WHAT ARE GOOD OPERATORS AND WHY ARE THEY NEEDED?

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Abstract

Sophisticated computer control and automation have made possible the operation of today's enormously complex particle physics facilities. Yet with all of the versatility that this sophisticated technology provides, it would be difficult, if not impossible, for these facilities to attain even minimum required operational goals without the constant supervision and regular intervention of human *operators*. Furthermore, if operational goals are to be pushed to new limits, then human operators with rare, esoteric talents and skills, commonly referred to as *good* operators, are required. The need for these operators, together with a discussion of the qualities associated with good operators, are the subjects of this paper.

1. WHAT IS AN OPERATOR?

Of the five definitions for the word *operator* appearing in **The American Heritage Dictionary of the English Language**, two fit within the context of this paper. The first, "A person who operates a mechanical device" rather mundanely defines the root function of an accelerator operator. The second, "A shrewd and sometimes unscrupulous person who gets what they want by devious means" is believed by many to be the pragmatic definition of an accelerator operator. Operators would no doubt argue that the words *unscrupulous* and *devious* are a bit strong. Crafty and imaginative are much better descriptors than unscrupulous and devious; but aside from those minor details, the second definition, as modified, accurately describes the role of an accelerator operator, namely, to continually strive for scheduled production goals through any safe means possible.

Through definition number one, nearly everyone on earth operates something in their lifetime, whether it be a German-made automobile or a Tibetan-made prayer wheel. But through modified definition number two, few can actually be referred to as operators, with many fewer still belonging to the select group known as the accelerator operator.

To be an accelerator operator, one must have had extensive training and experience in any number of related technical fields. Ideally, one should have some expertise in electronics, computer, or general engineering system operation and maintenance. Regardless of the discipline, the expertise must provide an adequate knowledge base upon which subsequent accelerator training and experience can be built.

Just as important as knowledge and experience are the human characteristics that would allow individual expertise to be utilized to the fullest extent possible. These characteristics include the ability to rapidly assimilate large, diverse, and complex systems, as well as the capability to cope with severe physical and mental stress. Accelerator operators must be capable of examining the minutest of details without losing sight of overall operational objectives. The ability to make swift, sound decisions based upon a multitude of constantly changing sensory inputs, experience, and human intuition is essential. An operator must also be willing to conscientiously listen, learn, question, and act.

All of these requirements constitute the ideal *minimum* for an accelerator operator, as a sufficiently experienced individual equipped with these abilities can adequately meet the minimum scheduled objectives of a large accelerating facility. But if minimum available is to be transformed into maximum allowable, then an even more select group of individuals, known as *good* operators, are needed.

2. WHAT IS A GOOD OPERATOR?

It is important to note that an operator can be novice or average and still perform well. However, a novice or average operator can not repeatedly solve unusual problems or extend operational goals. To accomplish these, an accelerator operator must have a great deal of training and experience in all phases of accelerator operation, as well as possess certain intangible qualities beyond those already mentioned. The training and experience are essential, because without a strong technical base, the intangibles would be useless. But the intangibles are what really separate the good operators from their peers.

Now the real trick of this paper will be to briefly describe the intangible. It would be virtually impossible to pick two equally trained individuals off the street and be able to tell, just by looking at them, who had the intangible qualities and who had not. One might be able to glean this insight through the job interview process or through some sort of psychological testing, but the only absolute way to gain this knowledge is by actually observing the individual under various operating circumstances. At any rate, when interviewing, testing, or observing, the following fall under the umbrella of the intangible.

Many individuals are very knowledgeable in specific areas of operation but have difficulty contending with the wide range of expertise required of a good operator. The ability to gain this expertise through a practical understanding of the breadth of accelerator operations, rather than an in-depth theoretical knowledge of individual systems, is generally necessary to becoming a good operator.

All operators must have good concentration and memory, but good operators should be able to coincidentally apply the two when confronted with operational challenges. One should be able to recognize complex patterns, recall the unusual or insignificant, and mentally rehearse possible actions, all in a potentially chaotic environment.

Good operators should be adaptable, ready to act either spontaneously or deliberately. They should also be able to acknowledge personal limitations *and* be willing to seek the necessary assistance or training that would allow rapid response to current and future problems or requirements.

The above are but a few of the intangible qualities that a good operator may possess. Operators do not necessarily have to possess *all* of the above to be considered good, and in fact, few do, but they will possess some of them. There are two intangibles, however, that an operator *must* have to be considered good: a finely balanced combination of qualitative and quantitative thought processes, and a healthy amount of creative, artistic flair.

Good operators can analyze a comprehensive set of data, surround themselves with a myriad of sensory inputs, quantify all of the information, and then make qualitative decisions based upon overall situation requirements. With the same set of data and sensory input, a good operator is just as likely to make a *quantitative* decision based upon *qualitative* situation requirements.

This sort of thinking is most often used by good operators at the Los Alamos Meson Physics Facility (LAMPF) when addressing the intricacies of tuning the accelerator for simultaneous operation of two or more distinct particle beams. A great deal of machine tuning is required to efficiently deliver the 1 mA-average H+ beam to its associated experimental-areas. Once this tuning is complete, the 80-100 μA-average H- beam is delivered to the Proton Storage Ring (PSR) on the same rf cycle as the H+. Since providing acceptable beam to the PSR and its experimental-areas often appears to require some sacrifice of the H+ beam tune, a real dilemma develops. At what point does one sacrifice the H+ tune? Does the H+ tune actually have to be sacrificed? Can a reasonable tune be developed which efficiently delivers both beams at scheduled intensities? Which are the predominant factors involved in these decisions? What if low-energy polarized H- (P-) beam is also scheduled for delivery? The good operator must weigh all of these possibilities and quickly reach some rational decision. The decision-making processes involved may seem mystifying, but good operators must subconsciously use them on a continual basis when attempting to solve difficult problems or advance facility objectives.

Equally as important as the decision-making processes are the methods used in executing these decisions. It is not uncommon for many different operators to arrive at similar conclusions when pondering problems or debating objectives. However, few are able to correct the problem or reach the objective. Some measure of success is achievable through the use of standard techniques when dealing with routine accelerator operational challenges. But these techniques are often not successful when dealing with the non-routine. Unfortunately, most are unwilling, or unable, to see beyond the standard and visualize the abstract.

The aforementioned tuning dilemma is a perfect example of this. Many operators would decide to sacrifice the H+ tune to provide the PSR with reasonable beam and completely ignore the P- beam. The PSR beam would then be tuned, and because the two problems do not seem to be simultaneously correctable, the H+ average beam intensity would be reduced, with any subsequent beam instabilities receiving only marginal attention. The P-beam would then be tuned around the other two beams with necessarily mediocre results. With the accelerator tuned in this manner, any further machine adjustments that might be required to correct various problems could result in severe tune degradation of all operating beams.

The good operator thrives in just this sort of operational environment. A good operator probably would have avoided the above by choosing *not* to sacrifice the H+ tune and bringing on the PSR beam in such a manner that would improve the tune of both beams, thereby providing a satisfactory environment for the P-beam as well. Using an unorthodox approach that may have occurred to them only moments before, the problem which had befuddled so many would slowly begin to resolve itself. Through some unusual method, the goal previously thought unreachable, would appear attainable. Call it creativity, artistic flair, abstract thinking, whatever, but, for some reason, only the good operators are able to consistently succeed.

3. WHY DO WE NEED GOOD OPERATORS?

Can a good computer-control system with solid software achieve similar results? Perhaps when talking about day-to-day, routine operations with minor predetermined problems, yes, a good system might be able to perform the job on a level equal to that of the average operator. But when situations as mentioned earlier come up, only humans can repeatedly achieve results.

In recent months, much pressure has been exerted by the U.S. Department of Energy (DOE) on its facilities to comply with national safety and environmental standards. Out of this pressure has come a new catch phrase, *the human factor*. The human factor is widely recognized by DOE as a key reason for insisting that all of its facilities move toward more formal operations, cookbook-style operations manuals, increased hardware safety systems, and so on. Humans, with their unpredictable and often erratic behavior, and seeming unwillingness to conform, are seen as the main source of concern behind operational safety and environmental problems. Unfortunately, for the most part, this is true. But if everything becomes automated, computer-controlled, and absolutely regimented, then the *positive* aspects of the human factor will be lost.

Can an operations manual make a decision based upon experience, perception, feeling, and intuition? Will a state-of-the-art main frame computer with intelligent front-end hardware be capable of recognizing the existence of the future, and somehow perceive time and its limitless scenarios? Can a computer act on its own perceptions, and then spontaneously change its programming or memory to adapt to an unforeseen problem? Do hardware safety systems exhibit personal pride in facility achievements and then try to prove that no record is unbreakable? These are exactly the human factors, along with countless others, that are lost as the machine replaces humanity.

Earlier a paradoxical suggestion was made that it might be possible to replace the average operator with a machine, but that a machine could not replace humans. Why *humans* and not *good operators*? A very important human factor that can not be overlooked is the ability of all people to learn, adapt, and improve. Imagine the possibilities if most, or all, of the operators at an accelerating facility **became** good operators. No facility could be upgraded fast enough to keep up with them.

4. CONCLUSION

Do not for a minute believe that removing computer control and automation, operations manuals, or hardware safety is the point of this paper. On the contrary, accelerators can not be safely operated without them. The point of this paper is to make it clear that accelerators cannot be operated without people either.

Computer control allows the operator to remotely manipulate the thousands of devices that make up the accelerator from a central location. Without remote computer control, literally hundreds of people would be needed to operate the machine. A good control system allows a relatively small number of operators to control the machine.

Computer automation, along with associated equipment, releases operators from the trivial, mundane, inconvenient, and often overlooked tasks which constitute a large part of accelerator operations.

Besides providing the reliable documentation necessary for safe accelerator operation, operations manuals ensure the solid knowledge base spoken of earlier and are therefore also important for the development of good operators.

Hardware safety systems are absolutely essential for safe operation of any facility. Anything less than redundant hardware safety systems, combined with operator action, would be unthinkable.

Without going into unnecessary detail, the above is a very modest attempt to demonstrate that operators cannot operate any complex facility simply by using their wits. Without the aid of all of the above, and much more, no facility would be safe or operable. But let the computers, hardware, and documentation perform the functions for which they were originally intended, to *assist* people in their efforts to safely operate these enormously complex machines. Leave creativity, artistry, achievement, and independent thought to the human beings, for these are the functions for which *we* were originally intended.

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