1. Purpose of Experiments
Include immediate goal of the experiments, scientific importance and/or programmatic relevance. Refer to any relevant program milestones.

Disruption mitigation using massive gas injection (MGI) has been studied in a number of tokamaks over the past decade, and generally has been found to successfully reduce thermal energy deposition to the divertor by rapidly converting plasma energy into radiation, as well as reducing peak halo currents. But nearly all of these studies have been done by using MGI to trigger disruptions of stable plasmas. In actuality, active disruption mitigation will mostly be used on plasmas that are experiencing warning signs of an impending disruption, such as large MHD activity and/or locked rotation. ITER has requested that experiments using MGI on such ‘sick’ plasmas be carried out on several machines to gauge its mitigation effectiveness compared to previous experiments.

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

Disruption mitigation using MGI has been studied on a number of tokamaks, including Alcator C-Mod$^1$, DIII-D$^2$, ASDEX-U, JET, KSTAR, MAST, etc. By optimizing gas mixtures, pressures, injection geometry, and valve programming, it has been shown that MGI can reliably and reproducibly convert as much as 90% of the total plasma energy (thermal + magnetic) into radiation, which is spread over the entire first wall, thereby reducing the instantaneous thermal load at the divertor strikepoints, while also speeding up the current quench, which reduces halo currents in the divertor structure. Modeling of these experiments$^5$ shows that MGI’s success is due in part to the self-generateion of MHD modes, particularly $n=1$, which bring the injected impurities into the core much more quickly than diffusive processes would. Experiments using two MGI valves on C-Mod have also shown that there is a linkage of MGI-generated $n=1$ MHD modes and...
asymmetries in radiated power during mitigated disruptions, including rotation of these features\textsuperscript{4,5}. However, nearly all of these studies have been done by using MGI to trigger disruptions of plasmas that do not have significant pre-existing MHD modes in them, such as classical or neoclassical tearing modes, resistive wall modes, or locked modes. There presumably is a possibility that pre-existing MHD modes could affect the MGI-generated MHD in a deleterious fashion, perhaps reducing its mitigation effectiveness, or effecting toroidal $P_{\text{rad}}$ asymmetries. For this reason, ITER has requested that mitigation experiments be carried out on ‘sick’ plasmas, i.e. plasmas that have some form of pre-existing MHD modes in them.

### 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.

In C-Mod, we can reliably generate plasmas with a locked mode and no rotation. This capability is used frequently to calibrate the HIREX rotation measurement. The technique relies on running the A-coils at full current, instead of in their normal feedback mode, to generate an $m=2/n=1$ locked mode. Into these locked plasmas we can then fire the MGI and measure the radiated energy using the 2pi diode and 2pi foil, measure toroidal asymmetries using the AXA and AXJ arrays, and the DMBolo diodes. The MHD $n=1$ modes will be monitored with our standard Mirnov diagnostics. Thermal deposition on the divertor may be possible with thermocouples and IR thermography.

There are many possible parameters that could be varied, but in order to save run time, most of the MGI-relevant parameters, such as gas mixture, pressure, and valve pulse length, will be fixed at optimal settings based on our past experience. This also makes comparison to previous results, i.e. with stable plasmas, more relevant. The principal parameters that we do want to vary are the timing between the two MGI valves, and the toroidal phase of the locked mode.

We would like to compare these shots with our large database of existing MGI shots. Nearly of all of those are at 1 MA, $n_{\text{H}_0}=1 \times 10^{20}$ m$^{-2}$, with 1 MW of ICRF. However, the standard locked mode HIREX calibration shot is at 0.8 MA, $\leq 0.6 \times 10^{20}$ m$^{-2}$, and ohmic. So we would like to spend some amount of time on the first day of this MP to see if we can develop a reproducible locked shot at the higher parameters.

### 4. Resources

#### 4.1 Machine and Plasma Parameters

Give values or range for:

- Toroidal Field: $+5.4$ T
- Plasma Current: 0.8-1.0 MA
- Working Gas Species: $D_2$
Density: $n_{l_04} = 0.6-1.0 \times 10^{20} \text{ m}^{-2}$

Boronization Requested (if yes, specify whether overnight or between-shot, how recently needed, and any special conditions.): No

Equilibrium configuration (if possible, refer to database equilibria): Shot 1140723012 is a recent standard locked mode shot for the field in the forward direction. But see discussion under ‘experimental plan’.

4.2 Auxiliary Systems

ICRF Power, pulse length, phasing: 1-2 MW (match previous MGI experiments)  
LHCD Power, pulse length, phasing: none  
Pellet Injection (species): no  
Impurity blow-off injection: no  
Diagnostic Neutral Beam: no (keep gate valve closed)  
Special gas puffing: gas jet system; both valves, 70 bar; mixture 15% Ar + 85% He  
Cryopump: no  
Non-axisymmetric Coils (Connections, Current): Yes, with programming from shot 1140723012  
Other:

4.3 Diagnostics

List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.  
DMBolo array, AXA/AXJ arrays, Mirnov fluctuations, 2pi bolo & diode, divertor IR imaging, divertor thermocouples

5. Experimental Plan

Both sections must be filled in.

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.

2 days, but not in the same week, so that we can analyze data from the first run day to optimize planning for the 2nd run day. Since we do not need very high ICRF power, nor boronization, the first run day could be scheduled early in the physics run campaign. Note that these MGI runs have a reduced number of shot cycles due to the extra time between shots required to pump out the gas.

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.

4-5 shots: Start with a recent locked mode calibration shot (1140723012) and try to develop it into a 1.0 MA, $n_{l_04}=1 \times 10^{20} \text{ m}^{-2}$, with 1 MW of ICRF shot to better match our existing MGI dataset. If unsuccessful after 4-5 shots, stop and use the closest one that works reliably. (No MGI on these development shots)
12 shots: Using the locked mode target plasma, fire MGI from B-port only, with fixed MGI parameters, to look at total radiated energy, $P_{rad}$ asymmetries, divertor heating, and n=1 MHD. Also run 1 or 2 shots without the locked mode (i.e. with A-coils in normal feedback mode) for comparison. Vary toroidal phase of locked mode if possible.

12 shots (2\textsuperscript{nd} day): Use both gas valves to look for effects on $P_{rad}$ asymmetries and rotation with and without locked modes. Vary toroidal phase of locked mode if possible.

6. \textbf{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, an ITER request, or an external database.

I expect that MGI mitigation of locked plasmas will have the same behavior in regards to total radiated energy fraction (75-80\% with 15\% argon) as stable plasmas. Ditto for the current decay times. But I would not be surprised if there are some differences in $P_{rad}$ asymmetry and/or rotation. The results will be presented at the next ITPA MHD and shared with ITER.

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