Research Needs Workshop (ReNeW)

Reliability, Maintainability, and Testability: Issues for Control Systems

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From Plasma Physics Experiment to Prototype Fusion Power Plant: Growth in the Scale and Importance of RM&T of Control Systems

As fusion energy experiments progress toward the DEMO goal, steadily increasing complexity and cost of the experiments drives a steady increase in the importance and complexity of Reliability, Maintainability, and Testability (RM&T) of the facility as a whole and of the systems that comprise it. Because of its critical role in safety and protection of the investment in the facility, RM&T is particularly important for the control system. Fusion energy experiments now being designed have already reached the point at which RM&T activities are sufficiently complex that formal methods are needed to cope with them. The fusion energy community has already recognized the need for formal methods, and has already begun to look to related communities for guidance, an example being the recent decision by ITER IO to establish a formal relationship with CERN for transfer of administrative expertise. However, the author believes it would be wise for the fusion community to cast a wider net in its search for guidance. Because the goal of fusion is commercial power plants, rather than ever more complex experiments, the fusion community would be wise to also look to industries that must manage complex and potentially dangerous systems in the public domain while producing a profit.

Technical Requirements for Resolution

There are many domains from which the fusion community can usefully derive guidance and inputs for methods for managing RM&T. These include the "Big Physics" side of the particle physics community, the power and chemical industries, the nuclear power industry, and the aerospace industry. No one or combination of these will provide all the expertise needed, it will be necessary for the community to produce the fusion-specific elements; but the accumulated knowledge of the other communities will provide the vast majority of the guidance needed, and useful lessons of what, and what not, to do.

Of the other communities, the aerospace industry is particularly well suited to supplying RM&T insights for fusion energy in general, and controls in particular.

The overall methods for arranging and executing an RM&T program for a large project are roughly the same in the power, chemical, nuclear power, and aerospace industries. However, the similarities between three key issues of fusion energy and the aerospace industry lead to the medium-level of details of the aerospace processes to have the greatest similarity to the corresponding level of details that will be needed for fusion energy RM&T for control systems. The three issues are those of operating mode stability, stored energy content, and consequences of failure. The author posits that for fusion energy controls, the operating mode is marginally stable to unstable; the stored energy content is small, but can be concentrated in one spot so as to act moderate; and the consequences of failure are moderate. Of the industries considered, the fusion conditions

match most closely to the aerospace conditions, where the operating mode is also marginally stable to unstable, the stored energy content is moderate, and the consequences of failure are major.
The aerospace industry has had approximately 100 years in which to develop procedures for RM&T, and for the last 90 years, the industry has been of sufficient importance to have had to generate those procedures under the regulatory eye of the government. With that experience, the industry has produced entire sets of multiple documents that describe in great detail how to set up and run an RM&T program for a major project, and how to tailor the program to suit the nature of the project.

Research Thrust Elements

The vast set of compiled data and instructions for RM&T programs available in the aerospace industry is of sufficient scale that a large group of people would be needed to review and adapt it to fusion energy control systems. The author proposes instead that a small, but critical, part of an RM&T program should be the focus of a near-term review and adaptation effort by the fusion energy community.
In particular, the author suggests that the fusion controls community should review three key analyses methods as they are applied to controls by the aerospace industry, with regard to determining what can be adopted from the existing procedures, what can be adapted, and identifying those areas that are of importance to fusion that are not covered by the existing procedures.
The three analyses that should be the focus of the initial effort should be the analysis processes known as Failure Modes and Effects Analysis (FMEA); Criticality Analysis (CA), often combined with an FMEA as a Failure Modes, Effects, and Criticality Analysis (FMECA); and Diagnostic Fault Coverage Analysis (DA).
Within the aerospace industry, multiple general industry and company-specific documents exist which describe how to perform just those three analyses; including, Source Requirements and Objectives Documents, Process Specifications, Process Guidelines, and Analyst's handbooks. Many of these documents can be made available for review by the fusion controls community.
The documents listed above are not the only sources of the needed information, but they are likely to be the best starting places for evaluating the information, as those documents are an aerospace-tailored compilation of aerospace experience and data with requirements from professional and governmental organizations, including the FAA, SAE, DoD, and NASA. Furthermore, a review of the aerospace documents, would supply the insight needed by fusion controls personnel for them to know what to look for when searching for useful inputs from requirements organizations of importance to fusion, but not involved with aerospace, in particular, DoE and the NRC.
It is perhaps of value to note that a similar review and adaptation of a formal procedure to fusion energy is already underway in the ARIES program, in which for more than a year the members of the ARIES team have been reviewing the Technology Readiness Levels process developed by NASA and used by DoD for assessing the suitability of technologies to programs. The author suggests that a similar program devoted to FMEA/FMECA and DA should be created by the fusion community.