Integrated control of instabilities

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Integrated stability control in AT plasmas

- **Integrated stability control includes:**
  - Early detection of stability boundaries
  - Early identification of growing instabilities
  - Action to avoid stability boundaries
  - Action to suppress growing instabilities
  - Safe plasma shutdown - as a last resort

- **Goal: Reliable, sustained operation near stability limits**
  - For a range of AT plasma conditions

Operation of ITER without disruptions will require multiple levels of protection

Plasma configuration →	Multivariable shape control	Current, pressure profile control	Rotation profile control
Detect &avoid operational limits →	Radiated power, density, q(r), …	Real-time beta measurements	Real-time stability code
Actively suppress instabilities →	NTM stabilization (ECCD)	Rotation, error field control	RWM feedback (int./ext. coils)
Off-normal condition: soft shutdown →	Action depends on plasma state	Change heating, fueling	Radiated power (small pellets)
Onset of disruption: fast shutdown →	High-pressure gas jet, liquid jet	Large pellets: High-Z, Low-Z	Magnetic perturbations

These features must become integrated and routine!

Why should integrated stability control be an element of future AT research?

Fusion performance is maximized at high beta (approaching stability limits)

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- Stability control enables full use of machine capabilities

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- **Integrated stability control requires a defined research effort**
  - Extension of stability control methods to AT regimes
  - Development of robust, model-based control methods
  - Demonstration of compatibility between the various elements of stability control, profile control, etc.

Integrated stability control requires new hardware and control elements

- Real-time kinetic equilibrium fits
- Real-time stability calculations (DCON)
- Antenna for real-time measurement of MHD damping rate
- Diagnostics for internal MHD modes
- Optimized coils for control of ELMs and RWMs
- Fast steering mirrors for ECCD
- Upgraded injectors for gas, pellets
- PCS upgrade
- … others?

Development of integrated stability control would represent a major research theme