme II Measurement panel)

- Deploy turbulence and alpha particle measurements
- Diagnostics

Theme II: Creating Predictable High-Performance Steady-State Plasmas

Plasma modification by auxiliary systems

- Neutral Beam Injection
  - Long pulse megavolt accelerator operation
  - Long pulse megavolt power supply operation
  - Long pulse negative ion source operation
  - Long pulse positive ion source operation
  - Neutron shielding of insulators
  - Steady state neutral beam operation (lithium jet neutralizer)
- Fuelling
  - Steady state fueling technology
  - Fueling efficiency and isotope mixture control
  - Fueling method compatibility with ELMs
- Theory
  - Pellet fueling (including ablation and flows)
  - Wave and wave particle interactions from antenna to separatrix
  - How RF drives flows and currents
  - Efficient RF current drive
- ICRH
  - Launchers; Steady state high power, large gaps
  - Elm resilience with arc protection
  - Impurity production and sheath formation
  - Physics of breakdown and conditioning
  - ICRF seed current drive in AT scenarios
  - Antenna performance at high density
- Lower Hybrid
  - Steady state launchers
  - AT scenario control; rotation, current profile, pedestal, NTM
  - Edge fast electron production
  - Density limit
  - Optimal frequency in high density burning plasmas
  - Penetration through high temperature pedestal
- ECRH
  - Effect of dominant electron heating and Te > Ti on confinement.
  - Steady state high power gyrotrons with improved efficiency
  - Frequency tuning of gyrotrons
  - Multiple frequency transmission lines
  - Steady state high power launchers and components
- Additional issues for alternate configurations
  - Heating in over dense plasmas

Theme II: Creating Predictable High-Performance Steady-State Plasmas

Control

(Joint with Theme I Controlling and sustaining a self-heated plasma panel)

- Operating Regime
- Plant Startup and Shutdown
- Kinetics
- Fusion plant
- Stability
- Off-normal control
- Reliability and Certification
- Modeling and Design
- Algorithms and Approaches
- Experimental demonstrations

Integration of high-performance steady-state plasmas

- Assessing ARIES/DEMO requirements
- Core performance requirements.
- SOL/divertor compatibility
- Heating and current drive
- Control needs
- Diagnostics
- Modeling requirements for DEMO era

Note: Above topics include assessment of integration issues for 3-D/stellarator devices

Validated predictive modeling

- Predictive tritium retention
- Pedestal and ELMs
- Prediction of core plasma pressure, current, flows
- Stability, including effects of intrinsic rotation
- Disruptions
- RF and fast particle physics (including interactions)
- Integrated modeling needs

Theme II: Creating Predictable High-Performance Steady-State Plasmas

Measurement

(Joint with Theme I Diagnosing a self-heated plasma panel)

- Measurement Capability for steady-state burning plasmas
- Measurement Compatibility with S-S BP conditions and Diagnostic Access
  - concerns about radiation field, fluxes, fluences
  - 1st-wall footprints for measurements
- Reliability and Calibration of Measurements under steady-state burning plasma conditions
- Interpretation and analysis of measurements
  - Sensors for plasma control

Magnets

- Reliability
- Maintainability
- Demountability
- Alternate magnet geometries
- Materials-conductor, insulation, structural

Note: Panel is considering multiple magnet types and configurations.

Off-normal plasma events

(Joint with Theme I Mitigating transient events in a self-heated plasma panel)

- Disruptions
- Runaway electrons
- Large ELMs
- Energetic Alphas

Note: Above topics include assessment of issues for 3-D/stellarator devices

Theme III: Plasma-Material Interface

Plasma-wall interactions

- SOL and Divertor Plasma
  - Turbulent heat and particle transport
  - SOL particle flows
  - Impurity transport
  - Radiation transport
  - He pumping
- Erosion & Redeposition
  - Impurity generation
  - RF sheaths
  - Dust production
  - Morphology changes
  - Component lifetime
  - Energetic a effects
- ELMs & Disruptions
  - Off-normal heat flux
  - Energetic electrons
  - Impurity injection
- Tritium Retention
  - Safety
- Innovations
  - High radiation frac'n
  - Flux expansion
  - Stellarator edge
  - Material development
  - Liquid surfaces
  - Active coating

Plasma facing components

- Solid Surface PFC
  - Heat transfer development
  - Materials Development
  - Integrated PFC Development
  - Integrated Component Testing
  - Chamber Geometry Optimization
  - NDE technique development
- Liquid metal surface and design
  - Temperature limits
  - MHD Effects
  - Heat Removal
  - Materials Development (pipes, nozzles, etc.)
  - Diagnostics
  - Hydrogen and impurity retention, removal

Theme III: Plasma-Material Interface

- Integrated Testing
- PFC Maintenance
  - Tools and Techniques Development
  - Off-line Testing
  - Integrated Testing

Internal components

- Measurement Systems
- RF Antennas (ICRF, LH)
- Microwave launchers
- Control Coils
- Innovation (materials, active coatings)

Theme IV: Harnessing Fusion Power

Fuel cycle

Needs for DEMO

Need to adequately process fusion fuel

Need to provide torus vacuum and fueling

Need to adequately contain and handle tritium

Need to adequately perform tritium accountability and nuclear facility operations

Need to breed tritium

Need to extract tritium from the breeding system

Need to characterize, recover and handle in-vessel tritium

Power extraction

Operation of plasma chamber and divertor components at temperatures high enough for efficient power conversion

Thermofluid/MHD, heat and mass transfer of reactor coolants and liquid breeders (He, liquid metals, water)

Fabrication of complex plasma chamber structures and loop components from candidate materials

Diagnosis, monitoring and control of blanket and primary cooling loop operation

Effective radiation shielding of vacuum vessel, magnets, and personnel

Development and validation of integrated plasma chamber system predictive capabilities

Characterization of blanket system synergistic effects, failure modes and lifetime in fusion environment

Integration, maintenance, and replacement methods for plasma chamber systems

Efficient power conversion systems for electricity and hydrogen production including compatible heat exchangers

Interaction of plasma chamber systems with plasma operation (high temperature walls, error fields, etc.)

Interaction of plasma chamber system with tritium breeding functions and fuel cycle requirements

Theme IV: Harnessing Fusion Power

Materials science

- Alloy Development
- Chemical Compatibility
- Design Criteria
- Erosion
- Fabrication & Joining
- Plasma-Material Interactions
- Radiation Effects
- Safety, Licensing, RAMI
- Thermal Creep & Fatigue
- Tritium Inventory
- Tritium Permeation

Safety

- International Fusion Safety Standard Framework
- Integrated Management Strategy for Activated Material

RAMI

- Need for integrated design
- Component reliability and maintainability
- Component lifetimes
- Maintenance systems
- Disruptions and off-normal events

Theme V: Optimizing the Magnetic Configuration

Compact toroid

- FRC
  - Stability at large s (normalized ion gyroradius)
  - Transport mechanisms and scaling
  - Current drive and sustainment
  - Fast particle effects on current drive, stability, confinement
  - Heating methods
- Spheromak
  - Sustainment and confinement
  - Efficient formation techniques
  - Transport mechanisms and scaling
  - Beta limiting mechanisms
  - Particle balance and density control
  - Fast particle effects on sustainment, stability, confinement
  - Resistive wall mode control
  - Technology for long pulse operation

Reversed-field pinch

- Transport mechanisms and confinement scaling
- Current sustainment
- Integration of current sustainment and improved confinement
- Plasma boundary interactions
- Energetic particle effects
- Beta limiting mechanisms
- Self-consistent reactor scenarios
- Optimized resistive wall mode control for a fusion environment

Spherical torus

- Start-up and ramp-up
- Plasma-material interface
- Electron energy transport
- Integration at high beta
- Magnets
- Stability and steady-state control
- Disruptions
- RF heating and current drive
- Ion scale transport
- Fast particle instabilities
- Neoclassical tearing modes
- Continuous neutral beam injection systems

Theme V: Optimizing the Magnetic Configuration

Stellarator

Simpler coil systems
Integrated high performance of Quasi-Symmetric optimized stellarators
Confinement predictability
Divertors
Operational limits
Impurity and fusion ash accumulation
Reduction of anomalous transport
Energetic particle instabilities
Disruptions (limits on plasma current generated rotational transform)
ELM-free high performance
Profile sensitivity of operational limits
Superconducting stellarator coils