TMT: Best Location for the Best Science

—An Interview with Dr. Gary Sanders

Dr. Gary H. Sanders, Project Manager of the Thirty Meter Telescope. (Photo: TMT International Observatory)

Astrophysicist Gary Sanders probably won't describe the past two years as a best beginning for the construction of the Thirty Meter Telescope (TMT), a cutting-edge astronomical facility set to be built in Hawaii for which he has been working as the project manager since a decade ago. From the road blockage by local demonstrators at the groundbreaking to a subsequent worldwide protest, the project seems to be sliding into an abyss of endless political and religious disputes.

The comforting thing for him, however, is that the research and development work of TMT in each partner country is moving ahead smoothly. For instance, despite funding gaps, a team at the Chengdu Institute of Optics and Electronics, Chinese Academy of Sciences has completed the preliminary design of the telescope's laser guide star facility, and a prototype of the large and precise tertiary mirror system of TMT is now under development at the Changchun Institute of Optics, Fine Mechanics and Physics.

"TMT is ready to construct," Dr. Sanders told *BCAS* during his visit to Beijing in May. "Mauna Kea is of course still our first choice. But after the experience we've had in Hawaii, frankly, it's not crazy for TMT to go someplace where people really want us, where we're welcome."

Dr. Sanders is an experimental physicist and accomplished manager of many scientific mega-projects, including the Laser Interferometer Gravitational Wave Observatory (LIGO). The following is an interview between him and *BCAS* reporter XIN Ling on the latest news about TMT and TMT China.

TMT: Ready to Construct, but WHERE?

BCAS: Considering the present situation of TMT, did any of you ever expect such a dilemma to happen?

Dr. Sanders: No. The political situation in Hawaii was a surprise. It was a surprise to us, and it was a surprise to the government of Hawaii.

When we studied, in the first five years of the TMT project from 2003 to 2008, three sites in Chile, one in Mexico and one in Hawaii, we knew that the existing 13 observatories in Hawaii did not have a good political relationship with the native Hawaiian community. They were on Mauna Kea which is a sensitive cultural site for Hawaiians, and they were paying rent of one dollar per year which made some of the Hawaiians angry.

So we knew that if we were to go to Hawaii, we had to do a better job. And we set out to do a better job. We had some advice from very insightful people, and we spent a lot of time engaging all the elements of the Hawaiian society. We worked very hard for seven years with the community on the environmental impacts statement and on the application for the permits. We were told at all levels of the Hawaiian government, by the business community and Hawaiian groups, that we had set a new standard. So we thought we were doing very well. All of the new process for putting a telescope on Mauna Kea for managing it, for protecting the mountain and for respecting the local culture was something we embraced. We were told we were doing everything right.

But the political climate changed for a number of reasons, and it surprised everyone. First of all, with the spread of self-determination among indigenous peoples worldwide, with the rise of the sensitivity to environmental and cultural issues, everyone is more sensitive. Indigenous peoples all over the world are more assertive about their history, their place and their society. Social media has made it much easier for them to communicate their thoughts, whether their thoughts are anger, resentment, hope for the future, or hope for independence. This is a worldwide thing and Hawaii is no exception. The fact is that the United States government took over the government of Hawaii in the 1890s, followed by a very unfortunate history of the arrival of settlers and disease and diminishing the Hawaiian religion and cultural practices. The US takeover was largely motivated by business interests, and the resentment is there. Now we have a young generation, educated in Hawaiian language schools to preserve Hawaiian culture, aware of their past, able to communicate easily over social media, and TMT was a convenient symbol of their anger.

We tried to do a good job, but it wasn't good enough, and we weren't able to sense the shift in history. Hawaii is in a different political setting right now. We are working very hard with the local community, and it is still our first choice for a site. I think it's true that most people in Hawaii are for astronomy and for TMT. But in the kind of democracy that we have, and given the unfortunate history of Hawaiian culture being suppressed and their land being taken over, we have to do better.

We are trying hard to succeed once more in Hawaii. But as we've said publicly, the risks are very high, and we are also looking at other sites because TMT is ready to construct. Hawaii is a wonderful place to build an observatory, but it's not the only place on Earth. We are considering sites in Chile, Mexico and the Canary Islands. Even China and India have proposed to us, which we haven't thought about before.

BCAS: How do you picture the best and worst scenarios for TMT?

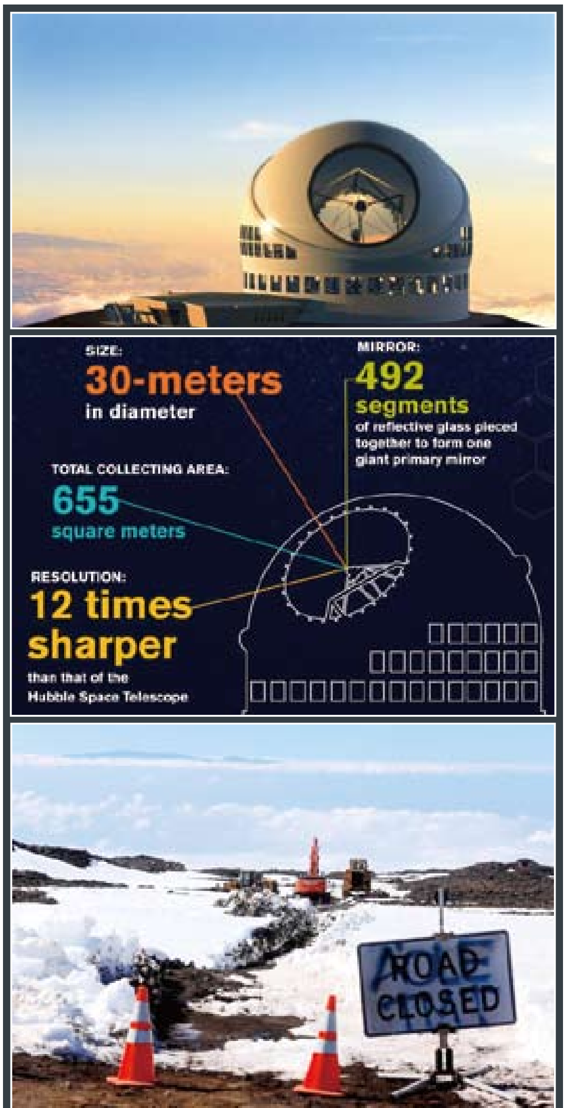
Dr. Sanders: The best is that we will pick a mountain within a year, and two years from now be building on that mountain. Our partnership will come together and things will go relatively smoothly. I think they can go relatively smoothly because we have a great design and a great team. I've led a number of large teams, and this is the best team I've ever had. We really can do this.

The worst is that we'll go forward also, but it'll be stretched out. Well, science doesn't have to be urgent, but there are other telescopes out there being built, and we'd like to get there as fast as they do and make the discoveries as fast as we can.

So I worry about stretching out, because we don't get restarted smoothly, and we don't close the financial plan quickly. But first we'll have to pick the mountain. Then we'll solve these other problems.

TMT China: "They Are Getting There"

BCAS: According to Dr. XUE Suijian, project manager of TMT China, China has chosen TMT for three reasons: located in the northern hemisphere, best technical readiness allowing for flexible in-kind contribution, and top level international collaboration. What is the reason for TMT to choose China?



Top: A rendering of the Thirty Meter Telescope. (TMT Observatory Corporation) Center: Some basic facts about TMT. (Lance Hayashida/Caltech) Bottom: "A'ole TMT" is written with spray paint on a sign outside the TMT construction site on Mauna Kea in March 2015. "A'ole" means "no" in Hawaiian. (Hollyn Johnson/Hawaii Tribune-Herald)

Dr. Sanders: If you are building a scientific facility which is really a global asset, it's entirely natural to have China as a partner. For instance, China has been a part in high energy physics internationally. I have to say that I was very attracted, and I still am, by the idea that if we build TMT in Hawaii, we would have Canada, the United States, China, India and Japan working together—it's a Pacific Rim partnership. What we are creating is not just an observatory; it's an entirely new global community of scientists different from the traditional North American-European community.

Although we are having political difficulties in Hawaii, I still have hopes for such an idea. And even if we have to build TMT in Chile or elsewhere, it would be really good to bring together scientists from these countries. It's going to be one of the high watermarks in human cultural history. International science collaboration is a very powerful force for peace. There is nothing like watching two countries have difficult relations at times but knowing that many of their scientists and scholars are working together, understanding each other and making a way to communicate.

BCAS: Here is a schematic of work division within TMT. Would you explain a bit about what China will be doing?

Dr. Sanders: In general, there are several reasons for a country to join a big international science project. One is that they know it's an international challenge, and they want their own scientists, engineers and industry to work at a world standard with the global community. Most countries want to have not only excellent science but also industrial return, and the industry will grow stronger if they can solve challenging technical problems. So it's about science, community building, innovation and industrial return.

And I divide the work into two kinds: conventional work and noble work. Noble work is the challenging part. What we did when we designed the partnership for TMT was to take the conventional work and pull it in to be done as a common effort by the project office. For each partner, 30% of their contribution should be in cash to run the project and to do the conventional work: digging a hole, pouring concrete, building the bricks, etc. The rest, a 70% contribution they will do in their own country and deliver what I call "noble work" to the project.

When we formed the TMT partnership, I visited each of the countries, the institutes and industries to see what people were interested in, what they were able to do, and if they weren't quite able to do it, what they could learn in the next few years to be able to do. I made a trip to China in 2010. I visited a number of institutes, and I made some proposals on what kinds of technical contributions China could make. In 2011 and 2012, we began some R&D. I did similar things in India and other partner countries. So we divided up the noble work.

What is the most challenging work in a telescope like this? The big mirrors and adaptive optics. And what is China working on? Producing mirrors for the big primary mirror, doing the entire tertiary mirror system, and working on the laser guide star facility and the guide star laser itself for the adaptive optics system. These are parts of the most challenging systems in TMT. They are being done in China.

Canada is doing the dome, which is semi-noble work. It's a lot of conventional steel construction, but they have a very innovative and cool design. They are also doing the facility adaptive optics system. Japan is building the telescope structure, polishing some of the mirrors like China is, and providing the glass. The 574 segments of the 1.45m mirrors of the big primary mirror will be made in four countries: 40% in the US, 30% in Japan, 15% in China and 15% in India. They will all be the same quality, and it's a very challenging thing.

How do you make a mirror? You take a piece of glass, rotate it, and put a material with an abrasive on it. Very often it's like rouge, like what you put on your face. When you rotate the mirror, it makes a curve. That curve is naturally the curve of a sphere, not the kind of curve we need in TMT. Our mirror is a hyperboloid because we want to focus the light in a certain way. It's extremely difficult to polish a hyperboloid, and very few optics industries in the world can make what we call aspheric mirrors. When I visited LAMOST, I saw Nanjing had made a segmented mirror telescope. But one mirror's segments are spherical, and the others are flat. I said, "LAMOST has brought astronomy optics technology in China right up to the door step of making a large aspheric mirror telescope. You can do a good job as you've done on LAMOST. Now take the next step and make aspheric mirrors."

And that is what China is doing now. The team at Nanjing has adopted the stressing technique that's being used in Europe and the US, and has made three aspheric mirrors successfully. Now they are making a fourth full-size mirror. They've shown they can make aspheric mirrors, and they are making the plan to build a system and make 15% of the mirrors in China. This is a technology advance. Nanjing has learned a very challenging technology that can be used on telescopes and optics in China for other purposes, too.

BCAS: Are the Chinese making progress as scheduled?

Dr. Sanders: They are still at the stage where you prove the technology can work. I often say, in these big science projects, you start by doing something almost impossible; but by the time you finish, it's routine. You go from the nearly impossible to the routine. And that is progress. I just told you how Nanjing has learned to make aspheric mirrors, which in most parts of the world are nearly impossible. Now they are at a point of routine to do it.

For the guide star laser developed at TIPC here in Beijing, there is only one German company that can make such a guide start laser in the entire world right now. TIPC has a very good design, and they are trying to make it reliable—sending up enough lights so that the right kind of light comes back from the guide star. They are making progress, but they are not there yet. They are on the path from nearly impossible to routine.

The laser guide star facility being built in Chengdu has made progress as well. They've done the preliminary design, and I'd say they are about two thirds or three quarters on the way to routine. That's very good progress.

The Changchun Institute is working on the very large, flat, precise tertiary mirror system. They've been consulting with a famous optics expert named Jim Burge from the University of Arizona. In fact, some of Jim's former students are working in Changchun now. They are making good progress in prototyping. Actually they did a very smart thing. They realized this system is very challenging, so they decided first to build one that's one quarter the size of the mirror, so it costs less money. I'm very pleased with what they are doing now.

So each one of them is a good story, and they are getting there.

BCAS: Rather than technical difficulties, TMT people in China are more concerned about the funding problem.

Dr. Sanders: Yes. I think your challenge is funding. In each country, the funding agencies approach things in a different way. Like I said, the United States is very strange and unique in astronomy—and only in astronomy. The Chinese system is not so different from the rest of the world. It is government funded.

And right now, because of the political difficulty we are having on the site, it's perfectly natural for the governments to watch carefully and see how we solve this before decisions are made.

BCAS: What would happen if the Chinese scientists cannot get money from the government?

(a) A prototype of the TMT guide star laser developed at the CAS Institute of Technical Institute of Physics and Chemistry (TIPC). **(b)** Virginia Ford and Glen Cole working with Chinese colleagues on the verification of TMT tertiary mirror at the Changchun Institute of Optics, Fine Mechanics and Physics (CIOMP) in March 2016. **(c)** August 2015, Larry Stepp, Eric Hansen, Glen Cole and Fengchuan Liu at the Nanjing Institute of Astronomical Optics and Technology (NIAOT), talking with local TMT team on the polishing of the segment mirrors of the big primary mirror. **(d)** A joint laser test by TIPC, CIOMP, NAOC and TMT at Xinglong Observation Station in December 2014. (Photos: NAOC)

Dr. Sanders: The Chinese contribution will regrettably, unfortunately, have to be smaller. I think that would be *very* regrettable. I already told you my vision for an international Pacific Rim observatory. That's a very important accomplishment in the history of science, and it would be wonderful if China is a part of it. In fact, it may be even crazy to happen without China. China is such an important part of the Pacific Rim community.

But still, what we have to do now is to solve the site problem first. That'll give confidence to the funding agencies. TMT has a number of options for very good mountains. We just have to work hard and make a good choice. And then we will complete the financial plan.

In fact, this is not uncommon. In the difficult challenges a big project faces, one of them is that governments don't make their decisions on the same schedule, or in the same way. Every project goes through these periods where some of the partners have committed and the project moves forward, while others don't come along. It's not unusual. I really hope that China will become a full funding partner of TMT soon.

TMT and Chinese Astronomy

BCAS: You talked about China's emerging role in global astronomical collaboration. However, that doesn't change the fact that our astronomy community is still small and developing.

Astronomical forum "TMT in China: Scientific and Technology Frontiers" was convened at the Kavli Institute for Astronomy and Astrophysics, Peking University from November 2 to 4, 2014. (Photo: NAOC/KIAA)

Dr. Sanders: Well, China's astronomy isn't big considering how big China is. But I'm not an astronomer. As far as I know, China is certainly very active in radio astronomy. LAMOST and FAST are your major thrusts now, and I think participating in TMT will help propel Chinese astronomy forward.

The Chinese situation with a small astronomy community, especially with respect to the size of the country, is not that unusual. India's astronomy community is also very small, and it is also historically stronger in radio astronomy. The Indian government officials have said that they look upon TMT as an opportunity to build up the size of their astronomy community. They said educating young people as astronomers and astro-engineers is a main purpose they are participating in TMT. This is a good way to help young people stay in astronomy, and to build up a workforce for making innovations in the high-tech industry. The Indian government has made it clear that they are not only supporting TMT, but also setting aside some money for this kind of community and workforce development. And we've been planning to do the same kind of thing in Hawaii.

As for Chile, the total size of their astronomy community was about 80 to 100 people ten years ago. When I gave my talk to the Chilean Astronomical Society this year, there were 240 people there, and most of them were young. So the community is growing. Many of them will stay in astronomy, or end up in precision industries, optical industries, or industries with controls or software—because of the very good education in astronomy and astronomy engineering. So I think for a country like China, which is in many ways building up huge high-tech workforces, an investment in astronomy will be a good investment.

BCAS: LAMOST is probably the most important thing we've achieved in the past decade in astronomy. How do you see its value?

Dr. Sanders: Again—I'm not an astronomer. I'm not calibrated to talk about what science LAMOST has done. But what I'm qualified to say is that LAMOST is a very important step in astronomy-related technology development in China. When I walked around the LAMOST telescope, and walked behind the mirrors, saw the structure and controls, I said, "this is impressive; this is at the world standard." I was impressed by the segmented mirrors—even though they were not aspherical, and the supports, the controls, the sensors… This was a big step in designing, making and integrating a cutting-edge telescope. It has put China right in the position to work on next generation telescopes, and I hope TMT is part of that next generation for China.

BCAS: How do you see the potential of the upcoming FAST telescope?

Dr. Sanders: FAST is definitely an exciting project. It fits a big niche in radio astronomy that's really important, and will carry forward China's traditional strength in radio astronomy. It's very different from SKA or ALMA, but that's good. It means China is filling out the human observation of the radio sky. To me, in radio astronomy, I'm mostly interested in pulsar timing, which I believe will see the gravitational waves at very low, nano-hertz frequencies. In many ways, FAST has the opportunity to make its success.

BCAS: Thank you very much. Last question: your messages for young astronomy students in China?

Dr. Sanders: First, why go into astronomy? My idea is that every time we look at the universe in a different way, we see a different universe. That's amazingly exciting. That's a main reason to be in astronomy, and be in astronomy for the next 50 years—because we *are* looking at the universe in new ways.

Then I think young people need to be aware of the social side of doing science. Because when they come out of school and go to college, they study science—but they don't really know how science is done out there in the world. They just know what's in the books or papers or what their professor teaches them. They only think about the technical details of science, and may not realize that science is also a social, organizational and sometimes even political activity. This is especially true in astronomy.

So it turns out that some scientists do wonderful science in big groups like TMT, and some prefer to work alone just because they find it more exciting to solve scientific problems by themselves, or just because of the way they are. What I learned in my life is that I discovered myself. I found myself working very happily in a group of a thousand. And you just need to find out who you are.