Granting the Seasons
Sources and Studies
in the History of Mathematics and
Physical Sciences

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Granting the Seasons:
The Chinese Astronomical Reform of 1280,
With a Study of its Many Dimensions
and a Translation of its Records
　授時曆叢考

Springer
Dedicated to
Professor Chen Meidong 陈美东
and my other colleagues, past and present,
at the
Research Institute for the History of Natural
Sciences,
Chinese Academy of Sciences
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Introduction

This is a translation and study of the Season-granting system (Shou-shih li 授時曆, 1280). It is arguably the most innovative, and certainly the most sophisticated and influential, of China’s many astronomical treatises. This inquiry looks at its many dimensions, not merely its computational techniques. The astronomical system that it contains was a method for generating annual almanacs. It was also an important component of the imperial charisma, a means of livelihood for officials and others, a bureaucratic project, an expenditure probably unequalled in the history of imperial Chinese astronomy, and a key tool for Mongol rule over a newly vanquished China. Understanding it will be indispensable for any history of astronomy that does not arbitrarily restrict itself to one civilization or another.

Granting the Seasons has several purposes. First, it is time that an important East Asian astronomical treatise be available in a Western language, and fitting that the first one fully translated be this one. The Season-granting system is a remarkable attempt to predict a wide range of important phenomena in the sky, using methods and assumptions that differ greatly from those of the European, Muslim, and Indian traditions. Unlike the last two, it developed without significant influence from the Greek tradition. On the other hand, the Season-granting system exerted great influence in East Asia.

The work of evaluating the strengths and weaknesses of Chinese predictive techniques has barely begun. The Evaluation that was included in the treatise is an important early contribution to this work. I have taken some additional approaches in notes to the Evaluation, but a systematic project would require a good many additional man-years on the parts of well-prepared scholars.

Second, given the technical complexity of this system and the social complexity of its creation and use, an introductory study can only begin to explain it. I have designed this book in a way that should facilitate solving more of the many problems of understanding. The astronomical terminology of my translation is not only in-
ternally consistent, but compatible with those of other Chinese systems. I have explained as clearly as present understanding permits what each step in the procedures is meant to accomplish. I have also pointed out where the gaps in our comprehension lie.

Third, because this system was the culmination of over a thousand uninterrupted years of mathematical astronomy in China, it is essential to understand what the norms of practice were with respect to such matters as computation, the recording of time and celestial locations, the use of instruments, the keeping of records and the social and political organization of astronomical work. Chapter 2 is an orientation on a wide range of such matters.

Finally, unlike previous studies of Western astronomical treatises, I have devoted equal effort—and almost equal space—to reconstituting the remarkable project that produced the reform, not only as a technical accomplishment but in its political, social, instrumental, intellectual, and other dimensions.

This book will also, I hope, prove itself useful to several kinds of reader. Its most obvious audience is people curious about an astronomical tradition that differs in many important ways from the other main traditions, those of Europe, the Muslim world, and India. Some will want to know about its techniques, and others about its technical institutions, thought, and practitioners. Other readers will want to understand an important but inadequately studied facet of Chinese culture, fundamental to imperial ritual and significant in daily life. Finally, there are astronomers who wonder about potentialities of their science that were not greatly developed in the West.

I have tried to make this book comprehensible to all those drawn to it. This has meant summarizing aspects of Mongol rulership in China with which specialists in society and politics are already familiar, and explaining technical usages that many astronomers already know. That is the price of writing a book that, although it strives for depth of explanation, is designed for anyone who wants to learn something from it, not mainly for specialists.
China in World Astronomy

All the astronomers of the ancient world studied the same sky, and used the same mathematical tools, to explore the same questions: Where will the celestial bodies be at a given time? When will their prominent phenomena—eclipses, changes in direction of planetary motion, and so on—take place? That is how many people who have read some astronomical history tend to put it; but that is too coarse a view. Each culture made its own sky. Each grouped the stars into its own constellations; each saw the sun, moon, and planets as moved by different movers or volitions. Ptolemy (circa A.D. 100–circa 175), the greatest computational astronomer of the Hellenistic world, explained that the planets move as they do because each was a living god, and that was its will—a view that Chinese would have considered nonsensical. The Greeks, on the other hand, would have laughed at the Chinese habit of seeing governmental bureaus in the heavens.

Out of the many techniques that mathematics offers, each astronomical tradition used a different subset, variously preferring numerical or geometric methods. Some, particularly those in the temperate zone, organized coordinate systems around the equatorial or ecliptic pole. Others, usually close to the equator, mainly measured events on the horizon, or with respect to celestial objects.

Once I had looked closely for a while at more than one tradition, I realized that any one of them used too narrow a range of possibilities to give an adequate picture of what the whole spectrum was. Only sheer parochialism has led Western historians to offer their histories of European thought and practice as “the history of astronomy.”

It also became clear that narrow technical studies, as more and more of them appeared, would not spontaneously generate a picture large enough to be adequate. The charter myth of the research university, when the Prussians invented it in the early nineteenth century, was that, if specialists engaged in rigorous, tightly focused analytic research, less blinkered scholars would, from these technical results, build an overview. Others, atop their syntheses, would
raise still more overarching levels of understanding. Eventually, out of this would come not only truly reliable, seamlessly integrated knowledge but, on its foundation, wisdom. This was a mirage. Except in a few areas of physical science and mathematics, that well-shaped tower of learning has failed to appear. Modern sub-sub-specialties, despite their bounteous harvest of fact, offer precious little connection to wisdom.

In no area is that more obvious than in the history of astronomy. Consider the longest uninterrupted, well-documented tradition in world history, that of China. As the list of sources cited in this book reminds us, a mass of primary documents has survived, partly because they were routinely printed centuries before Gutenberg. Monographs in Chinese, Japanese, and European languages based on their study have piled up to form a figurative mountain. Nevertheless, there is no usable overview of the tradition in any language but Chinese, and—until this one—no translation of any major source into any Western language. What we have learned over the past generation about the character of Chinese astronomy, its evolution, and its particularities lies outside the ken of the most learned historians of Europe. The situation is even worse for Islamic and Indian astronomy, for their sources are much less accessible. For that matter, only in the last generation have colleagues translated with high accuracy a handful of the most influential early European classics out of the Greek and Latin. There is still no comprehensive and intellectually substantial history of European astronomy as a whole.

This book is a modest effort to make a historically consequential non-European classic available in translation, accompanied as it must be by an explanation of how and why the astronomers did what they did. Any attempt, even a tentative one, to do that for one of the more sophisticated Chinese systems is bound to take up a good many pages. I merely hope I have made it easier for the tradition of China to take part in a dialogue with those of other cultures.

At the same time, I aim to portray the technical methods of astronomy as part of a continuum that enfolds every dimension of
human activity, from algorithms to political maneuvering—what some scholars call a cultural manifold. It is easy enough to recognize when we look about us today that first-rate science is a result not only of individual technical talent and effort, but of the ability to adopt certain institutional values, to establish productive relations with colleagues, to use the rhetoric of technical writing persuasively, and to attract money and other resources. Historians, when they write about the technical past, often ignore these matters, or set them to one side as mere context. Scientists of earlier times, like those today, knew that they were essential—at least those scientists who turned out to be productive.

Most readers will find it odd that the Season-granting system, which historians generally consider the high point of Chinese mathematical astronomy, came into being to inaugurate a regime that emphatically did not share China’s culture, that had subdued the country after devastating it for generations. Its emperor, known to his own people as Great Khan, was by Chinese standards illiterate. How occupation politics and astronomical reform came to be coupled is one of the large questions I seek to shed light on. To what extent the Muslim and Chinese astronomers who served the same emperor influenced each other, and what set limits on the interchange, is another.

**Contents of this Book**

That is why this book begins by looking (to avoid even greater length) at only five representative dimensions of the manifold that created the Season-granting system: the cultural, political, bureaucratic, personal, and technical. The first chapter explains why the unlikely coincidence of astronomical reform and occupation politics led to new technical heights. It introduces many of the themes that later chapters explore in detail.

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The next five chapters provide the reader with the background needed to understand the translation in its several dimensions.

Chapter 2, a historical orientation, outlines aspects of the Chinese astronomical tradition pertinent to this study. That is all it does; a general history of the tradition would be out of place here. The Season-granting system, in the thirteenth century, was not the endpoint of this tradition, but those that succeeded it were either adaptations of it, or—from the Manchu conquest of 1644 on—hybrids of European astronomy with it. The chapter describes the computational systems used to generate Chinese ephemerides; the key problems as the tradition defined them; conventions for recording positions in space and time; the mathematical techniques on which astronomers relied; and the character of astronomical writings. In addition to describing these aspects, it gives a rough idea of how they changed and evolved.

Chapter 3 is a brief overview of the reform project, how it came about and what happened. Chapter 4 looks more closely than chapter 1 at the people who planned it and carried it out, what brought them together, why they were chosen, and what sort of staff they gathered. Chapter 5 reconstructs the observatory and its instruments. In order to make the historical role of the instruments clear, I also look into their predecessors over the preceding two centuries, as well as a few of the fourteenth century and later that throw light on those of circa 1280. I also take up the vexed questions of the extent to which the Season-granting system responded to foreign influence, and why.

Chapter 6 takes up the form in which the system was published, its relation to other astronomical treatises, and how it was transmitted before its publication. Because there were many studies of it in China, Japan, and Korea from the time of its publication on, I have tried to give a rough idea of the most important research in East Asia and the occident over the centuries to the present.

The translation follows. It attempts to be both literal and faithful, characteristics that are often at war. The treatise is also rich in tables. I reproduce them, replace lost ones that survive in later
sources, and add new ones that aid in understanding and evaluating the techniques. There are also a few places where discursive text is so stereotyped and repetitive that I have put it—more readably, I believe—in tabular form.

Since the treatise is written concisely in technical language (sometimes with interlinear notes of its own), I have added a commentary that, for each step, clarifies the procedures being explained, and explains how they articulate with those that precede and follow.

I have added in appendices translations of two important contemporary documents, the description of instruments in the “Treatise on Astrology” of the Yuan dynasty’s official history, and a biography of the renowned astronomer Kuo Shou-ching 郭守敬 written shortly after his death. The book ends with glossaries of Chinese technical terms and their English translations, designed as aids to anyone studying early astronomical documents.

It is easy to think of additions that would have enriched this book. One is a set of worked examples for the procedures in the Canon. Another is a spreadsheet that would have allowed readers to work their own examples. The first would have made this study a great deal longer, and it is long enough already. I do provide a few examples where they are needed to clarify the text; see, for instance, the commentaries to the Canon, 3.8 and 3.9. I experimented with a spreadsheet that necessarily would have been distributed separately, but it turned out not to be practicable. Even one that included only the first three sections of the Canon, to predict positions of the apparent sun, would have involved reiterated input from the user, so much that only one already quite familiar with Yuan astronomical practices could have used it successfully.

**Principles of the Translation**

The goal of faithfully transmuting thought from one language to another is never quite attainable, but nonetheless irresistible in the pursuit. Let me describe my approach.
A great deal of translation from classical Chinese is literal, preoccupied with accounting for every word in the original. This often leads to an English version that reads grotesquely. That would be defensible if the original were grotesque, but otherwise it is anything but faithful. Another kind of translation focuses on finding in English an equivalent in some sense of what the original meant to say. The problem is that what one translator considers equivalent someone else may well see as a failure to get the point. Such a translation often sacrifices too much of the source’s language.

Like many colleagues, I simply try to balance translation that is as close as possible to the content and tone of the original—what the author would say if he were writing in modern English—with respect for its diction, structure, and rhetoric. There is no ready-made methodological formula. Translation is an art, not a science. One must often compromise when there is no happy medium—or at least none that one can find. I leave it to the reader to judge in each case whether a loose paraphrase of ideas or a word-by-word trot would have been more serviceable.

Since I am trying to reveal the document’s original ideas and habits of thought, I have avoided translating directly into modern astronomical terminology. Still, readers encountering those ideas and methods for the first time will need some link to what they already know. Therefore, my commentary—unlike my translation—often explains concepts and approaches in minimally technical modern language. For the same reason, I begin each section of the Canon with a concise list, in accessible astronomical language, of what its steps aim to accomplish.

I also avoid translation into equations. I do not believe there is an ideal language of quantitative astronomy, independent of cultural accident, into which one can transpose ancient assertions to fully reveal their meaning. Such transposition imposes a complex of logic and value that the original was not pursuing, and thus does as much to hide the meaning as to reveal it. Equations may give an impression of generality that hides the limited scope of the verbal originals, or may imply limits that were not originally there.
One might defend translation into equations on the ground that if ancient Chinese had had modern algebra, or even computer programming languages, they would have used them. They were undeniably bright enough to have done so. But it is obviously not that simple. If they felt frustrated by having to write in classical Chinese, they were articulate enough to have complained. They did not. One does not have to read many of their scientific texts to realize that the authors were able to write in exactly as precise, as relaxed, or as ambiguous a way as each wanted. It is an elementary fallacy of reasoning to claim that, given the opportunity, they would have chosen to be modern astronomers.²

On the other hand, the readership for this book is likely to be more at home in mathematics than in the artful use of ambiguity. I therefore do not reject any means available to clarify every part of the treatise. That has led me from time to time, when commenting on passages about mathematical relationships, to use equations when they are the only way I can say clearly what the text is about.

There is finally the question of whether to translate. Some readers familiar with writing on Chinese history will be surprised that I transpose into English the names of reign periods (nien-hao 年號). That is hardly standard practice. Nevertheless, a date given as “year 4 of the Ta-yeh era (Ta-yeh ssu nien 大業四年)” conveys a great deal less information than when fully translated “year 4 of the Great Patrimony era.” Translation makes it clear that this reign title—like all of them—is a political statement, a motto much like the American “New Deal.” Imperial ritualists (who were, among other things, ideologues) composed names of eras that any contemporary reader would understand, motos meant to encourage confidence in the government. In this case, the great patrimony is unmistakably the state; it asserts that the ruler takes seriously his responsibility as its inheritor. There are, of course, many contexts in which a date does

² For a final disproof of the frequent assertion that the Chinese written language was inherently unfitted for scientific writing, see Robinson 2004. The classical language translated in Granting the Seasons was no more limited in its expressivity than Ptolemy’s Greek or Copernicus’ Latin.
nothing more than record a date, in which case I translate *Ta-yeh ssu nien* “A.D. 608.” Since the new year may fall between 19 January and 18 February, the overlap is not exact.

There is another reason never noticed in past debates on whether to translate names of reign periods.² Not only were reign periods supposed to transmit meaning, but so were the titles of astronomical systems. In fact one was often named for the other, as a glance at section 11 of the Evaluation, Englished below, makes clear. To translate neither is a good deal less trouble, but it deprives the reader of important information that every Chinese reader had.

**Conventions**

- The rich studies of scholars in China and Japan have provided much evaluative insight. Because their work is inadequately known outside East Asia, whenever possible I cite them, and refer to their critical studies of accuracy, precision, etc. Some readers may think it odd that I often cite computations from others instead of my own. I prefer to give credit to colleagues who have earned it.

- As for computations in this book that use the thirteenth-century procedures, many are by Takebe Katahiro (1664–1739), a great Japanese astronomer who worked within the Season-granting tradition as it was passed down in Japan. His corrections of the Evaluation are most valuable, because he was still using the complicated rounding-off and other computational habits of his Yuan predecessors. His calculations based on the Canon, I believe, are more likely to represent the result the reformers were striving for than my own could do. On the other hand, I have checked his calculations and have corrected a few. A full reconstruction of early computational practice remains badly needed; until colleagues have

³ The classical debate on the topic is Schafer 1952 and 1965 vs. Wright 1958. The historian Wright’s position is that it is extremely difficult to find out what reign titles actually mean; the philologist Schafer’s is that the research is worth while. I agree with both, but the difficulty that Wright pleads is characteristic of all classical Chinese.
done it, all results must remain tentative. Computations for which I do not cite a source are my own.

- Two systems for transliterating Chinese are in common use. Neither has much to be said for it from a linguistic point of view, although Sinologists are often vehement about their personal choice, and scold those who choose differently. I use the Wade-Giles system because almost all previous literature on the history of Chinese astronomy employs it. I make one exception. In order to make clear to non-Sinologist readers which are ancient place names and which modern, I write the former in Wade-Giles (which uses hyphens in multisyllabic words) and the latter in the Pinyin system (which runs the syllables together). Thus the Ming dynasty’s northern capital was Pei-ching, which on the whole coincides with present Beijing.

- There are also two systems for writing Chinese characters, the simplified form (chien-t’i tzu 简体字) used in the People’s Republic, and the traditional one (fan-t’i tzu 繁體字) that was the norm before 1950 and is still used outside the Chinese mainland. The former, when quoting ancient sources, is often problematic, since it sometimes collapses two or more traditional characters into one (e.g., it writes 里, 裏, and 裡 as 里). I simply reproduce the form that each source uses.

- I have striven to translate technical terms consistently, based on my study of all the surviving astronomical treatises and of astronomical problems in mathematical books. My primary sources were writing for educated readers of their time. Any faithful translation is bound to reflect what the nomenclature meant then, not earlier or later.

- In the translation there are two commentaries, one by the original authors or editors (printed in smaller type in the Chinese text) and one by myself. The first appears in the same type face but slightly smaller, and is set in angle brackets
  
  <like this.>

  The second appears in a different type face, also slightly smaller than the text, and begins and ends in square brackets

  [like this.]
In order to facilitate cross-reference and provide a tool that will be useful to other students of Chinese astronomy, I have numbered the sections and subsections of the Evaluation and the subsections of the Canon; its sections are already numbered. A reference to the Canon, subsection 4.0, denotes the introductory section of section 4, “Pacing the Travel of the Moon,” which lists the constants used in the lunar theory. In the introductory list of constants for each section of the Canon, each number includes a “C” and takes the general form “4.C1.”

For intermediate and final results of each computational step, the numbers take the form “4.6.1” in step 4.6, and so on. When a later step uses that result, I give the same number so that it is easy to trace the function of a result throughout the Canon. When the step gives no number for an earlier result, it comes from the previous step. When the result is clearly a technical term, I capitalize its translation to make that clear. It is impossible to rigorously distinguish technical terms from simple results of calculation; I have tried to make the numbering as useful as possible.

An excerpt from step 7.2 of the planetary theory will make this notation clear: “In each case set up the Intermediate Accumulation, add the Argument Interval Constant (7.C9) and Posterior Conjunction Parts for the desired [year], and cast out complete Argument Rates (7.C6). … The result is $tu$ and parts of the Argument of Mean Conjunction (7.2.1) for the given star.” Since Intermediate Accumulation and Posterior Conjunction Parts are not numbered, they are the output of the previous step, 7.1. They are numbered there. The Argument Interval Constant (7.C9) and Argument Rate (7.C6) are constants listed at the beginning of section 7. “Argument of Mean Conjunction” (7.2.1) is an intermediate term, the first outcome of step 7.2. The glossaries at the end of this book list all the numbered quantities and variables, and give their Chinese equivalents.

In addition to the commentaries, I explicate the texts of the Canon and Evaluation with diagrams and illustrations. The diagrams are designed to be as clear as possible for readers, whether technically adept or not. For that reason, they are seldom to scale.
For old-style Chinese books, I cite chüan 卷 and page numbers in the form n: nn.

For the sake of readability, the translations in this book reduce all linear units to ch’ih and abbreviate that unit as “c.” In measurements, 11.5c means 11½ ch’ih (or 11 ch’ih 尺 5 ts’un 寸). An astronomical ch’ih was equivalent to roughly 25cm (see p. 67).

For the tu 度 or Chinese degree (see p. 89), I either write “tu” or use a superscript “t” after the integral part of a number, for instance, 365½. In discussions, I use “degree” only for the European degree. In the translation, however, for the sake of simplicity, I translate tu “Degree” in the capitalized names of subsections, constants and variables such as “Accumulated Degrees after the Standard Crossing.”

In dates, 272–79 means “from 272 to 279,” and 272/79 means “at some unknown point between 272 and 279.” I ordinarily translate sexagenary dates and years of reign eras into modern notation—e.g., “sexagenary year 16 of the Perfectly Great era (chih-yuan chi-mao 至元己卯)” becomes “1279.” I translate them literally only to help the reader comprehend the text.

The modern distinction between true and apparent motions was meaningless in China. Copernicus made a strong case that the apparent motions (those visible from the earth) are not the true ones as seen from the centers of rotation of the planets (which are not the sun, but are near it). Twentieth-century astronomers have accepted the relativity of all cosmological systems, but the distinction lingers on in some textbooks merely as a historical souvenir. I use “apparent” throughout this book when discussing motions from the modern point of view.

In references to sources, “ch.” refers to the Chinese unit chiüan 卷. Chiüan originally referred to rolls of silk used for manuscripts, but for the last two millennia the word has marked subdivisions of a text, long or short, rather like a European chapter. A reference to pages in a given chiüan occurs in the conventional form 39: 42–54, i.e., chiüan 39, pages 42–54. In a few cases where it is not feasible to write “ch.,” I refer to chiüan in ancient Chinese books as “chapter.”
• In the translations of the Season-granting treatise, I note at the end of each subsection, in curly brackets, the pages it occupies, e.g., {1121–22}. In Appendix B, the biography of Kuo Shou-ching, these numbers mark the beginning of each original page.

• Books written before the twentieth century give ages in *sui*. A person is one *sui* at birth, and adds a *sui* at every new year. An age stated in *sui* is thus greater than in occidental years by one, or sometimes two. Since precision is seldom possible—we often have a year of birth, but seldom the actual date—in translation I normally subtract one from *sui* to give years. Anyone more interested in *sui* need only add one.

• In references to astronomical systems, “(#n)” refers to the number in table 2.1, which provides systematic information about each.

• Translations of book and article titles are my own except that those enclosed in quotation marks are those of the authors.

• For translation of official titles, I rely on the standard reference work, Hucker 1985 and, for titles he does not include, Farquhar 1990. The few not in either source are my own.
1 Astronomical Reform and Occupation Politics

This chapter has two aims: to furnish a bird’s-eye view of the book’s historical argument, and to explain its method. Let me deal with the method first.

This book is an experiment in doing away with the border between foreground and context, and studying a transition in astronomy as what some scholars call a cultural manifold. This term refers to all the dimensions of a given historical phenomenon or process. A cultural manifold includes not only the technical, cosmological, social, institutional, and other aspects of a complex set of events, but also the interactions that make all of these aspects add up to a single whole.

This approach implies that context is not an autonomous setting that may or may not be connected to inquiry. Technical work and its circumstances are parts of one thing. That one thing includes how people make a living, their relation to structures of authority, what bonds connect those who do the same work, how they communicate what they understand, what concepts and assumptions they use, and how they use them. I do not think of social factors determining thought, nor of ideas changing society. The point is to comprehend the interactions within a manifold as doers and thinkers respond to, and at the same time influence, institutions and prevalent values.

The concept of a cultural manifold is an aid to better understanding the technical high point of mathematical astronomy in China, the Season-granting system (Shou-shih li 授時曆) of 1280. That astronomical system was named for the classical idea that, because the emperor mediated between the celestial order and the state, one of his most basic rituals, at the new year, was to bestow a correct calendar on his people. Thus he granted them the seasons, and furthered the harmony between the two realms.
A large portion of the recent scholarship on Chinese astronomy has concentrated on explaining its computational methods. Such explication is essential, and this book is devoted to it among other things; but if done alone it sheds an inadequate light on astronomy as an enterprise on which people spend their lives. We can understand why this system’s sophisticated techniques evolved when they did, as they did, only when we are as attentive to its political and bureaucratic circumstances as to those of persons and methods.

Astronomers in China compiled about two hundred systems for computing ephemerides between 104 B.C. and 1911, and sovereign governments officially adopted about fifty of them for short or long periods. The ephemeris that emperors granted to their people at the new year was not a calendar in the modern sense. European calendars have had nothing to do with the sky for more than 400 years. Rather than predicting celestial phenomena, they simply count off conventional cycles.

The Chinese calendar was an ephemeris, part of an almanac that combined it with extensive divinations of propitious days to do one thing or another. The ephemeris predicted the year’s celestial events, including the winter solstice that determined the beginning of the year, the lunar conjunction that began each month, and eclipses and other phenomena of the planets such as their conjunctions or their passage through certain parts of the sky. By A.D. 100, astronomers were—mostly—getting the new year and the beginnings of months right, according to their own definitions. Still, predicting when an eclipse could be seen from a given place remained difficult in a tradition that preferred numerical to geometric methods. On top of that, a system that at first gave highly satisfactory predictions would, as time passed, lose accuracy due to minor sources of error adding up. Frequent astronomical reforms created new computational systems for generating annual ephemerides.4

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4 Historians who mechanically translate 里 “calendar” have caused a great deal of confusion. I call the computational treatises “astronomical systems,” and reserve “calendars” for the calendrical part of almanacs that astronomers used these systems to compute. I use “astronomical reform”
Every system included a canon: a set of step-by-step instructions, worked out so that a minor functionary with limited mathematical skills could calculate the annual ephemeris. When a step was mathematically complicated, all he had to do was look up the answer in a table that the canon provided.

The systems that survive are the ones whose treatises the official histories incorporate. The Season-Granting system, in addition to its sophistication, is remarkable for its documentation. It includes an evaluation that is just as long as the canon. The evaluation sets out in detail how astronomers used a remarkable archive of observations recorded over more than a thousand years to test the new astronomical system, proving that it would be more reliable than its predecessors. Scholars such as Ch’en Mei-tung 陳美東 and Yamada Keiji 山田慶児 have already used the evaluation to reconstruct the history of the reform.5

Drawing on the original documents and modern studies, I will examine five dimensions of the project—the cultural, the political, the bureaucratic, the personal, and the technical—and ask why they turn out to be complementary. These are only examples of pertinent dimensions, as my passing references to economic and intellectual matters indicate.

**Cultural**

It would be difficult to imagine a people in the first half of the thirteenth century more unlike the Chinese than the Mongols were. Even Europeans, to the extent that Chinese knew about them, seemed no more alien. It was not just that Mongols were nomadic and lived by raising animals. In fact they lived many kinds of lives, and the migratory herders were only the majority. Mongols were tribal, originally with no overarching government. Large political

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forms came into being as individuals assembled federations to extort wealth from agrarian societies such as China. Exaction and division of spoils was the key to power that extended beyond one’s tribe. The way most Mongols lived made them highly adaptable, always ready to move, and used to fighting. Succession to tribal leadership regularly involved violence; building wealth involved conquest or—more often—the credible threat of it; and everyone took part in internal and external war.

As the Mongols moved out of their heartland to conquer a great swath of the world, they learned to fashion a new “culture created for and bounded by the state,” no longer ethnic but using the skills of many peoples. Originally their only specialists were “shamans, bards, and perhaps metalsmiths.” Its elite learned to need many advanced skills, from those of administration to those of cosmopolitan cooking. The Mongol rulers thought of talented people as a kind of booty, to be shared. They often sent experts across their domains as gifts.

For Mongols, technical skill implied spiritual force. As rulers, they strove “to mobilize and monopolize the spiritual forces of the realm” embodied in the natural world, ancestors, ritual specialists, artisans, and scholars, as well as priests and monks of every faith. They had long used divination intensively; now they could call on prognosticators from half of Eurasia and compare their findings. Because in China the same people tended to be experts in divination, astronomy, and astrology—which Mongols lumped together as “yin-yang”—the rulers particularly valued these elaborate traditions that had always served imperial courts. They saw them not as competing with their own old methods, but complementing them.

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6 This section largely draws on the penetrating analysis of Thomas Allsen (2001), especially pp. 198–211, from which the quotations come. As Christopher Beckwith has noted in comments on this manuscript, Chinese farmers did not necessarily experience Mongol exactions differently from taxation by a native government.

7 I suppose that the Mongols’ use of “yin-yang” as a single type of skilled practitioner was part of learning to think about sophisticated occupational categories.
In fact, “Muslim astronomers came to China because the Mongols wanted second opinions on the reading of heavenly signs and portents, not because they or their Chinese counterparts wanted scientific exchange.”

When we study the uses of divination, it becomes obvious that the point was not which kind always came true. Competing forecasts could not dictate decisions to the Great Khan, but provided a diverse set of options to discuss, and a ritual for both broadening and focusing discussion. One might indeed say that prognosticators “divined the intentions of their masters, not future events.” In the final analysis, the routine use of divination in the rituals of court and military campaign legitimated policy, added to the cosmic authority that backed the decisions of policymakers, and built morale.

**Political**

Chinggis Khan (r. 1206–27) launched the first Mongol empire. Some among the generation of his grandsons created hybrids of their traditional culture and that of the peoples they ruled within what became five empires. As part of that cyclonic conquest along the breadth of Eurasia, the Mongols vanquished the Chin regime in North China in 1234, and the Sung empire in the west and south by 1276.\(^8\)

The new overlords of North China were poorly prepared to govern an agricultural and urban population. They saw their new subjects largely as providers of manpower and resources for further conquests. They did not see the point of farming, and turned vast areas into pasture land before their advisors convinced them that Chinese society could not survive without agriculture. Since the Mongol leaders were not used to reading and writing, they put together an administration from surrendered Uighurs, Jurchens, Khi-

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\(^8\) I will examine these circumstances more closely in chapter 3. The most judicious account of the Mongol world conquest is that of Fletcher 1986; see also Thomas Allsen in Franke & Twitchett 1994, 321–413, and Barfield 1989. For a map of the Mongol empires at Khubilai’s death in 1294, see Rossabi 1988, 111.
Granting the Seasons

tan, Chinese, and others. It extracted wealth at high human cost. This new model of government as extortion terrified the Southern Sung Chinese, and made a negotiated surrender unthinkable.

It was Khubilai (Hu-pi-lieh, 忽必烈, (born 1215, reigned as Grand Forbear [T’ai-tsung 太宗], 1260–94), Chinggis’ grandson, who came to understand Chinese culture and the benefits it offered its rulers. Although he could not read Chinese, and probably could not even speak much of it, his interest in the Chinese way of life attracted to him literati who nurtured it. As a young man, he gathered around him not only conventional scholars but members of Buddhist and Taoist movements. The example that concerns us is Liu Ping-chung 劉秉忠 (1216–74), who as a Ch’an monk joined Khubilai’s entourage early and became his main political advisor. He proposed, and his Mongol patron accepted, basic Chinese structures of government.9

Liu was more than a persuasive courtier. He was celebrated as a philosopher, classicist, diviner, mathematician, astronomer, poet, calligrapher, and painter. He became the only Han Chinese in all of the Yuan period to serve as one of the Three Preceptors, the state’s highest dignitaries. Liu was among the many Chinese literati whom Khubilai especially esteemed because of their skill at “yin-yang.” Educated Chinese who learned astronomy usually knew astrology and divination as well.10

Khubilai began campaigning against the southern Sung shortly after 1250. His Chinese advisors convinced him that victory could be quicker, less bloody, and less ruinous if he installed in the north a style of government that southerners could understand and eventually accept. He and they invented a style of just that kind. In 1276,

9 On Khubilai’s literacy, see Franke 1953 and Yoshikawa 1968–70. For the lives of Liu and others discussed below, see chapter 4.
10 In this respect Khubilai was not atypical of the early Mongol rulers; Endicott-West 1999. Historians have tended to think of divination among the Chinese as a preoccupation of only the lower classes, but that was never true. See, for instance, re the Sung period, Liao Hsien-huei 2005 and Liu Hsiang-kuang 劉祥光 2005.

I use “Han” in this book not to refer exclusively to China’s ethnic majority, but to distinguish the native population of China proper from the Mongols and their dependents from the Chinese periphery.
when the Mongols were pressing toward the Sung capital, the empress dowager actually surrendered the imperial seals of authority. The dynasty dragged on for three years longer only because refugee loyalists crowned two more baby emperors.

As early as 1251, Liu Ping-chung suggested an astronomical reform, as a way Chinese would recognize of asserting legitimate imperial authority. In 1273, he presented a concrete proposal, putting himself in charge, but nothing came of it and he died the next year. In 1276, Khubilai, certain that all of China would soon be in his hands, gave the order. Ritually marking the unification of China was an important matter, and a new system to generate the ephemeris was symbolically indispensable. Liu intended it to be more than a standard symbol of dynastic change. He wanted to take a step forward in technical practice as well. The Chin and then the Mongols had used the Revised Great Enlightenment system (Ch’ung-hsiu Ta-ming li 重修大明曆) of 1180 for a century. Whoever was in charge of pre-imperial Yuan astronomy in 1215 obviously chose this source for convenience, not because of its technical merits. By the late thirteenth century, it was showing its age in the many erroneous predictions it generated.

This was only one of a series of moves in the direction of imperial dominion. Khubilai had already taken a Chinese-style reign title (nien-hao 年號) in 1260, when he became Great Khan. In 1270 he had adopted the dynastic title Yuan 元, meaning “great,” an outcome of Liu’s studies in the Book of Changes. Liu then designed for him a new capital along classical lines, a bureaucracy, and a set of state rituals.

Another characteristic of Mongol politics is very much to the point. Mongols enjoyed the diversity of their trans-Asian order. Unlike Chinese scholar-officials, they did not think of other peoples as barbarians, or expect others to adopt their own culture. They drew avidly on the strengths of the many peoples they had brought under their sway. As Eugene Anderson and Paul Buell have recently pointed out, even the imperial palace’s menus drew on the