Sixty Years of Gazing at the Stars—Research Fellow Wu Lianda' s Journey in Satellite Orbit Computation

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Abstract

This paper reviews the main course of the theoretical research and engineering practice in artificial satellite orbit determination and prediction in China, as personally experienced by the author since joining the artificial satellite observation system of the Chinese Academy of Sciences in 1964. Starting with the development of the orbit determination and prediction scheme for the "Dongfanghong-1" satellite, the paper recounts the completion of major tasks such as satellite dynamical geodesy, space debris monitoring, and the development of photoelectric arrays, as well as research achievements in the fundamental theory of satellite dynamics. It summarizes the research experience of "missions driving disciplines" and offers suggestions for young researchers.

Full Text

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Sixty Years of Gazing at the Stars–Research Fellow Wu Lianda's Journey in Satellite Orbit Computation

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Abstract This article reviews the author's principal experiences in the theoretical research and engineering practice of orbit determination and prediction for China's artificial satellites since he joined the artificial-satellite observation system of the Chinese Academy of Sciences in 1964. Beginning with the development of the orbit determination and prediction scheme for the "Dongfanghong-1" satellite, the article describes the completion of major tasks such as satellite dynamical geodesy, space-debris monitoring, and the development of photoelectric arrays; presents research achievements in the basic theory of satellite dynamics; summarizes scientific-research experience in the "mission-driven discipline"; and offers suggestions for young researchers.

Keywords artificial-satellite orbit, satellite dynamics, space-object monitoring, astronomical observation, scientific-research career

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1 Introduction: The Call of the Times

I am from Wujin, Jiangsu Province (now Xinbei District, Changzhou). In 1959 I graduated from Benniu Middle School in Wujin County. Responding to the nation's call to "march toward science," and inspired by the launch of the Soviet Union's first artificial satellite, I applied for admission to the Department of

Mathematical Astronomy at Nanjing University. In 1964, after graduation, I was assigned to the Purple Mountain Observatory (hereafter abbreviated as PMO) to work in the artificial-satellite office.

On October 4, 1957, the Soviet Union successfully launched the first artificial Earth satellite, opening a new era in human spaceflight. At that time, Director Zhang Yuzhe of the Purple Mountain Observatory immediately responded by organizing researchers, who on October 17 of the same year successfully observed the rocket body of the Soviet Union' s first satellite. Director Zhang Yuzhe and Mr. Zhang Jiaxiang published China' s first paper on artificial-satellite orbits, "The Orbit Problem of Artificial Satellites," in 1957[1]. In such an academic atmosphere, I began a research career in satellite dynamics that would last for sixty years. In 1965, PMO established the Hefei Working Group. Using the 103 electronic computer of the East China Institute of Automation, it began routine work such as orbit computation and prediction for artificial satellites, laying the foundation for establishing China' s satellite orbit determination and prediction scheme and developing corresponding software. I was fortunate to take part in the working group, and from then on formed an enduring bond with satellite orbit computation.

2 Main Research Work

2.1 The "405 Mission": Orbit Determination and Prediction for China' s First Satellite (1967–1968)

On April 5, 1967, on the third floor of the Jiangsu Provincial Science and Technology Commission near Jiming Temple in Nanjing, the "405" working group was established to specialize in studying the orbit determination and prediction scheme and computer programs for China' s first satellite. The mission requirement was "measure accurately and report quickly." Participating units included Unit 8120, the Purple Mountain Observatory, the Institute of Mathematics, the Northwest Institute of Computing Technology, and the 701 Engineering Office. Working conditions at the time were extremely difficult. The Purple Mountain Observatory purchased an X-2 computer and installed it on the west side of the third floor of the Jiangsu Provincial Science and Technology Commission. The X-2 was a transistor computer, using paper-tape input and magnetic-drum external storage, with 4K of memory and a computing speed of 40,000 floating-point operations per second. In the past, none of us had used an electronic computer. We had to become familiar with the computer' s instructions, punch programs onto paper tape, and read and repair paper tape; the work was very tedious. To compare computational results, researchers had to queue and use the electronic computer in assigned time slots.

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The work of the "405" Group was completed by April 1968, and it formally submitted the initial orbit, orbit-improvement, and prediction plans for China' s first satellite. On the evening of April 24, 1970, China' s first artificial satellite was successfully launched. Zǐjīnshān immediately took the initiative to organize the Chinese Academy of Sciences' artificial-satellite system to carry out observations and orbit computation. We mainly used 202 MHz single-frequency Doppler data, and, using the schemes and software developed by the "405"Group, quickly determined the orbit and issued predictions to the world, meeting the requirement of "measuring accurately and reporting quickly."

In December 1982, the Mathematics Division of the Chinese Academy of Sciences organized 65 scientists to conduct an academic review of Zǐjīnshān. Its assessment of the work on artificial satellites was: "In such areas as artificial-satellite orbit determination and prediction, effective work has been done for national-defense construction," and "an important basic research force has been formed." In 1988, 26 satellite-using units sent letters stating: "The orbit schemes designed by the '405'Group (including initial orbit, improvement, and prediction) have been shown by engineering practice to satisfy, in correctness, reliability, and accuracy, the orbit-computation requirements for China' s first satellite, 'Dongfanghong-1,' and laid the foundation and provided experience for China' s subsequent orbit computation. The work they did was pioneering." Some people also called the "405" Group China' s "cradle of orbit computation."

The work of the "405" Group won a Major Scientific and Technological Achievement Award of the Chinese Academy of Sciences in 1978, and a Special Prize (Coverage Award) of the National Science and Technology Progress Award in 1985. On September 18, 1999, Zǐjīnshān Researcher Zhang Jiaxiang attended the award ceremony for "Two Bombs and One Satellite" and was received by the leaders of the Party Central Committee.

2.2 Satellite geodynamics research (1974–1985)

In March 1974, the National Defense Science and Technology Commission chaired the first specialized conference on research into the Earth' s shape and gravitational field in Beijing. At the meeting, Mr. Huang Kunyi of Zǐjīnshān presented a research report on carrying out satellite geodynamic surveying, which was endorsed by the conference. The Chinese Academy of Sciences issued a document assigning this task to Zǐjīnshān and to the various satellite-tracking stations under the Academy.

(1) Ten years sharpening one sword

Satellite geodynamics is the precise observation of satellites to determine their precise orbits, and then the precise geocentric coordinates of observing stations, thereby establishing China' s geocentric coordinate system and its transformation relationship with the major existing international geocentric coordinate systems. This was not only a scientific research task requiring the cooperation of many units and joint efforts to tackle key problems, but also a building of basic capability for national defense and the national economy. From the program demonstration that began in 1974 to the end of the actual-measurement phase in 1985, more than ten years elapsed. In October 1985, the Mathematics Division of the Chinese Academy of Sciences and the General Administration of Surveying and Mapping invited experts and scholars from the domestic astronomy, surveying and mapping, and aerospace communities to hold, in Nanjing, an appraisal meeting on the achievements of satellite geodynamic surveying. The appraisal committee held that the participating units had "outstandingly completed the satellite geodynamic surveying task and achieved the best results possible under the present conditions. The actual computational results show that the internal accuracy of the geocentric coordinates is about (±)1 m; checks using other existing data show that the errors are within the meter level." In 1987, the satellite geodynamic surveying achievements won the First Prize of the National Science and Technology Progress Award—an exemplar of a decade' s perseverance.

(2) Breakthroughs in second-order perturbation theory

In research on satellite geodynamic surveying, I completed research on precise satellite orbit determination and proposed a semi-analytical method for satellite orbits[1]. Compared with methods abroad, theirs were first-order theories, while ours was a second-order theory. In 1986, this project won the Second Prize of the Jiangsu Provincial Science and Technology Progress Award. In 1980, the U.S. National Aeronautics and Space Administration (NASA) invited me to give a related academic report. The significance of this research was that it improved orbit-determination accuracy and provided a more accurate theoretical foundation for satellite geodynamic surveying. Tong Fu, Gu Jiming, and others completed research on semi-analytical and semi-numerical methods for the second-order perturbation theory of artificial satellites, providing practical methods for satellite geodynamic surveying and precise orbit determination.

2.3 Space-debris monitoring and reentry prediction (1995–2012)

Beginning in 1995, I participated in China' s space-debris working group and served as leader of the observation group. Space-debris research is a new field that arose with the development of astronautics; it mainly studies the monitoring, early warning, and mitigation strategies for space debris.

(1) Outstanding achievements in international joint observations

The increasingly prominent problem of space debris requires global joint management. Internationally, the Inter-Agency Space Debris Coordination Committee (IADC) was established in 1993; it is an organization through which the space

[1]2

agencies of various countries cooperate in research on space debris. IADC often organizes international joint observations for reentry prediction, hoping to improve the prediction level of each country through joint observations. Because we had conducted long-term research on upper-atmospheric density, and had in the past carried out reentry predictions for targets such as the "American Sky Laboratory" (1979) and the "Soviet Cosmos 1402" (1983), we had a certain amount of experience; therefore, our joint-observation results were comparatively good. In the 1998 Inspector reentry-prediction joint observations, the report I submitted won second place, with a prediction error of only 19 min, while the U.S. NASA error was 62 min and Europe' s ESA (European Space Agency) error was 109

min. Our report received favorable reviews. In the 2005 Cosmos 2332 decay-prediction joint campaign, Xiong Jianing' s prediction ranked first, with a 48 h forecast error of only 2 min, markedly better than those of other countries.

(2) Capture and decay prediction of recoverable satellites

In 1993, China' s 15th recoverable satellite unexpectedly lost control. The Satellite Observation Research Center of the Chinese Academy of Sciences received from the Commission of Science, Technology and Industry for National Defense the task of "capture, long-term tracking, and decay-period prediction." Under the condition that the radio signal had been lost, searching for the satellite was like looking for a needle in the ocean. But we brought into play the advantages of optical telescopes: that very night, the telescopes in Nanjing and Urumqi successfully captured the out-of-control satellite. We overcame difficulties such as a shortage of observing equipment and an insufficient distribution of stations, carried out nearly 3 yr of long-term tracking, and in 1996 submitted the final decay-prediction results to the central authorities, providing data and technical support for risk assessment and diplomatic decision-making. This achievement won the 1999 First Prize for Scientific and Technological Progress of the Chinese Academy of Sciences, and accumulated theoretical experience in reentry tracking and prediction for hazardous targets[^3].

(3) Space-debris warning for Shenzhou crewed spacecraft

In 2005, in order to welcome the launch of Shenzhou VI, it was necessary to strengthen observations of space debris. We modified the Zijinshan Observatory' s SBG (Schmidtkamera für Bahnvermessung und Geodäsie) satellite geodetic camera and the Yunnan Observatory' s SBG satellite geodetic camera, added scientific CCD (Charge-Coupled Device) detectors, and installed them respectively in Delingha and Kunming; we also upgraded the CCD detector on the Xuyi 65 cm telescope. By building an independent collision-warning system, we provided regular collision-warning services for China' s spacecraft and decay-warning services for hazardous targets. The successful implementation of this project marked China' s becoming one of the few countries capable of independently carrying out space-debris warning.

2.4 Development of photoelectric arrays: original innovation in sky-area monitoring (2002–2014)

In the winter of 2002, at a place in the northern suburbs of Beijing, the Bureau of Science, Technology and Industry for National Defense of the Academy convened a "whimsical ideas" meeting. At the meeting I proposed the idea of using optical telescopes instead of phased-array radar to conduct large-sky-area monitoring—this was the prototype of the principle of the "photoelectric array."

(1) 15 cm photoelectric array

After the meeting, our team carried out optimized design, solved the method of target association, and designed a wide-field telescope. In 2003 we formally put forward the preliminary design plan for the "photoelectric array," and in 2004 received start-up funding support from relevant departments of the Academy. The detection principle of the photoelectric array is aimed at sky-area observation: without forecast guidance, and without knowing in advance what the target is, after observation the orbit is first associated and then the orbit is determined and catalogued. Orbit association is the strength of Zijinshan Observatory; the research was completed very quickly, and association can succeed with data from only one field of view (above 5″). In 2007, development of the 15 cm photoelectric array was completed, and it was installed at Honghe Station in Heilongjiang. The photoelectric array consists of 96 fixed-pointing 15 cm long-focus telescopes and two 40 cm tracking telescopes; its monitored sky area reaches 4800 deg^2. It realizes multi-target observation of a sky area and can carry out catalogue observation and new-target discovery for near-Earth space targets. It is a new type of observing equipment for the cataloguing of space targets.

(2) 30 cm photoelectric array

After the 15 cm photoelectric array was completed, we also designed a 30 cm photoelectric array. The project was established in 2007, and development was completed in 2011. The two sets of 30 cm photoelectric arrays were installed respectively in Yao'an, Yunnan, and Urumqi, Xinjiang; together they include 108 telescopes, and their monitored sky area reaches 13 000 deg^2. With photoelectric arrays, the number of space targets managed in the cataloguing of human-made systems increased substantially. The theoretical and technical innovations of the 15 cm and 30 cm photoelectric-array projects won the 2014 First Prize for Scientific and Technological Progress at the provincial and ministerial level.

2.5 Establishment of the satellite cataloguing system (1989–2007)

At an 863 Program seminar in 1989, I gave a report on "satellite cataloguing." The relevant recommendations received the attention of leaders in the pertinent departments, and the leaders suggested that "since China did not at that time have space defense, we should immediately use existing conditions to carry out satellite cataloguing work."

(1) Near-Earth space-target identification and satellite-cataloguing research experiment

In 1990, we undertook the 863 project "Research Experiment on Near-Earth Space-Target Identification and Satellite Cataloguing." The main task was, with the orbits of most targets unknown, to capture a complete series of satellite targets (86 objects), determine their orbits, distinguish which were satellites and which were rockets, and match them with international numbers and identifications. In the past, the Academy' s human-made satellite observation system had managed at most only a dozen or so satellites; capturing and identifying so many targets was a severe challenge. We adopted three measures: system-wide promotion of the use of observation-machine prediction software; a rational division of labor, whereby one observing station or one prediction staff member was responsible for targets in one orbital plane; and mobilization of all system personnel to participate in satellite capture, with an incentive policy adopted. In 1992 the task was successfully completed, and this achievement won the 1993 Second Prize for Scientific and Technological Progress of the Chinese Academy of Sciences.

(2) Design of the cataloguing system and national standards

After 2000, Zhao Changyin led the team in taking the lead in formulating the national military standard *Methods for Cataloguing Space Targets*, which includes six parts: numbering methods, contents and formats of observation plans, contents and formats of tracking data, orbit determination methods, orbit contents and formats, and orbit prediction methods. According to this plan, the team developed computer software and promoted its use in relevant departments in China. It is currently the third operational space-target cataloguing system in the world after those of the United States and Russia. This software has used optical observation data from the Chinese Academy of Sciences' Space Object and Debris Monitoring System to carry out routine cataloguing of thousands of space targets, making an indispensable contribution to China' s space-target monitoring. This project won the second prize of the 2007 provincial- and ministerial-level Science and Technology Progress Award.

2.6 Conception of space-based observation

To meet cataloguing needs involving more targets and faster response, I was among the first in China to consider the orbital-theory and methodological difficulties faced by space-based detection. In the book *Space-Based Detection of Space Targets*, I systematically presented the basic principles and data-processing methods.[4] To realize full-coverage space-based observation of near-Earth space targets, Xiong Jianing, Wu Gongyou, and I proposed, in *Space-Based Fence for Near-Earth Target Detection*,[5] the concept of an along-track fence: on a Sun-synchronous orbit, N platforms are evenly distributed; each platform is equipped with two telescopes, one looking forward and one backward, with the telescopes pointing within the orbital plane, so that the telescope fields of view form a space-based fence. Simulation calculations show that an along-track fence can meet the requirements for full-coverage detection of near-Earth targets and timely discovery of new targets. Of course, this is only a concept; it is hoped that an along-track fence can be developed and built as soon as possible, so that China can promptly and comprehensively perceive the situation in near-Earth space.

2.7 Numerical computation of special functions in dynamical theory

In satellite dynamics, inclination functions and Hansen coefficients are the two most important and most commonly used classes of special functions involved in the expansion of the perturbing function and in perturbation-analysis computations. How to compute them efficiently and accurately is an issue of great significance and challenge. Although I have retired, I remain concerned with long-standing difficulties in fundamental theory.

From 2009 to 2013, Wang Hongbo and I systematically studied inclination functions. When computing high-order functions, the efficiency of traditional methods decreases rapidly, and errors accumulate quickly, even to the point of complete failure, thereby limiting the application accuracy of high-order gravitational-field models. For this reason, we improved and proposed six higher-order recurrence algorithms with high timeliness, precision preservation, and no singularities. While maintaining stable accuracy, efficiency was increased by several tens of times. We published all the code and a series of articles,[6–14] and published an English monograph.[15]

From 2012 to 2024, Zhang Mingjiang and I systematically studied Hansen coefficients. We derived several new recurrence formulas for Hansen coefficients; comparatively analyzed the computational efficiency and stability of direct computational methods for Hansen coefficients and their derivatives; presented a more efficient batch recurrence computation method for eccentricity functions; and preliminarily solved the problems of summation-limit selection in short-period terms of the Earth' s tesseral-harmonic perturbations for highly eccentric orbits. We published a series of articles[16–19] and Chinese and English monographs.[20–21]

3 Reflections on scientific research work

3.1 Space-object work and the development of aerospace

In disciplinary terms, space-object work belongs to satellite dynamics. It includes satellite observation, data processing, software programming, satellite cataloguing, precise orbit determination and prediction, and the development of observational instruments, all of which require a solid foundation. In China' s early years, the theory of artificial-satellite dynamics was relatively backward, and the first-stage theory was not completed until 1968. In the initial stage of human spaceflight, there were large errors in models of Earth' s gravitational field and upper-atmospheric density, and station-position errors were also large. At that time, research focused on Earth' s gravitational field; the United States studied many standard Earth models and established a reference Earth framework. At present, atmospheric models still have significant errors and require further study. Around 2000, Xiong Jianing and I proposed and implemented a short-term atmospheric-model determination method,[22] and independently established PMO2000, the first atmospheric model usable for satellite-orbit computation in China.[23] On this basis, Wang Hongbo and Xiong Jianing developed a short-term modeling method for atmospheric density that fuses spaceborne accelerometer inverse-derived density data with double-line cataloguing orbits, and constructed the PMO2014ST short-term dynamic model. At present, PMO2000 and PMO2014ST have been incorporated into the latest national standard, *Space Environment—Reference and Standard Atmosphere Models* (GB/Z 189-2026).

It is worth noting that, in addition to ground-based observation, increasing emphasis has in recent years been placed on space-based observation. Besides observation accuracy, there is now also the issue of the number of observed targets. The monitoring of massive amounts of space debris, as well as SpaceX' s low-orbit mega-constellation program, have caused the number of observed targets to exceed tens of thousands. How to improve cataloguing and prediction accuracy while ensuring the number of detections remains an issue for which many problems await solution. New problems continue to emerge; the work can never be finished, and doing it well is even less easy.

3.2 The Relationship Between Basic Research and National Missions: Driving the Discipline Through Missions

There are two kinds of artificial-satellite work: one is basic research, and the other is national missions. In the 1970s and 1980s, there was a saying in the Academy: artificial-satellite work should take missions as the main line and basic research as a supplement—that is, "missions drive the discipline." Perhaps this was correct; at the time, this was all that could be done, especially in an era when research funding was tight. Looking back on my scientific research career, from the "405 Mission" to satellite dynamic geodesy, from monitoring space debris to developing photoelectric arrays, every major achievement was obtained in the process of carrying out national missions. Missions put forward clear requirements and indicators, compelling us to solve difficult problems in basic theory and to overcome technical bottlenecks; in the process of completing missions, our theoretical level improved, our technical capabilities strengthened, our data accumulated, and the discipline consequently developed.

3.3 Ten Years to Sharpen a Sword

Because artificial-satellite work requires theoretical research, data processing, software programming, computational verification, and so on, a research effort with any degree of visibility generally requires about ten years. If equipment must be developed, it may take even longer. Research on satellite dynamic geodesy lasted from 1974 to 1985, taking 11 yr; the idea for the photoelectric array was proposed in 2002, and in 2014 it won a ministerial/provincial-level first prize for scientific and technological progress, taking 12 yr. These experiences all confirm the rule of "ten years to sharpen a sword." Young researchers must be mentally prepared for long-term struggle, be willing to sit on the cold bench, and not be anxious for quick success; the state and the Academy of Sciences should also provide young people with an environment and policies that allow them to devote themselves to tackling key problems.

3.4 Artificial-Satellite Work Requires Research Teams

The scientific demands of artificial-satellite work are broad; everyone needs to work together, and one person alone cannot accomplish the mission. The "405 Mission" brought together the strength of many units, including the Purple Mountain Observatory, the military, the Institute of Mathematics, and the Institute of Computing Technology; 14 stations participated in satellite dynamic geodesy; the development of the photoelectric array involved many units, including Nanjing Astronomical Instruments Co., Ltd., the Changchun Institute of Optics and Mechanics, Fuguang Company, and the National University of Defense Technology. It is precisely this kind of large-scale collaboration that enabled us to complete one difficult mission after another. The Academy of Sciences now proposes organized, institutionalized scientific research; in artificial-satellite work this is appropriate and should be encouraged.

4 Suggestions for Young Researchers

First, one must have the courage and perseverance to "cross the Yangtze River." In 1966, when I was young, I once swam across the Yangtze River; the distance of 8.8 km required extraordinary courage and perseverance. Scientific research is the same: one must not shrink back in the face of difficulties and setbacks, but must persist.

In 1993, China' s 15th recoverable satellite unexpectedly went out of control on reentry. We accepted the order at a moment of crisis and conducted emergency tracking. To cope with the difficulties of insufficient monitoring equipment, few observing opportunities, and drastic orbital changes, the team, in the half month before the satellite' s fall, set up 14 mobile observation stations, laying out a tracking network across thousands of li from Mohe to Shantou and from Qingdao to the Hami–Barkol border sentry post; the forecast-group office became a "wartime command post," dispatching stations day and night, issuing forecasts, processing data, and reporting to higher authorities; the observers overcame the severe cold north of the Great Wall in March to carry out all-night field observations. In the end, we successfully predicted the time and area of the fall, relieving the country of its concerns.

Second, one must build a solid foundation. Artificial-satellite work requires multidisciplinary knowledge in mathematics, astronomy, physics, computers, and other fields; without a firm foundation, it is difficult to be competent. My studies in the Department of Mathematical Astronomy at Nanjing University laid a solid foundation for my later work.

Third, one must be good at learning new things. From the earliest electronic computers to the X-2, the 717, and the 108B computer, from visual observation to photoelectric arrays, technology has been advancing continuously; only by learning continuously can one keep up with the times.

Fourth, one must value the team. However capable an individual may be, one cannot accomplish great things alone. One must learn to cooperate with others and bring the strength of the team into play.

Fifth, one must be indifferent to fame and profit. In our era, people emphasized contribution rather than seeking gain. Tong Fu, Di Xiaohua, and others at that time could not participate in the "405 Mission" because of so-called family-background issues, but they passed their methods along to us in careful detail; their contributions should not be forgotten. This spirit of being indifferent to fame and profit, willing to contribute, and attentive to inheritance is a precious wealth of our artificial-satellite system.

5 Conclusion

In the more than sixty years of my study and work, beginning with the three generations of people represented by Mr. Zhang Yuzhe, under the cultivation and encouragement of the Party and the state, and under the leadership of the Academy of Sciences, we completed many national missions according to the needs of the country. The artificial-satellite system of the Chinese Academy of Sciences grew step by step from nothing in the course of carrying out these missions. Now, we have many high-precision observing instruments; observing methods already encompass both target observation and space-domain observation; and we have developed from ground-based observation to space-based observation, striving to grasp the space situation in real time.

What is especially important is that we already have a young research team. They are carrying forward a kind of "artificial-satellite spirit" —patriotic dedication, unity in struggle, exceptional ability to endure hardship, and exceptional ability to fight. I believe they will

In the future, we will certainly be able to make even greater contributions to the nation.

Acknowledgments I thank the colleagues who have worked shoulder to shoulder with me over the past sixty years. I thank the Chinese Academy of Sciences, Purple Mountain Observatory, and the stations of the artificial satellite system for their support. I thank the Editorial Office of *Acta Astronomica Sinica* for inviting me to give a brief review of my lifelong scientific research experience. The relevant historical materials for this article were provided by Zhang Wei; Xiong Jianing, Wang Hongbo, and Zhang Mingjiang participated in the textual editing.

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Six Decades of Reaching for the Stars—the Journey of Researcher Wu Lian-da in Satellite Orbit Computation

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Abstract This paper reviews the author' s research journey in the theoretical study and engineering practice of orbit determination and prediction for Chinese artificial satellites since he joined the satellite observation system of the Chinese Academy of Sciences in 1964. Starting with the development of orbit determination and prediction schemes for the Dongfanghong-1 satellite, this paper summarizes major research undertakings, including satellite dynamic geodesy, space debris surveillance, and the development of photoelectric array systems, as well as fundamental theoretical achievements in satellite dynamics. It concludes with the research philosophy of "discipline development driven by major missions" and provides insightful suggestions for young researchers.

Key words artificial satellite orbits, satellite dynamics, space object monitoring, astronomical observation, research career

Note: Figure translations are in progress. See original paper for figures.