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Peer Review, Basic Research, and Engineering; Defining a Role for QA Professionals in Basic Research Environments*

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PEER REVIEW, BASIC RESEARCH, AND ENGINEERING; DEFINING A ROLE FOR QA PROFESSIONALS IN BASIC RESEARCH ENVIRONMENTS

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ABSTRACT

Within the context of doing basic research, this paper seeks to answer four major questions: 1) What is the authority structure of science, 2) What is peer review, 3) Where is the interface between basic physics research and standard engineering, and 4) Given the conclusions to the first three questions, what is the role of the QA professional in a basic research environment like Fermilab.

FRAMING THE QUESTION

The motivation for this paper began in a technical session at last year's ASQC conference, when one of the speakers complained about how resistant scientists were to having their work checked by QA audit teams. He attributed the resistance to *rebelliousness* and not wanting to have *any accountability* for their work. But is there more to it than this? The speaker's solution to the problem was to put a "Ph.D." on the review team to act as a peer. As I told him during the question and answer period, just because a person has a "Ph.D." (even if it's in that particular field) does not *necessarily* make him a peer. The issue is not that scientists don't want their work reviewed by other people, it is that they want their work to be reviewed by *competent* people who are able to criticize it *intelligently*. In other words, they want it reviewed by *peers*.

Although the discussion which follows can be applied to many disciplines, I will limit my comments and examples to the context of a basic high-energy physics research laboratory like Fermilab. This must be distinguished sharply from the kind of applied R&D done at some other national laboratories or in industry. Applied R&D focuses on developing or improving tangible products or services.[2]

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[1] Fermi National Accelerator Laboratory (Fermilab) is operated by Universities Research Association Inc., for the United States Department of Energy (DOE).

[2] This type of applied R&D is described in George Roberts, *Quality Assurance in Research and Development*, (New York: Marcel Dekker Inc., 1983). It is also important to note here

This paper seeks to address four major issues: 1) What is the authority structure of science, 2) What is peer review, 3) Where is the interface between basic high-energy physics research and standard engineering practices, and 4) Given the conclusions to the first three questions, what is the role of the QA professional in a basic research environment like Fermilab.

AUTHORITY STRUCTURE IN SCIENCE

Since the entire notion of peer review rests upon the credibility of the individuals involved, it is important to clearly define what it means to have *authority* in the high-energy physics community. There are at least two aspects to scientific authority. In regard to the first one, Kuhn claims that the ultimate authority in a scientific community is contained in the shared network of commitments to conceptual, theoretical, instrumental, and methodological ways of carrying out the goal of the discipline. He calls this network of commitments a "paradigm." In high-energy physics (HEP) where the goal is to isolate the fundamental constituents of the universe and the forces that interact between them, the paradigm consists of the "Standard Model" along with current accelerator, detector, and computing technologies. The theoretical and experimental aspects of the paradigm for HEP are articulated in the textbooks and journal publications used to train new physicists. According to Kuhn, physicists have no intrinsic authority *independent* of the authority contained in the paradigm. A physicist achieves *vicarious* authority only to the degree that he can articulate the parameters of the paradigm and design theoretical and experimental puzzles which heuristically probe and test them in every conceivable way.[3] The more tests and experiments the paradigm stands up to, the more "authority" it gains within the HEP community. Kuhn called this "Normal Science."[4] On this view, a physicist's authority is directly proportional to his understanding of the paradigm and the puzzles he devises to test it.

> "Bringing a normal research problem to a conclusion is achieving the anticipated in a new way, and it requires the solution of all sorts of complex instrumental, conceptual, and mathematical puzzles. The man who succeeds proves himself an expert puzzle-solver, and the challenge of the puzzle is an important part of what usually drives him on."[5]

The second component of achieving authority in the HEP community is what Pickering calls "opportunism of context." This is in fact a narrowing of the previous point. Why is it that certain scientists achieve authority in a *particular*

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that the type of QA done on research which is required by EPA documents like QAMS-004/80 (Guidelines and Specifications for Preparing Quality Assurance Program Plans) and QAMS-005/80 (Guidelines and Specifications for Preparing Quality Assurance Project Plans) apply to activities that are fundamentally no different than standard QC functions and are analogous to (for instance) checking the tolerances on a machined part that comes back from a vendor. I do not consider this type of research to be anything like the basic research done at Fermilab.

3 Thomas Kuhn, *The Structure of Scientific Revolutions*, 2nd ed., enlarged, (Chicago: The University of Chicago Press, 1970), pp 35 ff.

4 The theory of quantum electrodynamics has been tested against experimental results to an accuracy of 1 part in a billion, see Richard P. Feynman, *QED The Strange Theory of Light and Matter*, (Princeton, NJ: Princeton University Press, 1985), p 7.

5 Kuhn, p 36. In regard to the completion of experiments, see Peter Galison, *How Experiments End*, (Chicago: The University of Chicago Press, 1987), p 135 ff.

branch of experimental or theoretical HEP? Pickering claims that in addition to the preferences an individual may have to work in a particular part of the field (this includes the influences of the mentors he studied with), that the enormous size of most modern day experimental HEP facilities also dictates more specialization. "Resources for HEP experiments are limited by virtue of their expense; major items of equipment are located at a few centralized laboratories."[6] Those who have ready access to specific types of experimental apparatus are more likely to attempt to devise puzzles that test the paradigm in the areas that are more accessible by that type of apparatus. It subsequently follows that individuals develop sub-specialties like electronic detector design, electronics, software reconstruction etc. based on the resources available within the context they find themselves, the demands of their apparatus, and the kinds of physics problems they are called upon to solve (high background rate, low cross-section events etc.). An individual gains stature or authority in that sub-set of the community to the degree that he consistently solves complicated physics problems with the tools at hand. An extremely important part of achieving success also revolves around the ability to obtain financial support at that particular institution. This is also contingent on reputation and authority. The individual with authority has shown that he can pull all the components of the financial, theoretical, experimental, and technological aspects together within his own context. Doing this is a major miracle. Doing it *consistently* is an even greater miracle.

The most important thing to remember here is that even with all the sociological influences accounted for, true authority in HEP is *intrinsic* to the paradigm. Scientific authority is not a position that is bestowed once and for all in some continuous sense. The authority that individuals achieved by puzzle solving in the paradigm can be lost or "frozen in history" if they voluntarily choose to step out of the active pursuit of the field, begin making bad physics decisions, or cease to embrace the currently accepted paradigm. The classic example of authority that has been frozen in history is Einstein's refusal to accept the indeterminacy of quantum mechanics as the final form of a theory about the world. Up until the time of his death, he asserted that "God does not play dice."[7] There is no doubt that Einstein's *authority* remains "frozen" in regard to such issues as Brownian motion, special relativity, and the photo-electric effect, but as we will see later there is a vast difference between having *authority* and being a *peer*. Having authority is prerequisite to being a peer, but the two terms are not synonymous. Consequently, Einstein maintained much of his authority, but ceased to be a peer in regard to the Copenhagen interpretation of quantum mechanics.[8]

An issue that will become more important as our argument about the role of the QA professional proceeds, involves the possibility of two *conflicting* authority

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[6] Andrew Pickering, *Constructing Quarks; A Sociological History of Particle Physics*, (Chicago: University of Chicago Press, 1984), p 11.

[7] Heisenberg says of Einstein "'God does not play dice' was a phrase we often heard from his lips in these discussions, and so he refused point-blank to accept the uncertainty principle and tried to think up cases in which the principle would not hold." See Werner Heisenberg, "Reminiscences from 1926 and 1927" in *Niels Bohr; A Centenary Volume*, ed. by A.P. French and P.J. Kennedy, (Cambridge, MA: Harvard University Press, 1985), p 170.

[8] The Copenhagen interpretation of quantum mechanics is that view associated with Niels Bohr, Werner Heisenberg and the circle of physicists that were intermittently gathered to do research in Copenhagen earlier in this century. Einstein could not accept the indeterministic view of the world implied by Heisenberg's uncertainty relation or Niels Bohr's probabilistic interpretation of Schrodinger's wave function, i.e., giving only the *probability* of finding the localized wave-packet at a specific point. See Niels Bohr, "The Bohr-Einstein Dialogue" in *Niels Bohr; A Centenary Volume*, ed. by A.P. French and P.J. Kennedy, (Cambridge, MA: Harvard University Press, 1985), p 121 ff.

structures which are at philosophical odds with one another. It becomes difficult to resolve disagreements in management style, especially when one of the organizations is doing the work and the other is paying the tab. Most obviously, this is the case with government sponsored science like HEP. For example, what happens when the motives, goals, and agendas of the two authority structures are at odds? An example might be that the government funding agency begins to view the *primary goal* of doing basic high-energy physics research as producing superconducting magnets. In contradistinction, the HEP community views its *primary goal* as testing the parameters of the Standard Model with the development of the technology necessary to do that research as a very useful *by-product*. The tail should never wag the dog.

This type of philosophical disagreement is important to our case if management decisions that affect the physics program are made by an organization that is not part of the scientific community. In this regard, I agree with Kuhn who states that the "...scientific community sees themselves and are seen by others as the men uniquely responsible for the pursuit of a set of shared goals, including the training of their successors."[9] In other words, science must be directed by scientists or its not *really* science in the classical sense of the term.

> "One of the strongest, if still unwritten, rules of scientific life is the prohibition of appeals to heads of state or to the populace at large in matters scientific. Recognition of the existence of a uniquely competent professional group and acceptance of its role as the exclusive arbiter of professional achievement has further implications. The group's members, as individuals and by virtue of their shared training and experience, must be seen as the sole possessors of the rules of the game or of some equivalent basis for unequivocal judgments."[10]

This identification of a "uniquely competent professional group" whose role is to be the "exclusive arbiter of professional achievement", defining what *quality is* in regard to HEP, moves us directly into our discussion on defining what peer review is.

WHAT IS PEER REVIEW?

We will begin by trying to define the word "peer." If you go to a standard library and search scientific books for a definition of "peer review" you will find that it is not defined in the Encyclopedia Brittanica or the Encyclopedia Americana. Neither is it found in the McGraw Hill Encyclopedia of Science and Technology, the standard textbooks on physics (ranging from the most elementary to the most advanced) or even in histories of the development of the discipline.[11] The word *peer* comes from the Latin word *pariare* which means "to make equal." The Oxford English Dictionary claims that the transitive form of the verb has the sense "to make (a man) a peer to raise to peerage, to ennoble." In the intransitive sense, it

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[9] Kuhn, p 177.

[10] Kuhn, p 168.

[11] For instance see the introductory text by Dale D. Long, *The Physics Around You*, (Belmont, CA: Wadsworth Publishing Co., 1980), the standard college text by David Halliday and Robert Resnick, *Fundamentals of Physics*, 2nd ed., extended version, (New York: John Wiley & Sons, Inc., 1981), and the graduate level text on high-energy physics by Donald H. Perkins, *Introduction to High Energy Physics*, (Reading, MA: Addison-Wesley Publishing Co., 1972) or a present day view of the development of HEP in Laurie M. Brown and Lillian Hoddeson eds., *The Birth of Particle Physics*, (New York: Cambridge University Press, 1983).

simply means "to be equal, to rank equally."[12] If we key in on this last nuance, we can say that a peer is a "Colleague who is actively engaged in the same profession, more particularly he is a colleague who is working on the same types of physics."[13] It is important to note here, that although being trained and having authority in the same field is a prerequisite to being a peer, a more important factor is being an *active* practicing *competitor* who pursues the *same* type of research. The word "peer" is a relational or comparative term. Someone can only be a peer in relation to someone else with whom he competes for the same prize whether that be the first claim to a discovery, a new higher-resolution accuracy in measurement, beam time at an accelerator, the Nobel Prize in physics, or the grant money to carry out a research project.

What are the salient components of being a peer? It should be obvious from the above discussion that this is a multi-dimensional taxonomy which includes things like 1) Having an equal level of academic education, 2) Having an established track record of successfully proposing and solving experimental or theoretical problems giving the individual authority within the community, 3) Contributing to the basic premises of the discipline in which one works by publishing results that are of lasting value to the community and become a part of the paradigm, 4) Being identified by others in the community as a peer in the same types of physics problems. Once an individual has attained the position of peer, he becomes identified with and by that "uniquely competent professional group" whose role is to be the "exclusive arbiter of professional achievement," defining what *quality is* in regard to that field. But to remain a peer, one must be a continually *active competitor* in that field of study. Being a peer is not a title or position that is bestowed once and for all. Being a peer is an ever changing relationship to others who are actively pushing back the epistemological boundaries of a particular discipline.

Having defined what a peer is in this more formal way, we can now turn our attention to defining the nature of peer *review*. Peer review in jurisprudence is normally associated with a jury which is supposed to be composed of one's "peers." In this case, the group of peers listens to all of the evidence that is presented and judges whether one is guilty or not. The idea is similar in high-energy physics in that peers sit in judgement on the quality of one's physics. The objective existence of physical effects in the world and the scientific doctrine of defining initial conditions makes this type of judgement a case of determining the degree to which the effect is convincingly isolated by the detector and mapped to the predictions of theory. It is the successful completion of this type of experiment that is the real assurance of the quality of a scientific proposal.

As an aside, it is interesting to ponder why it is that peer review has had such great success as a methodology? The most salient insight here turns on the issue of *competition* (remember that the true peer must be an active competitor in the same field). At the risk of being branded a sociobiologist, let me suggest that *competition* in a particular niche or environment is an important part of our evolutionary heritage. We tend to limit this to primitive notions of survival. Yet I think this deeply ingrained evolutionary instinct can effect other more *sophisticated* portions of our lives. There are also some scholars who have even postulated a kind of natural selection of ideas and theories in which only the most robust and fit representations survive.[14]

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[12] *Oxford Compact Edition of the Oxford English Dictionary*, 2 vols., (Oxford: The Clarendon Press, 1972), vol. 2, p 2113.

[13] Private communication with Drasko Jovanovic, Senior Scientist at Fermilab.

[14] See the notion of "Memes" as found in Richard Dawkins', *The Selfish Gene*, (New York: Oxford University Press, 1978), pp 203 ff.

Peer reviews normally cover two broad types of activities: management reviews and technical reviews. In a management review, one looks at the goals of the organization and how upper management has attempted to achieve the organizational goals by putting together a "people design". Because organizations are basically "goal-seeking" organisms fathered by top management, the way individuals are tasked to solve problems is very important.[15] At first, this may not seem like the type of review in which one would need to have physicist peers. After all, we're talking about management right? The problem with this position in regard to a basic research laboratory is that because the management decisions about much of Fermilab's resources are intimately intertwined with carrying out the physics program, good management of those areas directly interfacing to the physics program must be done at least partially by peers within the physics community. It follows then that any *review* of that management responsibility must be performed by a committee composed at least partially of physicist peers as we have defined them above.[16]

The second type of review, the technical review, is the place that one would most naturally expect to find peer review. A technical review examines the technical goals and details of a project or experiment. In order for this *technical* review to be classified as a *peer* review, each aspect of the project should be reviewed by someone who is a peer as defined above.[17] The implication of the above for our study is that any and all reviews of either the management or technical aspects of the laboratory must include some form of bona fide *peer* contingent in order for it to be truly valid. This includes all *external* QA audits. We will discuss this further in our last chapter which deals with the role of the QA professional.

In conclusion, I am suggesting that we must determine the nature of the task and what discipline it falls under and pick our peers to review only the areas in which they are truly competent, i.e., the areas in which they are truly peers. This raises the issue of our next section, namely how does one define the boundaries of a particular discipline. More particularly, in the design and construction of today's sophisticated high-energy physics detectors which use people from many different disciplines as part of a team (hardware engineers, technicians, physicists, software engineers etc.), where are the boundaries between these disciplines to be drawn and how should peers be assigned to review those areas once defined? In other words, where does the basic research stop and the standard engineering begin?

THE INTERFACE BETWEEN BASIC RESEARCH AND ENGINEERING

Clearly defining the boundaries between basic research and standard engineering problems is one of the most difficult issues faced in defining the role of the QA professional. We will approach this by briefly defining what basic research is, then describing the boundaries. Ian Hacking claims that any scientific discipline (in our case HEP) can be explained by two symbiotic programmes that interact with one another: to represent the world and to intervene in the world.[18]

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[15] For a description of a functional approach to analyzing organizational structure see, Mark Bodnarczuk, "Reductionism, Emergence, and Functionalism; Presuppositions in Designing Internal QA Audits", published in *The Proceedings of the Fifteenth Annual ASQC National Energy Division Conference,* October 23-26, 1988, (Fermilab-Conf-88/77).

[16] This is in fact the case at the annual DOE Lab-Wide Review. At least two or three bonafide physicist peers are asked by DOE to join the review team.

[17] It is necessary that technical projects also have a management component.

[18] Ian Hacking, *Representing and Intervening; Introductory Topics in the Philosophy of Natural Science,* (New York: Cambridge University Press, 1987).

In regard to the first program (representing), scientists create theories which are often mathematical representations of the world. These phenomenological models (such as Feynman diagrams) and mathematical formalisms represent, describe, and image the world we live in. As Galileo so eloquently said, "The Book of nature is written in mathematical characters, without a knowledge of which men cannot understand it."[19] To the degree that the mathematical formalism maps to the physical world, to that same degree it is a likeness, a *representation*. Sometimes the representation precedes and predicts the experimental observation of an effect, other times the experiment changes, sharpens, or helps crystalize a new representation.

The second program (intervening) involves testing the degree to which the representations map to the world. This means performing experiments with technologies that alter or "vex" the properties of nature and then measuring and recording the properties of the changes. The important point to be noted here is that physicists from Robert Boyle onward have always been intimately involved in designing and building of their apparatus.[20] The main goal of an experimenter is to devise ways of "cashing-out" the physical phenomenology predicted by the theoretical portion of the paradigm into effects that can be measured in a detector. In order for a physicist to really be certain that he has observed a real effect and not some non-salient background or noise he must intimately understand even the finest details of his apparatus. "The ethics of the field of HEP as related to our historical roots is that the physicist should thoroughly understand the strengths and weaknesses of his *entire* apparatus. The issue in today's modern detector environment is should we still demand that the physicist be able to do *everything*. The answer to this is yes! More than ever the physicist must have a broad and detailed understanding of all the components of his detector."[21] The physicist's control over the design, construction, installation, and operation of all components of his detector is an undeniable part of what we would define as "basic research."

I will now attempt to locate the interface between basic research and standard engineering by analyzing the process of developing an experimental detector into various levels. It must be remembered that because each apparatus is different, the process will vary between detectors though the same basic principles hold in most cases of experiments and can also be extrapolated to the development of entire accelerator laboratories. There are a number of presuppositions that must be kept in mind here as we proceed through the analysis. First, the reference to "theory" in Level 1 depicts the portion of the theoretical domain that interfaces directly with "Normal Science" as performed by the experimentalist. This does not mean the heuristic work of the "theorist" portion of the HEP community. Second, it must be remembered that QA at Fermilab is a *line function* and is done by each participant in the overall collaboration team from the physicists to the technicians. This line function is important to our definition because the mechanism by which QA is carried out is *peer review* as defined above. Finally, it is a standard tenet at Fermilab that users and employees must "...do our research in a manner such that the safety of people and the protection of the environment receive the highest consideration while at the same time we make best use of our

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[19] Galileo Galilei, "Galileo Galilei" in *The Encyclopedia of Philosophy*, vol. 3 of 8 vols. ed. by Paul Edwards, (New York: Macmillan Publishing Co. and The Free Press, 1972), p 264.

[20] Robert Boyle built a vacuum chamber following Torricelli's work and performed various experiments in the evacuated area. Boyle explored the empirical effects of a "vacuum" on animals and inanimate phenomena. This was the beginning of demonstrations given by experimenters at meetings of The Royal Society. See Robert Boyle, *The Works of the Honourable Robert Boyle In Six Volumes*, vol. 1, (London: Rivington, Davis, Johnston..., 1772), p 7 ff.

[21] Private communication with Ken Stanfield, Head of the Research Division at Fermilab.

laboratory facilities."[22] With this three presuppositions in mind, we begin our analysis at a point well before the typical experiment becomes a formal Fermilab project. The various levels are listed below:

Level 1 Theory-Effect	**Level 5** Conceptual to Final Design
Level 2 Early Conceptual Detector Design	**Level 6** Fabrication and Installation
Level 3 Proposal Stage	**Level 7** Operation
Level 4 PAC Stage (Overviews Above Levels)	**Level 8** Data Analysis

At Level 1 (theory-effect), a physicist reflects upon the current theoretical representation of the world described in the Standard Model. The experimentalist specializes in designing ways of "cashing out" the predicted effect or anomaly into something that is measurable. At Level 2, he designs the broad abstract parameters of a detector in a way that will yield the optimal interaction rate in the detector. In addition to producing the effect, he must devise a way of digging the salient lower-cross-section effect out of a multitude of non-salient high cross-section details and recording it for later analysis. The peers at this level quite obviously must be physicist peers.

Level 3 involves the assembling of a collaboration with other physicists at other universities who are interested in working on the same type of physics problems. At this level the conceptual design of the detector becomes more defined as the collaborating institutions give their input to the design along with commitments in dollars and manpower to carry out those tasks. One of the most important points at this level is to be sure that the effects predicted by the theory and the capabilities of the detector and data acquisition design are matched in such a way to actually produce the effects. Another important aspect at this level is to match the beam and physical size constraints of the detector with an accelerator complex. Increasingly, engineers who specialize in HEP detector design at the universities are brought in at this level to do some preliminary design work. The culmination of this work leads to the proposal stage. The peers at level 4 are mostly physicist peers with specialized engineers reviewing their own contributions.

The Fermilab Physics Advisory Committee (PAC) is composed of prominent physicist peers from Fermilab and other laboratories and universities throughout the United States. The PAC functions at Level 4. It is here that an experiment becomes a formal Fermilab project, moving toward a firm conceptual design which takes into account such things as funding to support the experiment, beam parameters, the space necessary to set the experiment up around the beamline, and the schedule of available beam time. At this point, the decision to approve or reject the experiment is made by the Director of the laboratory in light of the recommendations of the PAC. The peers once again at this level must be physicist peers.

If approved the experiment moves to Level 5. It is at this level that a large number of engineers are brought in to "cash out" the design into what will become a final design. It is also at this point that basic research first interacts with the formal entities of the engineering disciplines. Consequently, it is at Level 5 that the basic research first touches the discipline practiced by engineers. Throughout Level 5, those aspects of the detector designed by the engineering staff should be reviewed by engineering peers. But in keeping with what was said above, the physicist in charge must be sure that the final parameters of all engineering decisions will produce a detector that will yield a data rate that will enable him to measure the mapping between the predictions of theory and reality of the effect as described at Level 1. Most of the engineering done at the beginning of this level is far out on the cutting edge of available technology so individuals must be familiar with this level of engineering detail in order to qualify as peers.

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[22] From Leon Lederman's written introduction to the *Fermilab Safety Manual*, June 2, 1986.

As Level 5 work continues toward the final design, it is continually optimized with a large amount of input from all branches of the engineering community (mechanical, electrical, civil etc.). Wherever a particular engineering discipline makes a contribution to the project, those contributions must be reviewed by peers from that discipline. But these reviews are always subject to the demands dictated within the parameters set up by Level 1 and 2. The general rule of thumb is that who ever does the work must have that work reviewed by competent peers as defined above. It is at Level 5 that we see the first contingent of state-of-the-art engineering decisions being reviewed by engineering peers, subject always to the approval of the project physicist. In describing the activities of Level 5, we have defined the broad parameters of the interface between basic research and standard engineering practices.

The next two levels (Level 6 [Fabrication and Installation] and Level 7 [Operation]) are rather straight forward and follow the same rule as Level 5, namely that all work should be reviewed by peers from that discipline subject to the approval of the Project Physicist.

It is at Level 8 [Data analysis], that the domain becomes once again exclusively controlled by the physicists. It is at this level that the collaboration (which is itself a group of competitive peers) totally dominates the project in an attempt to discover whether or not the proposed theoretical conjecture as evidenced by the signature effect has been manifested in the detector. The peers at this level must obviously be physicists. In addition to the peer review of the data by those in the experimental collaboration and at the facility at which the experiment has been performed, the results of the experiment are reviewed by peer referees before publication in journals and by other physicist peers who try to replicate, improve, or discredit a particular measurement after publication.

Thus far in this paper I have described the authority structure of science, the nature of peer review, and defined the interface between basic research and engineering. At Fermilab, QA is a line function. This means that the person doing the work is responsible for assuring quality. The mechanism for doing this is peer review as defined above. But none of this involves the QA professional!

THE ROLE OF THE QA PROFESSIONAL

The reliance on peer review as the primary QA mechanism in basic research produces a certain type of *voyeurism* for the QA professional. The QA professional is (so to speak) "on the outside looking in" because only those who are peers within a specific community are qualified to judge what quality *is*. This does not of course mean that the QA professional may not have some technical training in engineering for example. But as we said above, training alone does not necessarily make someone a peer.

In regard to external reviews by QA professionals, one might have expected that management assessments would be within the boundaries of his responsibilities. But as we said earlier even this demands the expertise of a peer in regard to many of the laboratory's programs which effect the physics program. Even if one wanted to concede that a QA review team having no peers onboard could genuinely review all aspect of Fermilab's program that do not impinge on the physics program, it should be noted that this type of institutional management review (including bona fide physicist peers) is actually done annually by the DOE Headquarters organization. This seems to make external QA reviews redundant. One way around this problem may be to attach QA to its historically related sister discipline, safety. This is one approach that is currently being taken by DOE.

The intuition about *QA voyeurism* is an important one. It is important precisely because it makes the distinction between doing QA (line function) and being a QA professional (independent audit function) crystal clear. In this light, let's use a number of analogies to try to qualitatively describe a role for the QA professional. Notice that all of the analogies contain an element of *voyeurism*. We can describe the QA professional as a consultant who gives advise to other people on how to run their business or invest their money. However, in the end it's the *client's* money not the consultant's. He gets paid for his time and advice, but must voyeuristically leave the actual decisions to the client. We can also describe the QA Professional as a therapist, who while seeking to help and guide a patient to a more productive healthy life must in the end allow the person to make their own decisions. It is also enlightening to describe the QA Professional as an evangelist who is brought into a church for a series of "revival" meetings then is on to the next church (sounds a lot like QA gurus). The evangelist is like a "hit 'n run" type that assumes no continuing responsibility for the lives of the people he preaches to. This is unlike the model of the pastor who comes and "lives among" his parishioners. But as close as the pastor is to his people, he still plays a *voyeuristic* role in regard to making their decisions for them. In the end, it is up to the parishioners. The pastor's role is to preach the "truth" and hope some of it sinks in. Although these are fairly impressionistic descriptions, they can be very instructive. Lest I be accused of not coming out of the impressionistic-theoretical clouds in my conclusion, let me suggest some practical components of the role of being a QA professional in a basic research environment.[23]

The **first** component of the QA professional's role is to mediate between the authority structure of science described above and the bureaucratic authority structure of the DOE. Many of the problems that have been caused between researchers and QA professionals are matters of semantics which can be avoided by developing models that communicate between the two parties. In this case, the QA professional is the "go-between." The **second** component involves helping the line QA people (department heads, etc.) to document the process of doing QA in a way that is acceptable both to them and the DOE. This involves interpreting the requirements of NQA-1 in a way that they can understand and in a way that will bring optimum efficiency and quality to the laboratories operation. **Third**, the QA professional must provide the type of training necessary to inform laboratory personnel about the NQA-1 requirements. This may also involve training about the general principles of quality as presented by some of the presently accepted QA gurus. Finally, the **fourth** component is to regularly audit the QA programs to insure that what's written truly reflect the day-to-day operation of the laboratory.

Depending on the circumstances, the QA professional may assume one or more of the voyeuristic roles described above (consultant, therapist, evangelist, or pastor). But it must be remembered that the QA professional is not a peer to anyone except *other QA professionals* and consequently has no place in the actual process of peer review as carried out by the line people. In regard to our initial objection of putting a "Ph.D." on the review team; even if his degree is in the same field as the work being reviewed that does not necessarily make him a peer. In fact this approach might accomplish nothing but to make people mad! This is not rebelliousness, it's just playing by the rules of peer review.

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[23] This entire paper and the rest of this section is predicated on the fact that ANSI/ASME NQA-1 is required of all DOE contractors, even non-nuclear laboratories. I discuss this issue at some length elsewhere, see Mark Bodnarczuk, "QA At Fermilab; The Hermeneutics of NQA-1", published in the *Proceedings of the Twenty Ninth Annual Meeting of the Institute of Nuclear Materials Management*, June, 1988, pp 413-416, (Fermilab-Conf-88/55).