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)

Fueling
- 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 $T_e > T_i$ 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

2 of 3  Status as of 2/20/09
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

Status as of 2/24/09
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