his correspondents could only have imagined his character from his letters, and we still have to do the same today: in later life, Denning was a recluse who hardly ever met anybody. Beech gives us a detailed study of his astronomical work, with a great deal of fascinating contextual detail, and a very good outline of what is known of his private life. Concerning as it does one of history's greatest visual observers, I am sure that this reasonably priced biography will be found to be interesting and absorbing for many readers. — Richard McKim.

Reference

(1) J. P. M. Prentice, *JBAA*, **43**, 376, 1933; and **46**, 329, 1936.

A City on Mars: Can We Settle Space, Should We Settle Space, and Have We Really Thought This Through? by Kelly and Zach Weinersmith (Particular Books), 2023. Pp. 448, 24 × 16 cm. Price £25 (hardbound; ISBN 978 0 241 45493 0).

Perhaps because my parents were working for NASA at the time (my father indirectly at Chrysler, doing static testing of Saturn rockets, and my mother, who knew Wernher von Braun well, directly), as a child I developed an interest in space flight. We moved temporarily from Huntsville to Cape Canaveral for a few months around the end of 1968 and used to watch launches from the beach. When I was about 14, I started reading old-school pro-technology optimistic science fiction (initially because I had asked my father to bring me some books by Asimov — I was a fan of his non-fiction books — from the library and fiction books (ordered by author) were easier to find than non-fiction books (ordered by topic)). Despite exceptions such as Asimov's 'Ad Astra', which deals with public opposition to space flight, the general feeling was that the colonization of space would happen more or less naturally, and not that far in the future. However, it wasn't long before Apollo missions were no longer televised live, and the programme was cut short because the USA had won the space race. (Of course it was mainly about politics, and the first scientist on the Moon — geologist Harrison Schmitt — was the last person to set foot on it.) But that was seen to be a temporary setback due to distractions such as the war in Vietnam and the false dichotomy that other important issues, such as environmentalism, had to be addressed to the detriment of space flight. Though it was clear to me even then that science is better served by means not involving putting people into space (recalling Carl Sagan's description of the cost of space probes as "a penny a world for each person on Earth"), the conquest of space still seemed inevitable for other reasons, and a natural extension of the exploration and subsequent colonization of the Earth (whether by Europeans in the Age of Exploration or thousands of years earlier in various out-of-Africa migrations).

My interests then shifted. (My interest in astronomy didn't come from space flight, but rather grew out of a general interest in science, sparked initially by palaeontology. The fact that Asimov — although a biochemist by training — wrote much about astronomy was an important factor.) I still considered the general vision of the future more or less inevitable, but it was no longer clear when it would happen. More recently, things have changed, due not just to billionaire space geeks such as Elon Musk, Richard Branson, and Jeff Bezos actually doing something, but also to things such as physics Nobel laureate Gerard 't Hooft being an ambassador for Mars One[1] (an idea to send people on a one-way trip to Mars, financed *via* a proposed reality-TV show). It still seemed inevitable, but now on a much shorter time-scale, probably with

permanent settlements on the Moon and Mars within my lifetime. However, I had become much less enthusiastic, due to the fear that human colonization of the Solar System would export the various problems we have on Earth, perhaps even magnifying them to some extent. (Consider the fact that former colonies of European nations are still strongly influenced by the culture of the mother countries hundreds of years ago, and there would be more contact — at least electronically, which these days is the primary route for the transmission of culture — between Earth and settlements on the Moon or Mars than there was between those colonies and their mother countries.) So it is something to be concerned with, even though, as with other causes, most individuals can do only a small amount.

Enter *A City on Mars*. The title sounds like something out of 1950s pulp fiction. The subtitle sounds much more pessimistic. I was drawn to the book because one of the authors is responsible for the SMBC web comic[2]*, which deals mainly with topics in physics, computer science, philosophy, and so on, and is obviously well informed, though not everyone will get all of the jokes. Most who believe that the conquest of space is possible and good tend to ignore potential problems, assuming that they will get solved along the way; most who are sceptical about either aspect haven't seen a reason to consider the details. What is needed is a balanced assessment and, in my view, that is what this book provides. Though written in an easy-going, humorous style, accompanied by a few comic-style black-and-white drawings, a huge amount of research has gone into this book, testified to not only by the approximately six hundred entries in the explicitly titled 'Partial Bibliography' (twenty pages of print substantially smaller than most small print) but also by the authors' collection of "twenty-seven shelves of books and papers on space settlement and related subjects." Also significant is that they didn't start out being sceptical and pessimistic: "We are space geeks. We love rocket launches.... We love visionary plans for a glorious future.... The data made us do it."

After a long Introduction about space myths, there follow twenty chapters collected into parts of two to four chapters each, the first five parts addressing biological and medical issues, possible habitats (only the Moon, Mars, and "giant rotating space wheels" are considered realistic enough to examine), artificial biospheres, space law, various scenarios (perhaps) allowed by those laws, and a final part looking at space society, expansion, and existential risk. Some readers might be surprised at just how inhospitable the Moon and Mars would be to settlers; it seems that most science-fiction space helmets are fitted with rose-tinted glasses. There is a large literature on the first three aspects, mostly optimistic and some of which I've encountered before. The last three are arguably more important: the first three might well have technical solutions (bottom line in many cases: we just don't know yet), but the last three involve politics, law, and sociology, and no quick solutions appear possible even if there were agreement with regard to the goals. As with regard to other topics as well, the easy-going narrative is backed up with copious references to the technical literature. (There are almost nine pages in very small print of end notes — in addition to the bibliography — with the disclaimer that they "contain only citations associated with quotes presented in the text and manuscripts we refer to directly".)

*Despite being a geek or nerd in some sense, I've never been interested in traditional comic books of any sort. I've also never played Dungeons and Dragons and didn't start programming until I was twenty-six.

Space law is complicated; no nation (nor person, nor any other entity) is allowed to claim anything not on Earth, though exploitation is allowed, which in some cases could result in *de facto* ownership. The authors make a good case that space law, despite its shortcomings, is still relevant, and that it is both possible and probable that it would be enforced.* Although the Outer Space Treaty essentially declares all extraterrestrial property to be commons, the stricter Moon Agreement didn't make it off the ground, so to speak. Cynics will, correctly, say that the self-interest of the spacefaring nations was the reason. On the other hand, despite self-interest, Antarctica and ocean beds are essentially treated as commons, and could be a model for extraterrestrial property. I found the ten chapters on space law and related issues very interesting, both because I hadn't read much about them and also because they are likely to be even more relevant than the more usual concerns. The authors, like many potential readers, certainly had an interest in space and so on before writing the book; the detailed yet clear legal chapters bring an important aspect to the topic.

The last part is concerned with economics (*e.g.*, the similarities and differences of space settlements and company towns), the question of the minimum population necessary for a vital independent settlement, and the possibility of space war. The same technology which can be used to deflect asteroids from Earth could also be used to deflect them towards Earth. Real or imagined benefits (many of which are debunked in the book) are often touted as a reason to settle space, but as always there is the question whether the potential benefits outweigh the potential dangers, especially as technology is evolving faster than morality. (H. G. Wells once described civilization as a race between education and catastrophe. Although one can argue that morality has significantly evolved for the better[3], for the past few decades it has been possible for one person to destroy, or at least seriously damage, all of humanity or a large fraction of it.) While the fear of law enforcement might suppress some over-ambitious tendencies, suicide bombers are clearly not thwarted by the death or any other penalty, and the fact that *Starlink*† satellites exist despite objections by the astronomical community and others demonstrates that laws and/or their enforcement might not evolve quickly enough to provide the needed safeguards.

This book covers a lot of ground (or space); navigation is aided by a thorough fifteen-page small-print index. It was an enjoyable and informative read, and is recommended not just to those with an interest in such topics (especially if they don't — yet — agree with the authors), but essentially to everyone, since the developments it is concerned with will potentially affect everyone. The arguments are clear and well documented and should convince the reader as they convinced the authors. I don't think that I can improve on the authors' summary, so I'll end this review by quoting part of it: "Our original assumption was that space settlement was coming soon.... We now believe the timeline is substantially longer and the project wildly more difficult and that the governance work to do is more about regulating the behaviour of Earthlings than designing a Martian democracy.... [W]e just cannot convince ourselves

*There are organizations which believe that they can legally sell property which they have claimed on the Moon, and there are gullible customers who buy it. That isn't mentioned in the book. Although the benefits from combating such fraudsters is presumably not worth the effort, the fact that they continue unabated does make me somewhat sceptical whether space law will be quite as binding as the authors suggest.

†Not to be confused with the former UK academic astronomical computing project of the same name.

that the usual arguments for space settlements are good. Space settlement will be much harder than it is usually portrayed, without obvious economic benefits. Attempting space settlement now may increase the likelihood of conflict on Earth in the short term and ultimately increase human existential risk.... We believe that space settlements are possible, and perhaps one day they could be done in safety. But doing something big requires us to assess the scale of the challenge. In healthy communities of thought, the [sceptics] aren't barriers on the road to progress, but guardrails.... Going to the stars will not make us wise. We have to become wise if we want to go to the stars." — PHILLIP HELBIG.

References

(1) https://slate.com/technology/2013/04/mars-one-supporters-nobel-prize-winning-physicist-endorses-plan-to-send-people-on-a-one-way-trip.html
(2) https://www.smbc-comics.com
(3) S. Pinker, *The Better Angels of Our Nature: Why Violence Has Declined* (Viking), 2011.

A General Relativity Coursebook, by Ed Daw (Cambridge University Press), 2023. Pp. 527, 24·5 × 17 cm. Price £22·99 (paperback; ISBN 978 1 00 924244 8).

Like other books on a common topic, books on General Relativity (GR) can differ in the breadth and depth of topics covered, but also with regard to being 'maths first' or 'physics first' and which sign conventions are used. This book (neither broad nor deep, maths first, 'East Coast' sign convention (−+++, 'mostly plus')) reveals another difference: level of detail. This is an introductory book, introducing the necessary tensor calculus after an introductory chapter on the principle of equivalence before moving on to the Einstein equation and three applications (the Schwarzschild solution, Friedmann cosmological models, and gravitational waves), but differs from most other GR books in the level of mathematical detail. The mathematics is not more advanced than elsewhere, but rather spelled out, with the 'work shown'. It is thus similar to a series of lectures, and is indeed derived from lectures (so are some other books, though they have often gone through a greater transformation). Ed Daw is Professor of Particle Astrophysics at the University of Sheffield, has worked on searches for dark matter and gravitational waves, and has been lecturing on GR since 2003. The book fills the gap between more qualitative introductions to GR and books which leave out the needed details (or leave them as exercises for the reader). Although, as Daw points out, it is true that tensor calculus has many other applications as well, many interested in GR will have had no prior experience.

Daw obviously knows the material, and spends some extra time on topics which often prove difficult for many students. The book is well written and clearly structured. Chapter 8, on gravitational waves, goes a bit further afield by discussing some of the technical challenges in gravitational-wave detection. The final chapter is a guide for further reading, mentioning other books, other sign- and tensor-notation conventions, and so on. (Interestingly, Daw's favourite is Hartle's book[1,2], which is 'physics first'. I tend to prefer the 'physics first' approach, though 'maths first' is sometimes more useful for introductory books[3].) I was pleased to read of the Lorenz, rather than Lorentz, gauge (something even professionals sometimes get wrong), so put the appearance of the Lorentz gauge in Chapter 8 down to a typo. Although I often quibble about matters of style, this book is not the worst offender in that respect. There