1. Purpose of Experiments

Include immediate goal of the experiments, scientific importance and/or programmatic relevance. Refer to any relevant program milestones or ITER R&D commitments.

The purpose of these experiments is to explore the operational limits of C-Mod with the present (Aug-Sep 2002) complement of auxiliary power (up to 7 MW ICRF, half at 70 MHz and half near 80 MHz) at plasma current up to 1.4 MA. The main aims are in support of enhancing the physics basis for next step burning plasma options. Both within the US program, and internationally, options for next step tokamak facilities to explore the alpha heating dominated burning plasma regime are being considered. They range from relatively compact, high field copper coil devices which would focus primarily on the burning plasma issues, to large scale superconducting facilities which would, in addition, explore fusion reactor technology issues. The basis for these designs rests on the results of world-wide fusion research over many decades. Several areas of uncertainty remain in the extrapolations required; many aspects of the C-Mod program are aimed at improved understanding of these issues, which should lead to reductions of these uncertainties. Pushing the machine to its present operational limits should provide important data in a number of areas:

1) Global energy confinement scaling with current and input power;
2) Reactor regime H-Mode edge confinement effects, including pedestal dynamics and the boundaries between ELM free, EDA and type I ELM regimes;
3) Power and particle exhaust with parallel scrape-off power flows at the 1 GW/m² level or higher;
4) Disruption dynamics and halo currents with maximum presently achievable stored energy and plasma pressure;
5) Extension of toroidal rotation measurements to higher stored energy and plasma current.
2. Background

Discuss Physics basis of the proposed research, Prior results at Alcator or elsewhere, and any related work being carried out separately.

In the past, C-Mod has operated up to 1.5 MA plasma current (for a single discharge), with coupled ICRF heating power up to about 3.5 MW. A summary of D-D fusion rate versus stored energy, from the core confinement data base, is shown in figure 1. With the approximate doubling of auxiliary input power which should be available with all 4 RF transmitter systems operating into the D, E and J port antennas, typical H-mode scalings (twice ITER 89-P confinement) give an extrapolation to about 0.4 MJ of stored energy at 1.4 MA plasma current, with $\tau_E \approx 0.06$ seconds. Reaching these performance levels is one of the goals of this miniproposal. At the same time, $\beta_{\text{toroidal}}$ in the range of about 2.3% would be achieved, with $\beta_N \approx 2$. Our record values for these parameters, achieved up to now, are $\beta_{\text{toroidal}} = .015$, $W_{\text{tot}} = .23$ MJ, $\beta_N = 1.7$, from shot 980217015, a 1 MA EDA discharge with just over 3 MW of injected RF power. On 980217013, which was a similar, slightly lower peak performance shot ($W_{\text{tot}} = .215$ MJ), the central toroidal rotation reached a steady-state value of $1 \times 10^5$ m/s.

Experiments on the nature of the H-Mode edge in C-Mod indicate that near threshold the plasma enters ELM free H-mode. At higher powers, the discharges evolve into the EDA regime, with its favorable particle confinement properties. At the highest plasma pressures achieved so far, small ELM-like instabilities appear on top of the EDA behavior (980217013 is a clear example); no type I ELMs have been observed. One of the important goals of these experiments will be to explore the nature of these small ELMs to the highest available edge pressure gradients, and to see if the boundary for type I giant ELMs can be crossed.

Operation at high power and current is likely to lead to some disruptions. It will be of significant interest to monitor the resulting halo and eddy currents, as well as vessel strains, under these conditions.

3. Approach

Describe the methodology to be employed; explain the rationale for the choice of parameters, etc. Describe the analysis techniques to be employed in interpreting the data, if applicable. If the approach is standard or otherwise self-evident, this section may be absorbed into the Experimental Plan.

The machine should be in a well conditioned state, as determined by: intrinsic H/D fraction 5% or less; radiated power fraction less than 50% for RF power greater than 4 MW.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

**Toroidal Field:** 5.0 Tesla (chosen so that the 70 MHz and 80 MHz resonances straddle the axis)
Figure 1. Present performance of C-Mod discharges from the core confinement data base, along with extrapolated performance assuming $\tau_e \propto I_p/\sqrt{P_{in}}$. The overall goal of this miniproposal is to access the 6 MW, 1.4 MA region of the plot.
Plasma Current: 0.8 - 1.4 MA

Working gas species: D$_2$

Density: $1 - 1.6 \times 10^{20}$ m$^{-2}$ (target densities)

Equilibrium configuration (if possible, refer to database equilibria): Lower single null X point such as 1020820003, but with higher upper triangularity ($\delta_u \approx 0.5$ if possible).

Pulse length, typical current & density waveforms, etc. Refer to database or sketch desired waveforms: flat top conditions should be maintained long enough for high power ICRF pulses of at least 0.5 seconds.

4.2 Auxiliary Systems

RF Power, pulse length, phasing: 4 - 7 MW for up to 0.5 sec; D & E near 80 MHz, J at 70 MHz

Pellet Injection (species): not required

Impurity blow-off injection: if available for $\tau_I$

Special gas puffing: standard valves; argon for HIREX

Other: H/D $\leq$ 5%; add B$_T$ waggle ($\pm$1%) for ECE during highest $\beta$ portion of discharge

4.3 Diagnostics

List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.

Fast magnetic pick-up coils (1 - 2 MHz sampling)

Core and Edge Thomson Scattering

Core and Edge x-ray arrays

HIREX for Ti profiles and rotation

Interferometer (at least 1 chord)

Visible spectroscopy

Z-Meter array

McPherson spectrometer

ECE Michelson, GPC, GPC2, radiometer

AXUV diode arrays (core and edge)

$2\pi$ foil bolometer

Lyman-\(\alpha\) edge AXUV array

Halo Current Rogowskis and inner wall strain diagnostics
DNB and related diagnostics (as available)
IR divertor imaging (if available)
Reflectometer for density fluctuations (if available)
Phase Contrast Imaging helpful for fluctuations (if available)

4.4 Neutron Budget
Estimate the neutron dose rate at the site boundary. Give basis for estimate. (Once some experience has been gained a standard formula will be provided for estimating dose rates.)
up to $5 \times 10^{14}$/shot

5. Experimental Plan

5.1 Run sequence plan
Specify total number of runs required, and any special requirements, such as consecutive days, no Monday runs, extended run period (10 hours maximum), etc.

One very full run day is required to perform these experiments. If things are going well, should extend to 10 hours if possible.

5.2 Shot sequence plan
For each run day, give detailed specification for proposed shot sequence: number of shots at each condition, specific parameters and auxiliary systems requirements, etc. Include contingency plans, if appropriate.

1. Start at 5.0 T, 1.0 MA, target $n_l04 = 1 \times 10^{20} \text{ m}^{-2}$. Bring the ICRF power up to at least 5 MW (4 shots)
2. Raise the plasma current to 1.2 MA. Keeping the RF power at about 5 MW, scan the target density up to about $1.6 \times 10^{20}$, in 3 steps. Evaluate the EDA/ELM nature, confinement, impurities, etc. (6 shots)
3. Choose the optimum density, and raise the power to full available (> 6 MW total input desired). (5 shots)
4. Reduce the RF power to 5 MW, and raise the plasma current to 1.4 MA. (5 shots)
5. Raise the power to maximum available (> 6 MW total input desired). (5 shots)
6. Reduce $I_p$ to 0.8 MA, RF power to 5 MW (3 shots)

6. Anticipated Results
Discuss possible experimental outcomes and implications. Indicate if the program may be expected to lead to publications, milestone completions, improved operating techniques, etc. Indicate if the experiments are intended to contribute to a joint research effort, or an external database.

These experiments will determine the plasma performance under H-mode conditions at high power in C-Mod. This should yield important results in a number of areas: high $\beta$ effects on H-Mode edge, including fluctuations and small ELMs; type I ELM boundary; confinement scaling; pedestal scaling; toroidal rotation; disruptions and halo currents.

7. References
Include references both to external and internal literature or communications which bear on this proposal. See Section 2.