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SPEAKING OF DIVERSITY*

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Abstract

Historically, attendance at the International Conference on Accelerator and Large Experimental Physics Control Systems (ICALEPCS) has not been particularly diverse in terms of gender or race. In fact, the lack of diversity amongst the attendees was noted during the closing session of the 2015 conference by an invited speaker from outside the accelerator community. Informal discussion and observations support the assertion that our conference attendance reflects the diversity of the broader accelerator controls workforce. Facing very low participation of women in our field and even lower minority representation, it is important to examine this issue, as studies point to the importance of diverse work groups to spark innovation and creativity as catalysts to solving difficult problems. This paper will discuss diversity in the disciplines that comprise the accelerator controls workforce, including background, barriers and strategies for improvement.

ABOUT DIVERSITY

By definition, diversity is about variety. We discuss social diversity in our communities, our schools and our workplaces. We enumerate our differences in terms of gender, race, ethnicity, age, disability, gender identity, sexual preference, socioeconomic status, religion, politics and more, when in fact, we have a lot more in common than not.

As professionals, it is easy to understand the importance of technical diversity as we consider the skills mix of our groups. We need people who are experts in hardware and software, operating systems and algorithms, user interfaces and device control. We might even think of the technical diversity of our control systems where we meet requirements for high speed data acquisition and relatively slow monitoring and readback. We may build our control system with a mix of different operating systems, computer hardware, languages, toolkits, controllers and interfaces. Certainly, our jobs would be easier if we supported a single type of CPU, one operating system, a single hardware interface and offered very narrow options for user interfaces. In reality, we build systems that are hardware and software diverse because it is necessary to meet the requirements of our facilities and customers.

Thinking more broadly, we should also consider the importance of social diversity in our work groups and by extension, our professional community. While expanding diversity can make people uncomfortable, including people with socially diverse characteristics in our ranks can enhance our ability to be more effective.

WHY DOES DIVERSITY MATTER?

Simply put, diversity matters because it can make us better, more innovative, more creative and in the end, more successful. A well-functioning, socially diverse group benefits from the different backgrounds, perspectives and life experiences of the members. These groups bring a more comprehensive set of ideas to the table and along with these ideas, more effective processes. Processes for vetting new ideas, design, development, implementation, training and testing. The way people think and approach their work permeates every aspect of their contributions. If we all think and approach our work the same way, we are bound to naturally narrow our options and constrain the results.

Many studies validate the higher performance of diverse teams, particularly when the work requires creativity or innovation. An article published in Scientific American in October 2014 [1] discusses research on the effects of team diversity on problem solving, decision making and even corporate profits. The article describes how the diversity effect goes beyond gaining different perspectives, but rather causes people to behave differently.

The author draws on different studies to demonstrate how diversity causes people to work harder and become better prepared for work assignments. This is attributed to a level of discomfort people experience when dealing with people they perceive as different from themselves in some way [2].

When someone presents a new idea or design to a room full of people who look and live just like themselves, they seem to naturally assume acceptance. The homogeneous group members tend to think alike, which is precisely what we want to avoid if we value innovation. The same presenter, faced with a socially diverse group, assumes they need a better presentation to gain consensus and do in fact come better prepared and more open to discussion. The article concludes that a diverse set of team members stimulates all team members to work harder, enabling better results.

THE CURRENT STATUS OF DIVERSITY

Workforce

While participation of women in the workforce varies by region and country, women make up 40% of the global workforce [3] and 47% of the United States (U.S.) workforce [4]. About 50% of women and 76% of men partici-

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pate in the global workforce. In the U.S., 57% of women and 70% of men join the workforce which is slightly less than the European Union where 64% of women and 76% of men are working.

Race and ethnic workforce participation data gathered in the U.S., is often presented using the categories White, Under Represented Minorities (URM) which includes African Americans, Blacks, Hispanics and Latinos, and Other People of Color (OPC) which includes Asians, Asian Americans and Pacific Islanders.

Universities

Control system developers are most commonly college graduates with engineering or computer science degrees, although we also draw from other Science, Technology, Engineering and Math (STEM) majors. The diversity amongst college graduates in these majors is a limiting factor in how diverse our groups can ultimately become, especially when we consider this is a relatively small pool of students. Only ~210,000 STEM degrees are awarded in the U.S. each year, which is less than 8% of all degrees [5]. Additionally, competition from industry for these same graduates is intense as demand for technical skills continues to exceed supply.

In the U.S., females and minorities continue to enroll in universities in increasing numbers, however, their participation in the STEM majors is proportionally much smaller [6]. Women now earn ~60% of all U.S. college degrees, but only 34% of the degrees in STEM disciplines. In 2014, non-white students earned 30% of all degrees. Whites earned 66% of STEM degrees while 17% were earned by URM and 17% by OPC.

Computer science is a particularly unpopular degree amongst women and minorities with the dubious distinction of being the only science major with shrinking female participation. Females now earn 17% of all computer science degrees, sharply down from a high of 35% in 1984. The percentage of engineering degrees earned by women has slowly increased from 2% in 1970 to 17% today. While most other science disciplines have realized slow gains in female participation, biology is the only science where female graduates now outpace male graduates with females earning 59% of these degrees. The growth rate of URM majoring in science and engineering is almost stagnant and OPC have realized small gains over the last 20 years [7].

Department of Energy National Laboratories

The U.S. Department of Energy (DOE) maintains 17 national laboratories for scientific research. Within these labs, there are numerous user facilities which operate unique machines as tools of discovery. These laboratories are managed by contractors who employ over 57,000 people, in both technical research and support positions, including 31% women, 17% URM and 10% OPC, to achieve their mission. These facilities utilize computer based control systems to operate their bespoke machines, and therefore employ many ICALEPCS participants. In 2016, the U.S. National Laboratory Leadership Council published diversity data for the national laboratory workforce on their website [8]. This data, shown for various job categories by gender and race/ethnicity in Figs. 1 and 2, details the national laboratory workforce demographics, showing participation by job category, which gives some insight into how various groups progress through higher career levels.

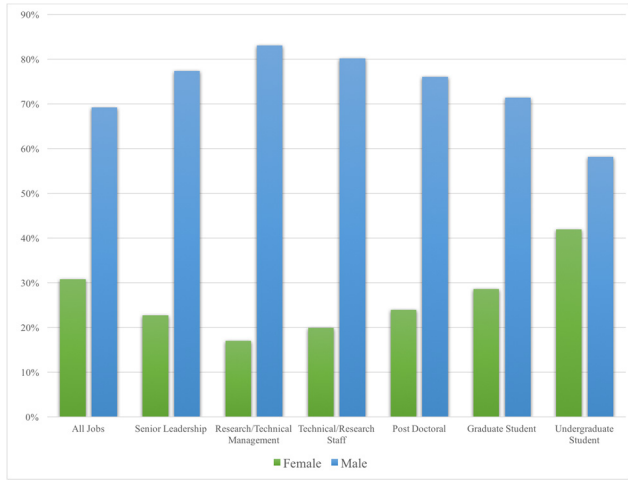

Figure 1: DOE workforce data by job category and gender.

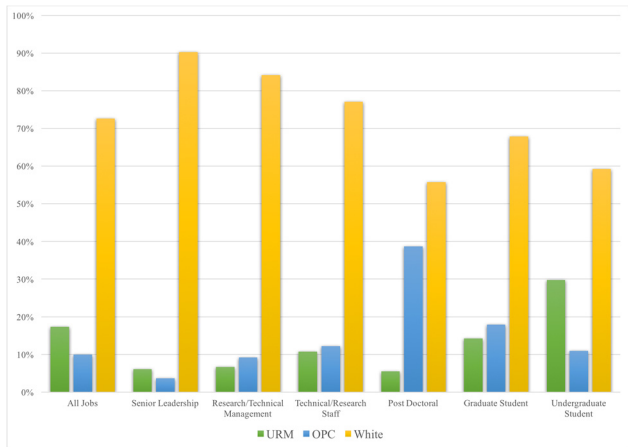

Figure 2: DOE workforce data by job category and race/ethnicity.

While this data shows the clear dominance of whites and males within the DOE workforce, it also indicates a reasonable fraction of females and URM as students employed at the undergraduate level. Unfortunately, the graphs show a notable decline in the number of females and URM throughout the career progression from student positions, to research positions, then into management and leadership roles. OPC employees have a different trajectory with increasing numbers moving from undergraduate through postdoctoral positions then a dramatic decline moving to research, management and leadership positions. This trend may be attributed to U.S. visa policies or student intentions to return to their native country after obtaining a Ph.D. The downward trend in the number of females and URM progressing into research, management and leadership positions clearly illustrates a

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leaky diversity pipeline where we appear to start with a healthy mix of undergraduate students but lose a significant fraction of our diversity at each career phase. While there are many reasons for such attrition, it appears the U.S. national laboratories could benefit from improving retention amongst these groups.

SOME HISTORY

Pioneers

While we currently have little diversity in our professional community and across the board in computing and engineering, there was certainly some diversity among important early pioneers who established a vision and laid essential groundwork for the modern computer hardware and software which forms the foundations of our control systems.

In 1815, Ada, the Countess of Lovelace was born and later married into privileged positions in English society. She was forced to study math and science by her mother at a time when it was highly unusual to teach girls math and science and only upper-class girls were educated at all. Her mother, also an accomplished mathematician, believed that learning math would protect Ada from inheriting insanity from her father, the English poet Lord Byron. Ada is credited with writing the first computer programs in the form of algorithms for the Analytical Engine being built by Charles Babbage. The machine, which Babbage designed to manipulate numbers much like the calculators we now hold in our hands, was never finished. Ada, viewed the Analytical Engine as much more than a calculator and expressed the view that music, text, photos and sounds could be expressed in digital form and manipulated by the machine, theorizing for example, that the machine might compose music. She published her vision, along with algorithms to program the Analytical Engine, under her initials, A.A.L., as it was not proper for a woman of her social class to participate in such unfeminine work. The programming language, Ada, was named after her [9].

Grace Hopper, born in 1906, received a Ph.D. in mathematics from Yale in 1934 and subsequently was one of the first people to program a Mark I computer. During World War II (WWII), she enlisted in the U.S. Navy Reserve because at 34, she was told she was too old to join the active duty Navy. Following the war, she remained in the reserves and went to work for UNIVAC where she developed the first compiler. She believed people should be able to read computer code and code should be somewhat independent of computer hardware. Hopper inspired the programming language COBOL. She later developed standards for early programming languages such as FORTAN. By Navy regulation, she was forced to retire from the Naval Reserve at age 60 but was later recalled to active duty twice and gained Congressional approval to work past the mandatory retirement age. She ultimately retired at 79 as a rear admiral. Grace believed mentoring students was her most important accomplishment apart from creating the first compiler [10].

World renowned British mathematician, Alan Turing, was born in 1912 and has been called the "father of modern computing" for his pioneering work on theoretical computer science, algorithms, formal languages and artificial intelligence. He is famous for describing a universal computing machine (Turing machine) that could compute anything based on a properly defined algorithm. Turing was also an accomplished cryptographer. He was instrumental to the British Intelligence Service effort to break the German Enigma code during WWII. Following the war, Turing worked on the design of the Automatic Computing Engine, wrote some of the earliest software for the Manchester Mark I and developed theory related to artificial intelligence. Although his work was considered ground-breaking and garnered many awards, in 1952, Turing was arrested and convicted of indecency after admitting a homosexual relationship to the police. Due to his conviction, Turing could no longer hold a security clearance which limited his work. Turing died in 1954 of cyanide poising, perhaps self-administered [11].

These examples give us a glimpse into a few of the brilliant and unique individuals whose great contributions to the field of computing could not be diminished by their non-traditional gender, age or sexual preference.

Historically

Ironically, computer programming was once considered "women's work". In fact, in 1945, the first programmers of the ENIAC were female mathematicians formerly working as human computers, performing calculations for U.S. aeronautical programs. And the ranks of these female mathematicians included many black women who were recruited by the National Aeronautics and Space Administration to fill staffing gaps during WWII [12]. While early computer hardware was almost exclusively designed and built by men, the required programming work was dominated by women for at least three decades. Despite the need to develop algorithms and apply complex mathematical and logic constructs, software development was considered a low skill job and was viewed as almost clerical in nature. Therefore, employers hired women and paid them far less than the men who worked on the hardware. Eventually, as programming became recognized as intellectual, professional work, salaries and prestige were elevated and men joined the programming ranks until a nearly complete reversal of the gender roles with respect to computer programming was achieved [13,14].

WHY DO WE LACK DIVERSITY?

Reasons for the lack of diversity in engineering and computer science are far reaching with deep roots spanning historical discrimination including education inequality, stereotypes and strong cultural norms which fuel unintended biases and the lack of relatable role models and mentors.

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Discrimination

While it used to be quite common for laws to impose restrictions on employment, voting, inheritance and property ownership based on gender, race or socioeconomic status, laws around the world have changed dramatically over the last 150 years. Such restrictions have largely been removed from the law in the interest of fairness and equality, enabling countries to slowly move away from legal discrimination. But simply changing a discriminatory law does not create instant equality as social attitudes and behaviours take generations to change. Even worse, in some cases, clever politicians pass new laws to replace the former restrictions triggering a lengthy cycle of court challenges and impeding progress towards parity.

Despite much legal progress, discrimination still exists, albeit in less overt and harder to prove ways. We have equal pay laws, but it is exceedingly difficult to win a case based on pay equity as the necessary data is usually not available to workers for comparison. Successful or not, such cases can result in, also illegal, retaliation against the challenging employee. When people are not selected for an interview, position or promotion, it is also the case that the candidate cannot reasonably prove they were denied due to age, race or gender as such decisions are highly subjective. Other forms of previously legal discrimination with respect to voting rights and education, have left a damaging legacy to equality in the workplace.

Voting America established voting rights for black males with passage of the 15th amendment to the U.S. Constitution in 1870, following the end of the Civil War. Many states, especially in the south, then created new laws adding poll taxes, property ownership requirements or literacy tests effectively preventing the majority of black men from voting until the Voting Rights Acts of 1965. It became illegal to continue to suppress women's right to vote in 1920 with the passage of the 19th amendment. Even today, efforts continue in the U.S. to minimize the political impact of minority voters by gerrymandering districts and imposing stricter registration and voter identification laws. The effect of over 150 years of laws that disenfranchised females and minorities effectively maintained a homogeneous power base with little motivation to put a high priority on equal rights.

There are similar histories in other countries with women in Saudi Arabia, for example, gaining the right to hold office and vote in 2015, however, they will not be allowed to drive until 2018. Ironically, Vatican City remains the only country that holds elections that still prohibits female voting because only cardinals can vote and only men are permitted to become cardinals. Such voting restrictions empower the status quo, perpetuate a lack of diversity at all levels of government and work against progress in equality across the board.

Education Historically, education has been for a privileged few such as the male children of wealthy aristocrats. Many early organized education efforts, particularly in Europe, were dedicated to serving the needs of religious organizations by teaching a small number of boys to read and write to preserve religious documents and serve as clergymen [15]. As education expanded, many schools were based in Christianity and churches began to extend charity education to poor boys. As education gained popularity, governments got involved and in some places, segregated schools became an option for girls, although mathematics was often considered appropriate only for boys. We now enjoy universal public education in most countries with diverse children studying the same subjects, together.

In the U.S., the public school movement began in northern states and slowly expanded to the south [16]. The first school for girls opened in 1727, nearly 90 years after the first school for boys although public schools for girls did not become widely available until 50 years later and then primarily in the north. Black slaves were deprived of any education until the end of the Civil War (1865) when separate schools began to open to teach former slaves, both children and adults. Mandatory public education in the U.S. was not required until the early 1900s. The lack of education afforded to slaves severely limited their employability once they were freed and kept most in low wage positions throughout the next century.

A landmark U.S. Supreme Court decision taken in 1954 made running separate public schools for black and white children unconstitutional, however, with numerous court challenges and outright illegal actions such as shuttering schools to prevent blacks from attending with whites, school integration was slowly implemented over the course of more than 50 years. The impact of a long history of education first for only affluent children of one race and gender coupled with over 100 years of lower quality education for minorities and poor children is multigenerational. Children without a college educated parent are less likely to earn a college degree than their peers from more educated families and this cycle has proven difficult to break. Moreover, the cost of a college education in America has roughly quadrupled over the last 30 years [17] putting higher education out of reach for children from poor families even when given partial government subsidies. When low income, first generation students do attend college, their graduation rates are significantly lower than their peers perhaps due to a lack of access to mentors from their family or social circle.

Culture

With plenty of anti-discrimination protections in place for workers, culture continues to be a dominant factor in determining workforce participation and demographics. Culture embodies our shared values and defines social norms. While there are significant variations between different countries, and cultures change very slowly over time, most cultures include a form of women as nurturers and men as providers. This naturally springs from the most basis biological difference – the unique ability of women to have babies. Pregnancy, childbirth and breastfeeding tie women to their offspring in a powerful way. While this bond is useful in terms of perpetuating the human species, it also serves as fuel for gender stereotypes which skew towards women in home based and

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nurturing roles and men working outside the home to support the family. In a similar way, the long history of racial and ethnic minorities in physical strenuous and low wage jobs has contributed to a stereotype that is in conflict with our image of a college educated professional.

People are viewed and treated differently, starting from birth, based on cultural norms associated with gender, race, ethnicity and wealth. Children are bombarded with messages from families, friends and teachers that often serve to reinforce stereotypes rather emphasize the unique capabilities of individuals. Stereotypical images and roles are pervasive in news, entertainment and social media. Everything from children's toys, books, clothing and entertainment are tailored for either boys or girls and true gender-neutral items can be difficult to find. Even well-meaning parents and teachers, socialized by the same cultural norms, speak to male and female children differently, often praising assertive male behaviour while reprimanding the same actions when taken by girls [18]. Similar social marketing often categorizes minorities as low-income and poor children as low achievers or somehow more suited to make a living by using their muscles instead of their brains. These ubiquitous messages play a strong role in influencing academic and career aspirations in children as early as elementary school. Imagine how difficult it must be to overcome such social brainwashing of bright young people when it comes to their ability to advance to higher mathematics courses that in turn form the foundation of computing and engineering degrees.

Bias

Such strong cultural stereotypes certainly play a role in our mental definition of normative types for controls engineers. These stereotypes contribute to establishing and perpetuating biases which impact the diversity of our workforce. While we recognize explicit bias as a belief regarding an individual or group that we are aware of and understand how this leads to discrimination, implicit bias can play a far greater role in keeping our field relatively homogeneous. Implicit biases are those we are unaware of and therefore do not acknowledge, however, these biases can influence our business decisions and behaviour at all levels.

We all have implicit biases formed by our life experiences and social context. These biases may not even be synchronized with our chosen or expressed values. When we are unaware of our individual biases, we cannot prevent these biases from leading us to act unfairly towards others. You can evaluate your own biases by using an online evaluation such as the one offered by Harvard University's Project Implicit [19].

An excellent example of the subversive impact of implicit bias can be seen in orchestra auditions. Traditionally, musicians have auditioned in front of a panel of judges who endeavoured to select the very best performers and this practice resulted in groups that were ~5% female. Following the advent of blind and barefoot auditions in the early 1980's, the percentage of female orchestra members has risen to over 30% [20]. The new audition format hid the gender of the musician by preventing the judges from seeing the candidates or hearing their footsteps.

Implicit bias can impact who gets interviewed, hired, mentored and promoted in otherwise well-meaning organizations [21]. These biases can govern how diverse employees are treated in the workplace by supervisors and peers. Even the words used in a job advertisement or position description can indicate bias towards one group of people over another. It takes a very conscious effort to reach outside of our comfort zones, which are most often composed of people very similar to ourselves, to ensure we attract diverse applicants, evaluate them fairly and foster an inclusive work environment.

WHAT CAN WE DO?

There is not a single or simple solution to increasing diversity in our field and we need changes both at the grassroots level and in organizations and government to enable equal treatment for people of all backgrounds across the board. Given our positions, it may prove difficult to change how our organizations work at a high level or how our governments define and defend discrimination. However, we can work from the bottom up by purposefully engaging on diversity within our community.

We can all work towards understanding both personal and organizational factors preventing non-traditional candidates from entering or staying in our field. We can be more proactive and purposeful as we work to fill and flow our pipeline of controls professionals. We can be role models and mentors and look outside our community for applicable strategies. Sharing our experiences, successful or not, can make us all stronger with respect to diversity and inclusion. By getting personally involved in some way, we can improve diversity in the accelerator controls community one career at a time.

Look at our Biases

Improving the diversity of our community requires us to identify our own implicit biases and to ensure we do not let biases influence our business decisions. For people who are developers, understanding and managing implicit bias works to make a more inclusive workplace for non-traditional staff. For managers, overcoming our implicit biases is key to ensuring we are fair in our recruitment and hiring processes and in how we develop and promote staff. Some laboratories have people in human resources who can work with managers to ensure the wording of job postings or questions asked during interviews do not put off female and minority candidates. It may also be useful to ask recruiters to remove names or other identifying information from resumes for the first round of screening to avoid invoking assumptions and stereotypes about a candidate's gender, race or ethnicity before their education and experience are properly evaluated versus the job requirements.

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Be Accountable

As professionals, we all need to hold ourselves, our peers and our higher-level managers and leaders accountable for equality based business practices that support diversity. Realizing that implicit bias can influence even well-meaning people to inadvertently discriminate, being willing to speak up when you think this may be happening can help to prevent business decisions based on unconscious stereotypes. Furthermore, engaging your colleagues in discussions about how to improve diversity can help to raise awareness, lead to better networking with a broader spectrum of candidates and help people expand their view of normative types for controls engineers. We can also be sure to personally engage with non-traditional staff to ensure they do not feel isolated, are not marginalized in team discussions and receive proper credit for their work.

Be a Role Model or Mentor

It is clear that the pipeline of students in computer science and engineering not only lacks diversity, but also the necessary volume to fill the expanding demand for STEM professionals in general. Unfortunately, many children, especially poor, minority and female children lack role models that can help them envision themselves as future engineers.

Consider being a role model in a disadvantaged or minority community by volunteering in schools, at career days, science fairs, robotics competitions or other community events that feature STEM activities. Giving children access, even for short periods of time, to a variety of professional role models helps them consider a broader variety of career options. Ensure you encourage students, regardless of their gender, race, ethnicity or other diversity factors, and emphasize how our profession makes the world a better place. Some children, particularly in poor communities, graduate from high school and the only college graduates they have ever met are their school staff, medical professionals and perhaps law enforcement officers. It may be hard for these children to even know what an engineer or computer scientist does, much less imagine themselves in such a career.

Within your organization, and in our professional community, we need mentors. People can benefit from mentors at all stages of their careers but often do not ever have one. In particular, it is important for new employees to have someone to help them navigate the organization and take advantage of opportunities for professional development. If you are past entry level, you can be a mentor. Not all laboratories have formal mentoring programs, but often the best mentoring relationships are more informal. Mentoring someone who is different from you in one or more social characteristics can have the added benefit of expanding your own viewpoint.

CONCLUSION

There are of course, far more factors impacting diversity in our field than can be covered in a single paper. Issues like the lack of benefit programs that help two career couples or working single parents, female and minority invisibility and self-defeating behaviours are not mentioned here. There are also some impressive success stories as universities work to improve the diversity of their engineering and computer science student populations by making small but significant changes. I hope there will be future ICALEPCS contributions on various aspects of diversity that help us to learn more as a community.

In the meantime, I encourage each of you to evaluate your workgroups and organizations from the perspective of diversity and inclusion. If you find that your organization is doing well, I would love to know how this has been achieved and hope your success story can be shared. If, on the other hand, you have room for improvement, I welcome you to engage with others in the community to form strategies and brainstorm towards future success. I welcome your e-mails at ksw@ornl.gov to start a discussion.

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