

Input to the FESAC Priorities Panel Alcator C-Mod – The One Word Solution

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Introduction: This whitepaper addresses the future of the Alcator C-Mod experiment. For me this is admittedly a very parochial issue. Still there are several crucial points to be made and just because I have a natural bias does not mean that my opinions are not correct. The discussion below separates into three parts: (1) a discussion of the process by which the current DoE decision was made to terminate Alcator C-Mod (a colossal failure in decision making), (2) an assessment of the impact and importance of Alcator C-Mod to the ITER program (grossly underappreciated by DoE) and (3) a proposed simple solution to address the Alcator C-Mod problem in FY-13, (the “one word solution”).

A colossal failure in decision making: I recognize that as a research program evolves there will times when existing facilities should be terminated in order to allow new ones to be built. My problem with the decision to terminate Alcator C-Mod is the way in which the decision was made. This decision was purely an internal DoE decision. In spite of the fact that the Alcator C-Mod experiment is a world class facility, has been contributing to fusion research for decades, and is one of the two major tokamak facilities in the US that directly support ITER, the decision to terminate was made without a national scientific review of the program or even a local review at MIT. This is not the way to terminate a major US facility. Clearly DoE at times has to make difficult decisions, but the process by which they decided to terminate Alcator C-Mod qualifies as a colossal failure in decision making.

Alcator C-Mod, grossly underappreciated: There are several very challenging plasma physics and plasma engineering problems facing tokamak based fusion energy. Two, for which a solution currently does not exist even for ITER, let alone a reactor are (1) plasma-wall interactions, and (2) steady state plasma sustainment. Either of these problems, if not solved, is a potential show stopper. Solving them requires experiments. Alcator C-Mod, while relatively small in terms of physical dimensions, is turbo-charged in terms of performance because of its large magnetic field and high plasma density. In fact the plasma parameters achievable in Alcator C-Mod are unmatched anywhere else in the world and are very close to the ones planned for ITER. Specific areas of high Alcator C-Mod impact are as follows.

1. **Boundary science:** Without clever plasma engineering and new materials, the first wall and divertor plates in ITER will not survive. Alcator C-Mod has pioneered the vertical-plate divertor and solid heavy-metal plasma facing components. Both have been adopted for the ITER design; this combination is the only viable solution for high power density handling, and low retention of hydrogen isotopes in the walls. The Alcator C-Mod group is taking this research to the next step, installing the world’s first and only high temperature tungsten divertor, which is the best, and perhaps only, hope for a Fusion Nuclear Science Facility (materials

testing in the intense fusion neutron environment), as well as for commercial fusion reactors. It is noteworthy that Alcator C-Mod is the only facility in the world that runs at wall power densities prototypical of a reactor, thus providing a test-bed for ITER.

2. Steady state operation: Unless an efficient way can be developed to non-inductively drive a toroidal current in a tokamak, the concept is doomed to pulsed operation, which is highly undesirable and almost certainly unacceptable in a reactor. The Alcator C-Mod group is the world's leading experts on radio frequency physics and technology for plasma heating, current drive and plasma control. Most other machines rely principally on neutral beams, which do not extrapolate to fusion reactors. Alcator C-Mod is conducting unique studies of current drive using microwaves, the only envisioned solution for a steady-state tokamak reactor. The C-Mod studies are at the magnetic fields, plasma densities and microwave frequency for ITER, FNSF and reactors – that is with the same plasma dielectric and thus the same RF physics. C-Mod is also the only facility studying metal influxes accompanying high power radio-frequency heating. These can seriously degrade plasma performance in ITER and reactors. The group is developing and testing innovative solutions to this challenge, including a potential game-changer: an advanced, magnetic-field aligned RF antenna.

The one word solution: Based on the above discussion I conclude that Alcator C-Mod has several unique features that make it highly valuable to the success of the ITER program. Shutting it down on short notice eliminates one of the two major US facilities that directly supports ITER. Believing that we will learn what we need to learn by outsourcing our scientists to the new Asian tokamaks seems to me a losing strategy – too much reliance on international collaboration without a strong base US tokamak experimental program just will not get the job done. Since the time is short and the FY-13 budget is tight I believe that we need to buy some critical time before arriving at any final decision regarding the future of Alcator C-Mod. To accomplish this goal I suggest that DoE change its “close it immediately” mentality which leads to the word “termination” and replace it with a “think carefully about it” mentality which is characterized by the word “standby”. In short the one word solution transforms **termination** ® **standby**. Without any change in the FY-13 Alcator C-Mod budget the closeout costs could be reallocated to put the experiment in standby. New experiments and upgrades would be on complete hold, but the scientific staff could be largely maintained to analyze extensive existing data and develop the case, to be reviewed, for continuing operation in future years.

Recommendations: I have two recommendations for the FESAC Priorities Panel.

1. Inform DoE that the process that they used to decide to terminate Alcator C-Mod was unacceptable from a management point of view.
2. Inform DoE that a high priority for FY-13 under any budget circumstance is at the very least to put Alcator C-Mod on standby and not call for its termination.