

---

# A brief introduction to Theodore Yao-Tsu Wu

by Thomas Y. Hou<sup>\*</sup>

**Abstract.** Professor Theodore Yaotsu Wu has a very distinguished career and is a true gentleman. He has lived a wonderful and very colorful life. In this article, I will give a brief introduction of Professor Wu, describing his early life in China, his graduate study and his professional development at Caltech. Many of the stories that I have adopted in this article are based on the oral history that was documented during a series of interviews conducted at Caltech in 2002.<sup>†</sup>

## Early Life

Professor Theodore Yaotsu Wu was born on March 20, 1924 in a small village in Changzhou, Jiangsu Province, China. His grandfather was a well-known Chinese doctor who specialized in surgery. He not only treated many patients in his house, he would also go to the north side of the village on the odd days and the south side on the even days to treat patients free of charge. His father attended college and graduated with a degree in economics and finance. His mother graduated from high school and majored in literature. After graduation, his father served in the Department of Transportation of the government. He managed to acquire for the government quite a few of the railroads that were built by foreign enterprises. His father did a great job in nationalizing these railroads. The trade was regarded as fair and square to all involved.

---

<sup>\*</sup> Applied and Comput. Math., Caltech, Pasadena, CA 91125  
E-mail: hou@cms.caltech.edu

<sup>†</sup> More details can be found at <http://oralhistories.library.caltech.edu/161/1/Wu-OHO.pdf>.

Professor Wu left his hometown when he was 9 years old and moved to Beijing with his family as his father was helping to nationalize a railroad built by a French enterprise between Shijia-zhuang in Hebei Province and Taiyuan in Shanxi Province. The nationalization went very peacefully with excellent cooperation between the original and the new owners. Professor Wu and his family lived in a modern compound, a charming, all-walled-in town. This compound was built for the French people when they were building the railroad. It was very much like a French village. Some of the French people still lived there. Professor Wu made very good friendships with them. Then later on they gradually returned to France.

When the Sino-Japanese War broke out at the Marco Polo Bridge (Lugou Bridge) in 1937, Professor Wu had just finished his first year of junior high school in Beijing. He took the penultimate train and his father took the very last train leaving Beijing, and they returned to their hometown. In the following year, he went to Changsha to attend the well-known Mingde School that was founded by Dr. Yuan-Tan Hu (his father also attended this school). Here he received an excellent education. In the third year of his junior high school, his father decided to send him to a private school in Shanghai. But this did not last long. Soon Professor Wu and his fellow classmates (about 24 of them) decided to leave Shanghai for the wartime capital Chongqing in May 1942. They walked over 1,000 miles through the battlefields to reach Chongqing and endured many hardships along the way. In particular, when they traveled south to Fujian Province, many people suffered from the plague or malaria. Many years later, Professor Wu read a newspaper report about evidence of bacterial warfare carried out by the Japanese Army, with the

time and place coinciding with their personal experience.

By the time they got to Chongqing, it was already November of 1942. They were told that they would have to come back the next year since the universities had already been in session for two months. Professor Wu and his fellow classmates did not accept this decision. They requested that they be given the opportunity to take the hardest exam to prove that they could do it. With the blessing from the Ministry of Education, they took the exam and did extremely well. Impressed by their performance, they were admitted to different universities in the same year without any delay. Professor Wu was admitted to the Chaio-Tung University, which had moved to the wartime capital from Shanghai. At that time, because Professor Wu saw that all those bombers were Japanese, he decided to major in aeronautics, hoping to build more planes to defend his country.

Professor Wu studied in Chongqing for three and a half years until 1945 when Japan surrendered unconditionally. Then he moved back to Shanghai with the rest of the university. In Chongqing, he received a great education even under the Japanese bombing. He attributed this to all his teachers. Professor Wu graduated in 1946 and stayed on one year as a lecturer. He originally planned to stay and help rebuild China after the war. So he did not apply to study abroad. But then his father convinced him that he could be in a much better position to serve his country if he received a solid education abroad. At this time, he already missed the application deadline to apply to the major universities in the US. But one of his friends was at Iowa State University. They admitted students four times a year. So he went to Iowa State University (called Iowa State College at the time). He studied at Iowa State College for three quarters and got his master degree. In the following year, he was accepted by Caltech aeronautics for his Ph.D.

## Graduate Study at Caltech

Professor Wu came to Caltech in 1949. There were very few Chinese students or professors at Caltech. Hsue-Shen Tsien (Xuesen Qian) and Yuan-Cheng (Bert) Fung were two professors at the time. Tsien was one of the two first Goddard Professors (the other one was given to Princeton). He was just recruited back to Caltech from MIT. One day, while eating lunch in the Greasy Spoon dining hall, all of a sudden, there was a distinguished professor sitting opposite to Professor Wu. After a few casual conversations, this professor asked him "Where are you from?", "Where is your family? Is your family all right?". Then he introduced himself "I am Robert Millikan" (our founding President). Professor Wu was so shocked and stood



*Figure 1. A young Theodore Wu with his parents, boarding an airplane.*



*Figure 2. Late-night studying at Iowa State University, 1947 or 1948.*

up to pay his respect. He was greatly moved that Millikan came to have lunch with him and had an interest to ask him these questions. Millikan said "Caltech is a small institute, and we are privileged enough to take the time to do these things". This was Professor Wu's first amazing experience at Caltech. He said that it was really very very nice and very touching. This showed the special and very unique culture of Caltech that was very different from that of other major universities.

In aeronautics, Professor Wu studied for his Ph.D. under the supervision of Paco A. Lagerstrom, a professor in Applied Mathematics. He shared an office with Julian Cole who was a very distinguished scholar and finished his PhD in aeronautics in 1949

under the supervision of Lagerstrom. Julian Cole is well known for his groundbreaking work in mathematical applications to aerodynamics and transonic flow, and in non-linear equations more generally. Professor Wu had benefited tremendously from interacting with him on a daily basis. He could observe in close distance the thinking process of Cole, how he made mistakes, how he spotted his mistakes and how he corrected his mistakes. He said that he learned a great deal from Cole and the research group led by Lagerstrom. And that group, later on, became the center of a new theoretical development called asymptotic method and perturbation theory.

Professor Wu was so happy to be part of this dynamic group that consisted of Julian Cole and Saul Kaplun and was full of energy and great ideas. They would bring up all sorts of exciting, challenging problems to solve. They worked late nights and would go out for a midnight snack and then come back again and work. The method developed by applying the so-called matched perturbation principle was widely used for a general class of problems in science and engineering afterwards. Many people followed up their work and used the method developed by his group in their own applications. Professor Wu said that this was like the sowing of a gem seed that could blossom and bear fruit in scientific gardens. Professor Wu got his Ph.D. in 1952 magna cum laude.

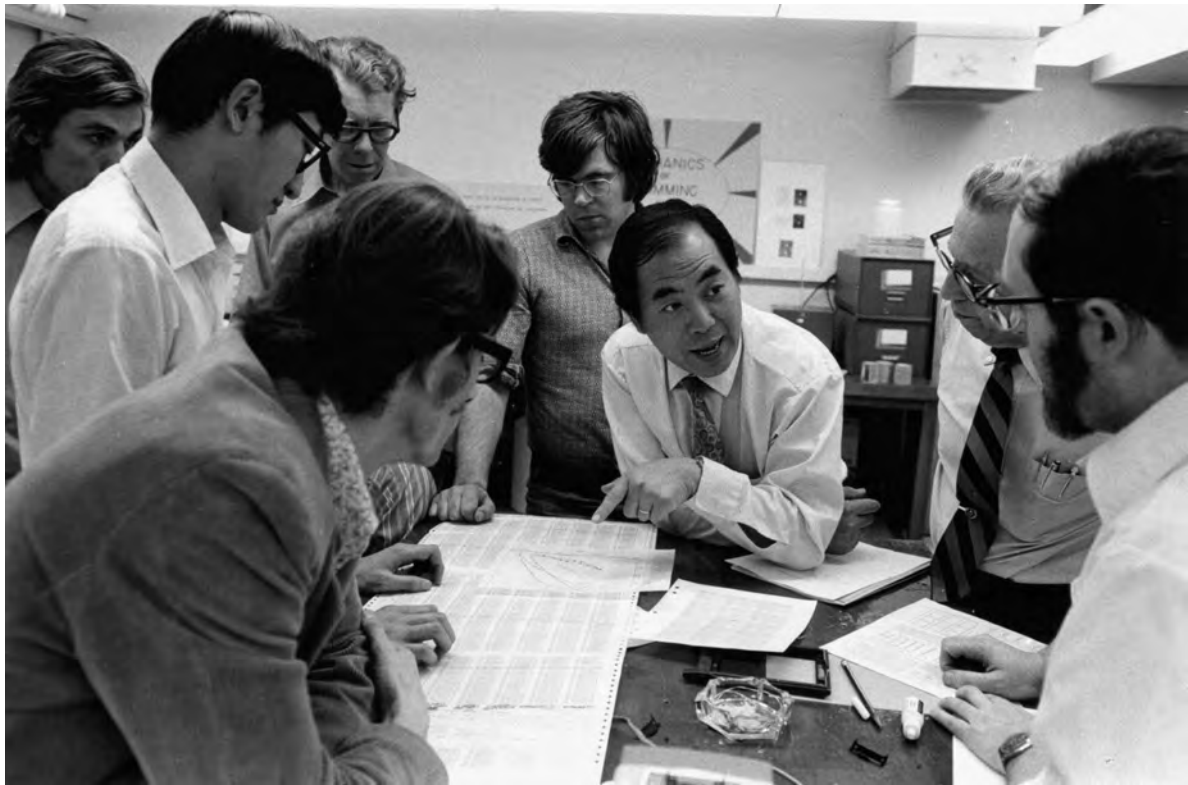
During his graduate student days, Professor Wu was fortunate to know Professor Tsien. Professor Tsien told Professor Wu that during the winter months Professor von Karman would be back in Pasadena. This gave them the opportunity to visit him at his house. Professor Wu learned that in the previous years von Karman and Tsien had held a few rounds of study sessions on water waves and hydrodynamics. So he was stimulated to look into this new field of hydrodynamics, and became quite interested. After reading some of the notes, he decided to change his field from aeronautics to hydrodynamics. After he got his Ph.D., Professor Tsien offered him a research fellow position at Caltech to work on hydrodynamics. Professor Wu studied the hydrofoils of finite span in which one takes the wing of an airplane and submerges it in the water to some depth, to lift the vehicle above the waters surface. This was known to be a very difficult problem. Professor Wu took on this challenging problem and made a very concentrated study, which turned out to be a very interesting work. He later published his findings, with a note of gratitude to Tsien and von Karman for their encouragement and stimulation and for pointing out this new direction to him.

## Research Career at Caltech as a Faculty Member

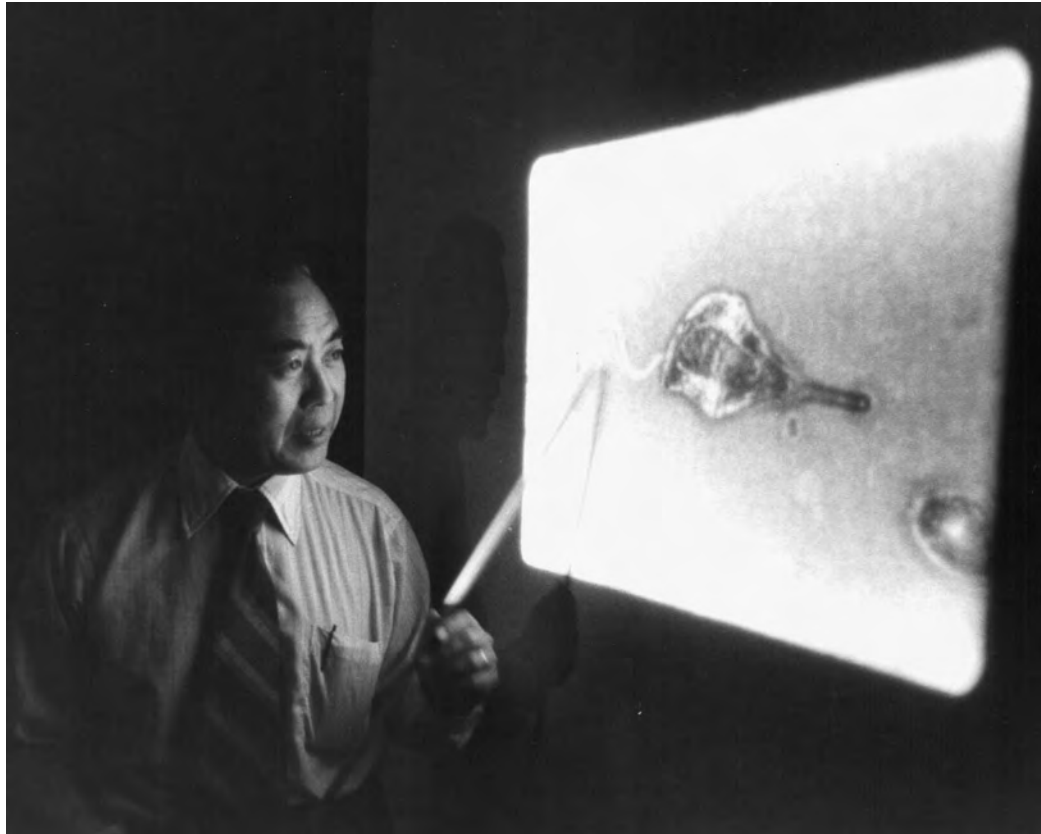
After three years as a research fellow, Professor Wu became an assistant professor in 1955 in the newly established engineering science department. This new department emphasized the interdisciplinary research with a strong theoretical flavor. They were not traditional engineers or traditional physicist/mathematicians. Professors Charles De Prima and Hsue-Shen Tsien were among the founding members of this department. In his academic career, Professor Wu has shown a broad and versatile interest in research, including flows of compressible, viscous and heat-conducting fluids; free-streamline theory of cavities, jets and wakes; water waves and free-surface flows, mechanics of fish swimming and bird/insect flight; wind and ocean-current energy, internal waves in the ocean, mathematics of nonlinear evolution equations, etc. During his early years at Caltech he has also contributed to the field of naval architecture and been involved in the International Towing Tank Conferences in the 1960s.

Of his many contributions, I would like to highlight his research contributions on studies of low-Reynolds-number hydrodynamics, microorganism locomotion and related biophysical phenomena. His interest in this field was inspired by the earlier work of G. I. Taylor. The first paper Professor Taylor wrote was on microorganisms. The second one was on larger animals, between macro and micro (Taylor called them elongated swimming animals). His work inspired many people to work on this field. Another influential figure in this field was Sir. James Lighthill, who later became secretary of the Royal Society for a number of years. He wrote a paper [Lighthill, M. J., "Note on the Swimming of Slender Fish," *Journal of Fluid Mechanics*, 9 (1960), pp. 305–317]. Professor Wu immediately became interested in his work and started to work on fish locomotion and bird flight. In the following year, Professor Wu published his first paper on this subject [Wu, T. Y., "Swimming of a Waving Plate," *Journal of Fluid Mechanics*, 10 (1961), pp. 321–344]. Then Professor Wu and Professor Lighthill started to interact. Professor Wu invited Professor Lighthill to visit Caltech, and Professor Lighthill arranged a visit of Professor Wu to Cambridge. They became quite close.

Then later on, without telling each other, they started to work on microorganisms again. Professor Wu worked on microorganisms called flagellated and ciliated microorganisms. He started first on the large animals and did the experiment in the hydrolab using the water tunnel. He actually put mechanical models as well as live specimens in there. His research group



*Figure 3. At Caltech in the early 1970s with his research group. Prof. Emeritus Christopher Brennen is at front left, and Prof. Howard Winet at front right. Photo courtesy of Floyd Clark.*



*Figure 4. Giving a presentation in 1979.*



Figure 5. *Laughing with good friends. From left to right: Zhemin Zheng (MS and PhD Caltech), Prof. Emeritus Bert Yuan-Cheng Fung (UCSD), Prof. Emeritus Chia-Shun Yih (Univ. of Michigan), and Theodore Wu.*

would put them in there, but it was too small for the fish to go through – upstream and downstream. Then they would watch them, and recorded all the data they needed. Then, later on, when they started to move into the subject of flagellar and ciliary locomotion, Professor Wu had two physiologists join his group, biology graduates from UCLA, Howard Winet and Anthony T. W. Cheung. This line of research had generated a number of very important results and attracted a number of very talented students to this project.

In 1974, Professor Wu organized the first international conference on biofluidynamics at Caltech. The term “biofluidynamics” (not separated, not hyphenated, all one word) was coined by Lighthill. Lighthill and other biologists, their biology school and also zoology school, their professors also came. And people came from all over the world. The symposium was called *Swimming and Flying in Nature*, and was a great success.

This is a natural place to mention Professor Bert Yuan-Cheng Fung. He was a professor in aeronautics at Caltech at that time. He graduated from aeronautics *summa cum laude* at Caltech in 1948. He soon started to work in aeroelasticity-airplane wing vibrations. Then he became interested in biomechanics partly because his mother was ill and he wanted to help to find some ways of therapy. He and Professor Harold Wayland worked together. Soon it became clear that they needed to form a group. Unfortunately, Caltech could not provide the resources to form a big group. At this point, UC San Diego

approached Prof. Fung and made him an offer that he could not refuse. So he left Caltech to join UCSD, which was a big loss for Caltech. Professor Fung played a very important role in persuading the Whitaker Foundation to lend their strong support to bioengineering. This foundation is now sponsoring work in that field at about twenty universities. Professor Fung’s work on biomechanics has been tremendously important and influential. His students have now emerged as the leaders in this field. Prof. Fung has received many honors and awards for his outstanding contributions. He is a member of the US National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, and a recipient of the National Medal of Science.

## Life After Retirement

Professor Wu retired from Caltech in 1996. He has continued to be very active in his research and has devoted almost all his time to his book project in recent years. Since his retirement, Professor Wu has made important contributions on forced generation of nonlinear waves at resonance of soliton-bearing systems, three-dimensional vortex dynamics, and coastal oceanography. His new theoretical model for fully nonlinear dispersive waves in water of variable depth is ideal for investigating mitigation and control of such natural hazards as tsunami, storm surge, and hurricanes. The new idea and concept, based on devising means for active and passive control and mitigation of devastating waves and fluid



Figure 6. Prof. Allen T. Chwang presents an ASCE award to Prof. Wu at Vancouver, BC in 2004.

flows, may germinate growth of a new field. Revisiting bio-physics, he has developed a fully nonlinear lifting theory for modeling bird flying and fish swimming.

In September 26, 2014, Caltech organized a one-day symposium to celebrate Professor Wu's 90th birthday. Professor Christopher Brennen and myself were the main organizers with strong support from Professor Kaushik Bhattacharya (the Executive Officer of Mechanical and Civil Engineering at Caltech). Many distinguished scholars, his former students, collaborators and friends from all over the world came to Caltech to celebrate his life achievements. I made a passionate opening speech for the conference, which was very well received. Many people shared their personal stories about Professor Wu. The conference was a great success.

Professor Wu has been a great mentor and a strong supporter for many young scientists. A former Ph.D. student of Mechanical and Civil Engineering, Dr. Lisan Hwang, and his wife, Anne Hwang, made a very generous donation to establish a chair professorship and graduate student scholarship in honor of Professor Wu. Dr. Hwang said that when he was a Ph.D. student, Professor Wu and Mrs. Wu helped him and his wife in many ways. He remembered vividly that when he prepared his wedding with his wife, their parents could not come to the US to attend their wedding. It was Professor Wu who served as the "father" of the bride and walked her to Lisan during the wedding. This was an unforgettable moment in their life.

Professor Norden E. Huang was one of the keynote speakers for this symposium. Professor Huang is



Figure 7. Dr. Lisan and Anne Hwang, 1979.

well known for his outstanding contributions in fluid dynamics and adaptive data analysis, and is a member of US National Academy of Engineering, Academia Sinica, and a foreign member of Chinese Academy of Engineering. He developed his well-known Empirical Mode Decomposition Method (EMD) at Caltech from 1997 to 1999 at the invitation of Professor Wu. He said that he was extremely grateful to Professor Wu's support for his work on EMD. In fact, it was Professor Wu who coined the term Hilbert-Huang Transform for his EMD method.

I have personally benefited tremendously from his support throughout the years and have learned



*Figure 8. From left to right: Prof. Emeritus Christopher Brennen, Prof. Thomas Y. Hou, and his wife, Yu-Chung Chang-Hou.*

a lot from him. He is not only a great scholar in science and engineering, he is also a great scholar in Chinese and Western cultures. And he knows many great stories about the history of Caltech. It has been extremely inspiring to listen to his fascinating stories about how Caltech transformed itself from an unknown vocational school into a world center of science and technology under the leadership of the three founders, George Hale, Arthur Noyes, and Robert Millikan. Over the years, our two families have established a very close relationship. In recent years, my research group has taken on the responsibility to provide computer related technical support for him as he continues to work on his book project. He has served as a great role model for many of us.

## Honors and Awards

Professor Wu has received many honors and awards for his outstanding contributions. These include John Simon Guggenheim Fellow in 1964, Australian CSIRO and Universities Fellow in 1976, Japan JSPS Fellow in 1981, Fluid Mechanics Prize in 1993, and the von Karman Medal in 2004. He is also a member of the U.S. National Academy of Engineering (1982), a member of Academia Sinica (1984), an Honorary Fellow of Institute of Mechanics (1988), an American Physical Society Fellow (1993) and a Foreign Member of Chinese Academy of Sciences (2002).



*Figure 9. Theodore Wu and his wife, Chin Hua Wu.*

In all, Professor Wu has authored or co-authored more than 150 papers published in archive journals and as book chapters. His contributions have been honored with lifetime achievement awards from the Chinese-American Faculty Association of Southern California in 1993, from the Chinese Engineers and Scientists Association of Southern California, and of the 2000 American Chiao Tung University Alumni Association.