By Dwayne O'Brien
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"Surely, He hath borne our griefs…"

The words, somber and sincere, are joined to like melody and lifted into the air by the voices of the faithful.

"And carried our sorrows…"

The music is from one of the lesser-known movements of one of the better-known pieces in history. It is from Handel's *Messiah.* Soon, there will be an orchestra, and scores of annual patrons will fill the now empty pews of the small chapel. But that will be in a few weeks during the holiday season. This is rehearsal, and all eyes are on the conductor. The fervent singing is brought to a hush by the metallic tapping of the conductor's baton on the music stand. An error has occurred that must be corrected.

"Sopranos and altos… softer, lighter; softer by a factor of two."

The mathematical phrase is the first indication the conductor's true calling. Although very musical, he is not a professional musician. His vocation is dedicated to order, accuracy and precision. He is an atomic physicist.

As a professor of physics at Vanderbilt University, Norman Tolk is a dedicated scientist, researcher, and educator. He is also passionately committed to his faith and to his church – the Church of Jesus Christ of Latter Day Saints, and it is there in Franklin, Tennessee that he volunteers his time and energy to conducting the annual production of *The Messiah.* A man of wry wit and considerable intellect, Norman finds no contradiction between his science and his faith. He sees them both as a search for the truth, and he is equally committed to their disciplines.

"I knew that I wanted to be a physicist when I was in the second grade," he says. "I was just really beginning to read, and I read a book that said that stars were not five or six pointed, but were actually suns that were a long distance away. Well, I got very excited about this." Tolk went to tell his teacher about what he'd read, and he remembers that she didn't believe him – or at least he didn't express it well. "I said 'Well, just look in this book!', but I couldn't find the book anymore to prove to her that stars were suns just farther away. And ever since that time, I've been sort of looking for that book."

Tolk grew up on a farm near Twin Falls, Idaho, not far from Sun Valley. "It was an irrigation farm with cows," he says. "I milked a lot of cows…I got strong hands from that." Tolk believes the lessons learned on the farm prepared him for his present work. "In earlier times, a lot of scientists came from farms and there was a reason for it," he explains. "When you live in the city, if something breaks, you call a plumber or an electrician. When you live on a farm, you have to learn to fix everything yourself. That is the spirit of the experimental physicist."

After high school, Norman and a couple of other buddies got scholarships to Harvard, a place he chose to go "simply because they gave a better deal," he says. At Harvard, he earned his bachelor's degree in physics in 1960, and then went on to earn his doctorate at Columbia University in New York City in 1966. He remained at Columbia for a couple of years as a post doc, and then went to

Bell Labs in Murray Hill, New Jersey. He was part of the radiation research lab at Bell for 16 years before coming to Vanderbilt.

Tolk's interests are in atomic physics and collision physics – not particle physics or cosmology although he has worked with telescopes at Kitt Peak National Observatory near Tucson and appreciates that aspect of the discipline. "I enjoy astronomy," he says, "and even though it's been professional, it's always been sort of hobbyish. Of course, my whole experience with physics is almost like a hobby. In fact, I'm surprised that people would actually pay me to do the kinds of things that I enjoy doing anyway."

What they pay him to do is investigate what goes on in atoms and molecules at the point where they meet – the interface. "All the action in the world takes place at interfaces," he says. "If you have brain activity, the synapses are where a couple of neurons that are close enough that they can transfer information by some sort of interaction." He feels that understanding what happens at the interface between different materials is the key to biology, physics, and the like. "Our world runs on technology that depends on electrons and other carriers moving around from one small material to another in a very nanostructured way. But as you get smaller and smaller, the physics changes, and you have to understand matter in a much more subtle way. You have to think quantum mechanically."

Tolk is politely hesitant to speculate on the future implications of his current research. "That's very difficult because the fact is that there are many things in the works [in physics], some of which will be revolutionary and some are just going to fizzle. I could try to be a prophet, but you could come back in five years and say ‘You were so wrong!’” However, there are two areas that he feels confident will have a major impact on future technology: spintronics and quantum cryptography.

All of our current technology essentially runs on electrons moving around from one place to another. Electrons have mass and charge, and those properties can be manipulated in order to do things like large-scale computing and signal processing. But one aspect of the electron that has not been exploited at all is the spin. Think of the electron as a child’s top. The toy can be spun clockwise or counter clockwise. In an electron, the spin is referred to as either “spin up” or “spin down”. This difference in the direction of the spin can be manipulated, and can be used as a switch much like those on the microchips of today’s computer processors. Quantum computers will be much smaller and much faster because another important application of spin is in the storage of information. Storage devices that utilize spintronics are already showing promise, and are capable of storing massive amounts of information on ever-smaller discs. “Magnetic storage is a big thing,” Tolk says, “and magnetism comes from spin.”

“Quantum cryptography is an important thing,” Tolk adds. “With this, you can create essentially unbreakable codes.” By utilizing the uncertainty principles of quantum mechanics, coded information could even be broadcast in the clear and the message would be meaningless to anyone except the intended party. “Because of this, the government is putting a lot of money into the research.”

Tolk explained how the uncertainty and randomness of quantum mechanics fit into his faith. “Part of the whole idea of appreciating order is understanding disorder,’ he says, “and when order applies and when it doesn’t. It’s a lot like religion, actually.” His conversation switches from science to faith as effortlessly as a person raised in a multilingual environment can change languages in mid-sentence. “A religion really defines both goodness and badness,” he explains. “If you go away from a religion, you are already being captured by it because it tells you what you do when you go away from it. And so, order and disorder are sort of good and bad mirrors of things. Without disorder, you can’t appreciate order…and there really is order involved.”

Tolk is also passionate about Vanderbilt’s Free-Electron Laser Center. He led the group that was instrumental in bringing the laser to Vanderbilt. “A free-electron laser is one that is based on free electrons - one’s that aren’t bound in atoms or solids; it’s a beam of electrons. This was the same type of laser that was intended by S.D.I. to zap down Russian missiles,” he says. “This is in principle the most powerful laser you can make. You can make holes in anything – even diamond. I’ve done it actually.”

Another important aspect of the free-electron laser is that it’s tunable. “That means that you can change the wavelength of the electron beam,” he says. “Now, you can’t see any colors because it’s all in the infrared, but it’s like being able to change from blue to green – all the way to red. Now, why is this important? There’s something called resonance. By adding energy at the right frequency and the right phase, you can make the molecules in a material vibrate with a much greater intensity – they resonate." He gave an example of the practical use of this effect. "What we've done is find a frequency that makes it possible to cut right through soft tissue with no collateral damage, making possible extremely delicate surgeries that would not be able to be done with a scalpel."

"I try to combine science and music," Norman says. "My wife and I are very much involved with the musical community. We met in New York.
She is a classical pianist, a Julliard graduate." She plays the organ in the production of *Messiah*. It didn't take long for the couple to adapt to Nashville and its music scene. "We started out wondering what country music was all about, but we've really come to enjoy it. You know, sometimes there is a relationship between physics and music." He thinks a moment and grins, and then tells me about their good friend Woody Paul.

Woody Paul is a member of the ultra-western group "Riders in the Sky". They are well known for their over-the-top cowboy attire and traditional western-swing music. Woody graduated from Vanderbilt with a degree in physics, and then went to M.I.T. and earned a doctorate in physics. "He then left immediately to go and do all this music stuff," Tolk adds.

Tolk's musical roots run deep. He plays the piano and the cello, although he confesses that he doesn't play either of them very well. "I have enough understanding to know the instruments and the voices and how the pieces should go," he says. He finds it very thrilling to conduct, to lead a group in the interpretation and performance of a piece. “It’s a very fulfilling thing – almost as fulfilling as physics,” he adds.

There is more to this relationship between physics and music, and he feels the necessity to explore it further. “The way that I explain it is that music represents order in some way. Mozart was an extreme example of this. When he wrote something, it was almost immediately familiar to everybody because it was so right, so ordered; so correct. And that is what a physicist tries to do: find the underlying order to what is happening in the universe…it’s just related that way.”

His blending of science and music goes back to his days at Harvard. He would study his physics and mathematics while listening to Bach or Mozart. “Later, when I was taking a test, I could replay the music in my head and it would bring to mind all of the things that I had been studying.” That information storage system served him well throughout his college days. “I still do that in some ways,” he adds.

Tolk is also concerned that people have the wrong idea about science in the sense that they feel that science is cold and not very human. “That’s the furthest from the truth in actuality.” He explains that it may be true that if you’re an engineer you have to be cold and calculated because, if you’re wrong, buildings collapse, bridges fall down. “But if you’re a physicist, you can be very intuitive. You can try things on, you can experiment and theorize. It’s a lot like art, really,” he says. “What we’re trying to do as a part of the universe is to step back and understand what we are and what the universe is and how we’re related.

And that is a very human endeavor. That drive to know has something to do with religion."

Tolk is completely at ease in discussing his science, musical passions, and faith. He is instantly comfortable in talking about things that other university professors, particularly scientists, might tend to keep to themselves. He is not pushy or preachy, but exudes a quiet confidence in all areas of his life, especially his religion. The reason is rooted in his religious approach to science, and his scientific approach to religion.

"If there is an apparent conflict between science and religion, it is simply because we either don't understand enough about the science, or we don't understand enough about the religion." He gives an example of a colleague and fellow Mormon that he knew in New York. "I had a friend at Columbia who was a Mormon bishop at the time, and whose work should have won him the Nobel Prize. When he was leaving to study physics in college, he asked his father 'What about religion?' His father said 'Son, you only have an obligation to believe that which is true.' I've never forgotten that."

"The problem comes in when you start to consider what is truth. The reason that I am a committed member of my church is because I believe it to be the truth. I consider myself very much a Christian and believe that Christ is central to all that is going on. The big problem lies with people's perceptions, and the cultural baggage that comes along with all religions including my own. In fact, the founder of our religion pointed out that one of the big difficulties is in the 'traditions of men.' So the key to understanding religion is getting down to the essentials. I believe that my religion represents the liberating power that allows us to discover what is truth."

Tolk also feels strongly that science should inspire people to do great things and to discover the unknown. Anything less is not enough. "I once saw an ad campaign for NASA that said essentially that NASA is great because they gave us better toasters. That's not NASA's function. The most important thing that NASA does is to inspire, not give us better consumer goods!" His love of education and interaction with students is one of the most gratifying aspects of his profession. "When you work at a university, you can touch the future in two ways. First, you can pass information directly to the students. But most importantly is that you can inspire them and fill them with a thirst for knowledge that they will carry with them long after the information that you gave them is obsolete."