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

The purpose of this experiment is to assess the divertor conditions depending on the secondary separatrix (SSEP) position around double-null. These experiments will inform design decisions for the Advanced Divertor and RF tokamak eXperiment (ADX) as well as SPARC. Results will guide the development of a null balance controller, likely based on divertor flux measurements.

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

The ability to share power and particle fluxes between two outboard divertor legs may be advantageous for a fusion reactor:

- The larger major radius reduces the fluxes due to total flux expansion.
- The total flux expansion on the outboard side will likely stabilize a radiating thermal front to large perturbations.
- There is more space for physical objects, such as additional divertor coils.
- This separates the inboard scrape-off layer (SOL) from the outboard, allowing for placing RF actuators in a region of relatively quiescent plasma and reduced impurity penetration.

However, having a double-null plasma necessary for the above benefits comes with challenges and uncertainties:

- How precisely do the two nulls have to be maintained to keep balanced heat fluxes to the outer divertor targets and minimal heat fluxes to the inboard targets given the very narrow (<1 mm) SOL heat flux widths expected in fusion reactors?
• Is it possible to even have a steady, balanced heat flux between the two outboard divertors?
• Are magnetic measurements of SSEP sufficient for maintaining heat flux balance or will it be necessary (or even possible) to develop a controller based directly on measurements of the quantity of interest: heat flux or a suitable proxy (e.g. particle flux)?
• Are heat (particle) fluxes sufficiently balanced when impurity penetration from the inboard side is minimized (which occurs at a slightly unbalanced null)?
• Performance of I- and H-mode confinement regimes are sensitive to the magnetic balance. Is the optimal divertor solution compatible with an optimal core solution?

During the maintenance break proceeding the FY16 campaign all divertor Langmuir probes and the divertor heat flux diagnostic sets were refurbished. Nearly all of the diagnostics are now functioning and it will be important to gather this data early in the campaign while they are still functioning.

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 approach for these experiments will be relatively simple in concept but may be challenging to implement directly as planned. The plan is to map out divertor profiles versus SSEP position using strike point sweeps or to sweep SSEP and move the strike point position shot-to-shot. However, it will be challenging to separate the two independently on a per-shot basis. The experiments will likely result in a trajectory in SSEP and rho profiles on the probes per each shot. Experiments will be performed in L-, H-, and I-modes over the course of ~3 run days with some discharge development done during non-physics startup plasmas.

4. Resources

4.1 Machine and Plasma Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toroidal Field:</td>
<td>5.4 T</td>
</tr>
<tr>
<td>Plasma Current:</td>
<td>5.5-1.1 MA</td>
</tr>
<tr>
<td>Working Gas Species:</td>
<td>D2</td>
</tr>
<tr>
<td>Density:</td>
<td>$n_{\text{el}} \sim 0.35-1.2 \times 10^{20}$ m$^{-2}$</td>
</tr>
<tr>
<td>Boronization Requested:</td>
<td>yes, recent boronization for EDA H-modes</td>
</tr>
<tr>
<td>Equilibrium configuration:</td>
<td>1150922017</td>
</tr>
</tbody>
</table>

4.2 Auxiliary Systems

ICRF Power, pulse length, phasing: sufficient ($\rightarrow$ 3MW) for access to I- and H-modes on those runs, 0 MW on L-mode run

LHCD Power, pulse length, phasing: not needed

Impurity blow-off injection: not needed
4.3 Diagnostics
List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.

Absolutely necessary:
- Divertor Langmuir probes
- WASP and ASP systems
- Divertor heat flux diagnostic set
- IR camera facing inner divertor

Nice to have:
- Chromex optimized for divertors
- Bolometers and diodes
- L-alpha
- Thomson scattering
- CXRS
- MSI

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.

0. Discharge development – During pre-physics phase try to develop shot programs that sweep divertor strike points over divertor probes necessary to map out profiles while keeping SSEP fixed. Or perhaps keep strike point fixed while sweeping SSEP. Determine range of SSEP sufficient for scan of relative balance of fluxes (from impurity screening runs, anticipate +/-10 mm will be sufficient, more likely +/-5 mm).

1. L-mode plasmas – Do plasma current (0.55, 0.8, 1.1 MA) and collisionality scans (sheath-limited, moderate-recycling, and near-detached) and map out divertor profiles over SSEP scan near double-null (values determined from experience in discharge development). Prefer forward field. Depending on results, may want additional time in reversed field to disentangle divertor geometry and grad-B drift direction. ~1+ run day.

2. EDA H-mode plasmas – Do standard 5.4 T, 0.8 MA. Will need sufficient ICRF power to stay in H-mode in unfavorable drift direction. Scan SSEP and strike point sweep. Do cases of both with and without radiative divertors. This should be
close enough to a boronization to maintain steady EDA H-modes. Prefer forward field. ~1 run day.

3. I-mode plasmas – Do standard 5.4 T, 0.8 MA I-mode with sufficient ICRF power to for steady I-mode. Scan SSEP and strike point sweep. SSEP scan may be limited to parameters in which plasma remains in I-mode. Do cases of both with and without radiative divertors (to the extent possible in I-mode). Prefer reverse field. ~1 run day.

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.

0. Discharge development (something to keep PO’s engaged during cleanup)
   0.1 Determine if SSEP can be held constant with a strike point sweep on both divertors. If not, then:
   0.2 Determine if SSEP can be swept with a strike point held constant. If not, then:
   0.3 Determine if trajectories in SSEP and strike point position can be used to fill out parameter space.

1. L-mode (may punt on current scan in near-detached conditions if time runs out)
   1.1 Sheath-limited:
      1.1.1 \( I_p = 0.55 \) MA, \( n_{i04} \sim 0.25 \times 10^{20} \) m\(^{-2} \) (sheath-limited): scan SSEP and strike point space. 5 shots
      1.1.2 \( I_p = 0.80 \) MA, \( n_{i04} \sim 0.35 \times 10^{20} \) m\(^{-2} \) (sheath-limited): scan SSEP and strike point space. 5 shots
      1.1.3 \( I_p = 1.1 \) MA, \( n_{i04} \sim 0.55 \times 10^{20} \) m\(^{-2} \) (sheath-limited): scan SSEP and strike point space. 5 shots
   1.2 Moderate-recycling:
      1.2.1 \( I_p = 0.55 \) MA, \( n_{i04} \sim 0.45 \times 10^{20} \) m\(^{-2} \) (sheath-limited): scan SSEP and strike point space. 5 shots
      1.2.2 \( I_p = 0.80 \) MA, \( n_{i04} \sim 0.70 \times 10^{20} \) m\(^{-2} \) (sheath-limited): scan SSEP and strike point space. 5 shots
      1.2.3 \( I_p = 1.1 \) MA, \( n_{i04} \sim 0.90 \times 10^{20} \) m\(^{-2} \) (sheath-limited): scan SSEP and strike point space. 5 shots
   1.3 Near-detached:
      1.3.1 \( I_p = 0.55 \) MA, \( n_{i04} \sim 0.65 \times 10^{20} \) m\(^{-2} \) (sheath-limited): scan SSEP and strike point space. 5 shots
      1.3.2 \( I_p = 0.80 \) MA, \( n_{i04} \sim 0.95 \times 10^{20} \) m\(^{-2} \) (sheath-limited): scan SSEP and strike point space. 5 shots
      1.3.3 \( I_p = 1.1 \) MA, \( n_{i04} \sim 1.20 \times 10^{20} \) m\(^{-2} \) (sheath-limited): scan SSEP and strike point space. 5 shots

2. EDA H-mode
   2.1 Develop steady EDA H-mode discharge. 5 shots
   2.2 Unseeded: scan SSEP and strike point space. 10 shots
   2.3 Seeded (probably using feedback system): scan SSEP and strike point space. 10+ shots

3. I-mode
   3.1 Develop steady I-mode discharge. 5 shots
3.2 Unseeded: scan SSEP and strike point space. *10 shots*
3.3 Seeded (probably using feedback system): scan SSEP and strike point space. *10+ 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, an ITER request, or an external database.

These experiments will give a dataset indicating the relative balances of particle flux to the divertor plates depending on the null-balance for dissipative and non-dissipative conditions in L-, H-, and I-mode plasmas. It will provide additional data on core plasma performance in high confinement regimes to complement previous studies. The results will provide an important basis for design and planning of future experimental devices at the PSFC and to the greater community. They will also inform the possibility of control of SSEP to balance divertor fluxes based on measurements of divertor fluxes. They will be published in a journal article and may be presented at a conference (APS2016?).

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