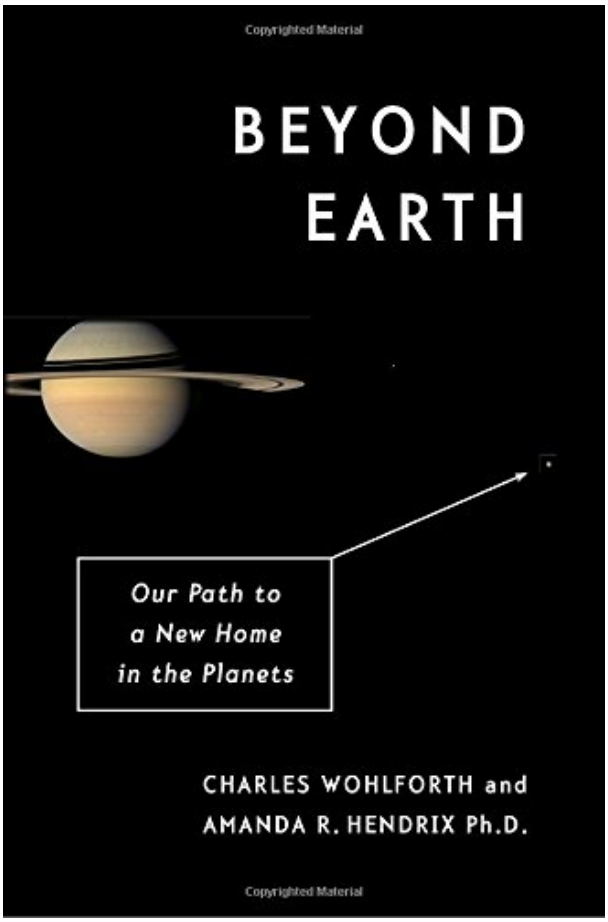
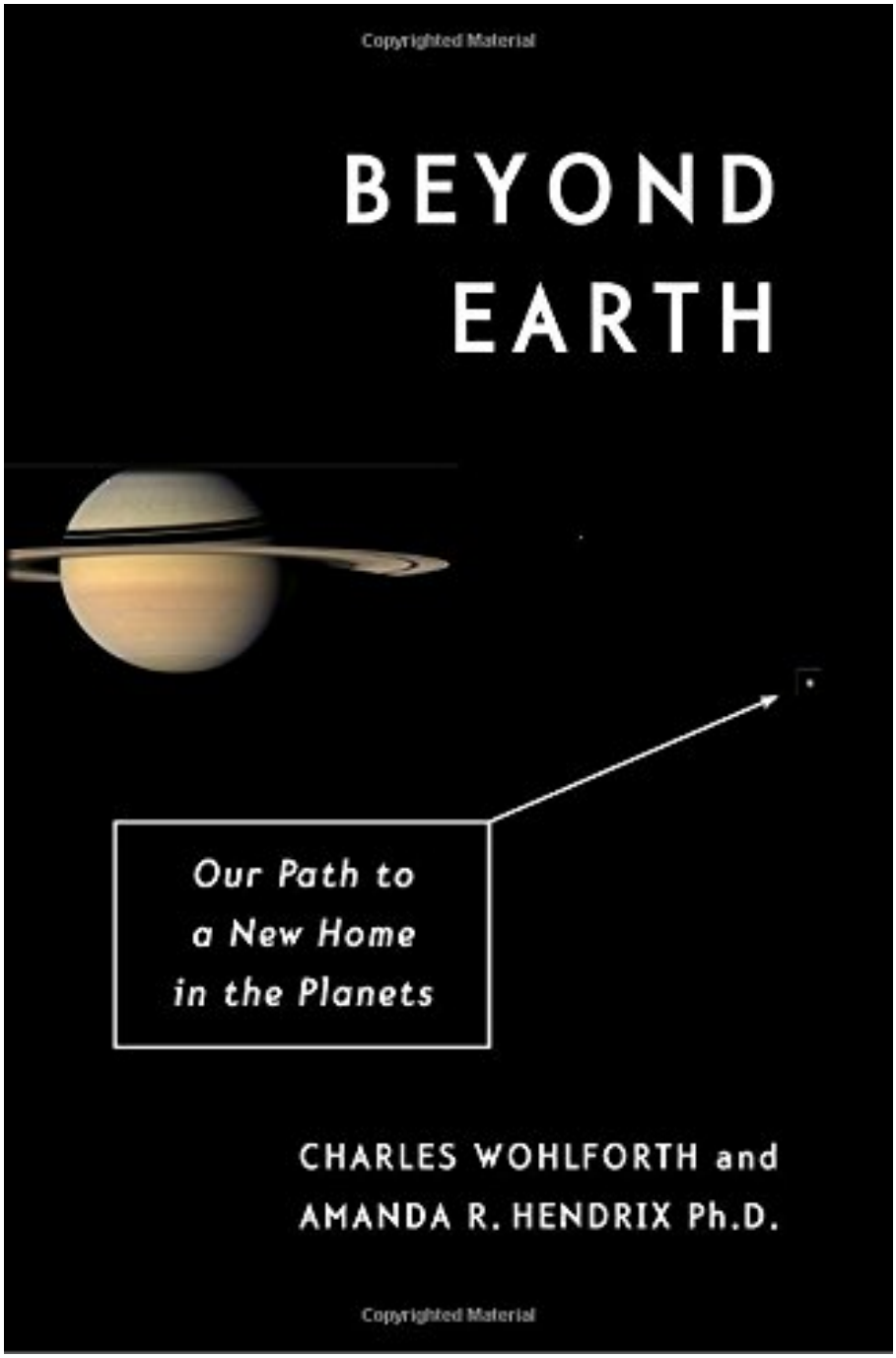
BEYOND EARTH: OUR PATH TO A NEW HOME IN THE PLANETS BY CHARLES WOHLFORTH, AMANDA R. HENDRIX PH.D.





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Review

“Refreshing….delightfully different from any other book I’ve ever read by human-spaceflight cheerleaders. The authors have put their thinking caps on and broken out of the usual orthodoxy by presenting cogent ideas on why humans should go into space, including their lovely idea of going to and living on obscure (to most folks) Titan….Mr. Wohlforth and Ms. Hendrix gracefully outline not just the mechanics but the philosophy and morality of human spaceflight in their well-structured book….It is decidedly a book that should be read by anyone intrigued by the possibility and feasibility of a future ‘out there.’” —Homer Hickam, The Wall Street Journal

“Long ago I’d come to doubt that humans might ever leave this planet to homestead another. But this impeccably researched, imaginative, and gracefully written book seized me right from its introduction and kept me rapt to the end, rooting for our future. Beyond Earth is epic science writing, the rare kind that I can’t get out of my mind – or my dreams.” —Alan Weisman, author of Countdown and The World Without Us

“An engaging mind game. It’s hard not to get swept up in the authors’ wide-ranging enthusiasm for space exploration and settlement. They find optimism in some surprising places—even in the gloomy prospects for our current planetary home.” —Tom Kizzia, author of Pilgrim’s Wilderness

“This wonderful book imagines the future and, most of all, made me think—a rewarding journey even when I disagreed. As enjoyable as any science fiction, it isn’t fiction, but a fascinating extrapolation of facts leading to a possible future. Everyone should read it.”
—Julian Nott, space scientist, pilot, inventor, and holder of seventy-nine world aviation records in balloons

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Introduction
THE WAY OFF THE EARTH

Someday, people will live on Titan, the largest moon of Saturn. Their energy will come from burning the unlimited supply of fossil fuels on its surface and their oxygen from the water ice that forms much of Titan's mass. The nitrogen atmosphere, thicker than the Earth's, will protect them from space radiation and allow them to live in unpressurized buildings and travel without spacesuits, in very warm clothes with respirators. They will go boating on lakes of liquid methane and fly like birds in the cold, dense atmosphere, with wings on their backs.

This will happen because, at a certain point, it will make sense. Today, the cold, gloomy Titan skies are unappealing and impossibly distant. We do not yet have the technology to put people on Titan. But the technology is coming at the same time the prospects for the Earth are getting worse. In earlier times, human beings struck out for strange and dangerous new places when their homes became intolerable. If humanity doesn't change course on this planet, a new world free from war and climate upheaval could someday draw colonists to Titan in the same way.

The technology required for a space colony is already visible. The largest barriers are institutional. An indifferent political establishment. A space agency, NASA, with a culture that squelches dissent and that lacks a coherent goal for human spaceflight. News media that have sold the public a false understanding of the real challenges of space exploration. Going to another planet will be difficult and, without breakthroughs, unacceptably dangerous.

But the ingredients for a space colony are coming together. Experience building space vehicles has spread to many countries and private industry. An Internet-spawned innovation culture that knows how to make new things fast has turned its attention to space. The concepts needed to get us there have been thought out already.

When the moment comes, it won't be the first time human beings have embarked on a voyage that seemed impossibly difficult, expensive, and technically challenging. Our kind repeatedly built new societies in places so remote as to forbid return. When we do it again, we'll probably have reasons similar to those they had then.

As authors, we have investigated science and technology as well as culture and the environment to construct our scenario about space colonization. We have pondered the fundamental issues facing humanity: our response to technology; our will to explore, expand, and consume; and how we treat one another and treat the world we already have. The most important ingredient for space colonization is the human animal: our

cellular response to cosmic radiation, our psychological ability to travel for years through nothingness, and our ecological fitness for a new landscape where no organism has lived before (at least no organism we know of). What are we? How far can we go?

Scientists we interviewed often asked if we were writing science fiction or journalism. We never intended to write a work of imagination, but a skeptic would never have predicted what has already happened. We visited a rocket factory floor where private space industry workers were sewing astronaut suits that Captain James T. Kirk would have been proud to wear. Our scenario is not based on a love of cool inventions and inspiring visions. It relies on our knowledge of people's tendency for dumb decisions, selfish drives, and messy politics. Recognizing these predictable truths makes it easier to see how technology could unfold, and more interesting and funnier, too.

We've had tremendous fun thinking and arguing about how this will happen. The work developed while we laughed together for many hours on Skype, Amanda at her office or kitchen table in Los Angeles and Boulder and Charles in a home office facing his snow-buried boat in Anchorage or in the Alaska wilderness.

Amanda works with space technology every day. She has practiced to become an astronaut and has managed equipment to capture the scenery of a world on the other side of the solar system. She has also navigated the bureaucracy of big science, a universe of meetings, travel, and egos like any modern organization. Laboring over the myriad details of new ideas, she has helped make the miracle of space exploration real.

Charles spends summers off the grid on an Alaskan beach and in winter he cross-country skis almost every day. His books seeking to understand the fate of the planet have taken him to the Arctic pack ice with Eskimo whalers and to a Cambridge, England, aviary with supersmart birds.

We're complementary opposites. Amanda brings the science and the wonder, but also an awareness of how technology unsteadily unfolds. Charles brings the skepticism of one who has studied human tragedy on Earth, but also the optimism of one who loves the nature in us all. Amanda would eagerly accept a one-way ticket off the Earth to fulfill her drive for adventure and her vision for the future. Charles can hardly sit still through a red-eye flight and cannot imagine saying good-bye to the snow, sea, and fresh air of this world.

We'll never be rich enough to send everyone off to another celestial body, but it isn't hard to imagine a day when governments or the very rich begin thinking of a spaceship as a lifeboat—or an ark. People are already thinking that way. In 2008, the Svalbard Global Seed Vault opened, deep inside a frozen mountain on an island halfway between Norway and the North Pole, to preserve millions of plant lines in case of disaster or apocalypse. An off-world colony would likewise shield a store of human genes out of the way of any earthly harm.

But, unlike seeds, human beings don't stay the same when you put them in safe storage. An extraterrestrial colony might begin as an annex to Earth, preserving our species, but it would develop into a world of its own, with its own culture, government, and future. Within a generation the Earth could be a foreign place to children born under an orange sky. For them, the smell of recycled air, not fresh breezes, would carry the nostalgic sense of home.

We envision their sky as orange because our scenario for this future leads us to Titan. Why Titan? We have screened each of the places colonists could go to find one where the requirements of human safety and sustenance can be met without direct support from Earth and without end. The process of constructing a scenario led us to this wet, energy-rich object in the outer solar system.

We aren't exactly predicting that a colony will be built there, and we certainly don't know when it will happen. A scenario is a way of organizing an investigation of the future, not a prediction. This powerful exercise generates a thought experiment that anyone can run in his or her own mind, using the hard information we provide. As you come with us through this journey into a possible future, you will find all the facts for your own thought experiment to see if your reasoning brings you to Titan, too.

The book's structure reflects this interplay of hard science and intriguing projections. Alternating sections cover reality and the future scenario. Sections labeled "Present" report the technology and ideas that already exist and tell the stories of the real people bringing space closer. Sections labeled "Future" project a scenario that responds to forces and opportunities that seem to us likely, as well as some whimsical predictions. The book interweaves these two modes to create an integrated picture of what's known and where that knowledge could lead. Readers are free to reach their own conclusions.

Building a self-sustaining space colony is several decades and technology steps away. But many space scientists and engineers think about it, because it represents the kind of adventure that brought them into the field in the first place. And because it raises fascinating questions about today's technology, research, and space industry. Indeed, the goal of moving people to a new planet is the strongest justification for a manned U.S. space program.

We've started with the current state of space science, then asked how we could get to another celestial body and build a colony there, where we would go, and why it might really happen. To be credible, the scenario must respond to these three questions—how, where, and why—with answers that are based in today's reality. That's why the book uses alternating sections: so the present can inform the future for each of the three questions.

The question of how addresses the technology of both advanced propulsion and the design of conventional spacecraft as they become commonplace. As the business of spaceflight becomes assimilated into our everyday lives, economics holds the key. The commercial spaceflight industry is transforming our sense of possibility. Using Silicon Valley's money and innovative confidence, it will soon bring mass space products to the market. This industry looks something like the computer business did when Steve Jobs and Bill Gates were leaving their garages: ready for a rapid spread beyond the confines of expensive, centralized government projects and into making space travel safe, repeatable, and affordable. As that happens, the cost of lifting materials to weightlessness will fall dramatically, transforming the practicality of every space endeavor.

The question of where brings out the many insights of planetary science, as well as space health, psychology, reproductive issues, and the interlocking needs of energy, shelter from radiation, and adaptation to low-gravity life. Colonists need a place they can survive and support themselves, indefinitely.

This "where" question has two steps: asking what human society needs for survival and picking the best spot in the solar system to meet those needs. Titan's hydrocarbon hills and lakes can provide unlimited fuel. Water and its constituents of hydrogen and oxygen make up half of Titan's mass. With water and energy we can make food, process materials, and power cities.

That leaves the question of why, which asks for plausible reasons to leave the Earth permanently.

This isn't a Lewis and Clark journey of discovery, probing the unknown and returning home to fame and glory. Space colonists are more like the anonymous pioneers who headed west in covered wagons to build homesteads. The trip won't be fun and they aren't coming back. Life will be hard and dangerous for at least

the first generation. Some exceptional people might be willing to go merely to be the first, but creating a colony will require more than adventurers. A colony will need people, a lot of them, with specialized abilities and the resolve to settle and build. Most of all, it will need a sponsor willing to pay the enormous cost of launching the endeavor. In some ways, the “why” question is the biggest of all.

Often, the colonies of the past justified their cost either by sending something of value back to the mother country or by giving the colonists themselves a way to get away from something bad back home. As for the first reason—making money—the business case for living in space remains murky. Space mining could produce materials that don’t exist on Earth or are extremely rare here. Heat-shocked graphite asteroids laced with diamonds. Moon deposits of a helium isotope, He-3, implanted by the solar wind, that could power fusion reactors.

But fusion reactors don’t exist yet and interplanetary payloads currently are worth more than diamonds (and we probably don’t need that many diamonds anyway). Indeed, no resource we know of justifies the cost of a mission, let alone a colony. The business proposition for colonization could improve with cheaper space travel, a big find by space prospectors, or a new technology that requires materials not found on Earth. For us as authors, these possibilities remain hazy, so in our scenario we have chosen another motivation to drive space colonization: the need to get away from the Earth.

Human beings can’t go west anymore. Our planet is full. Our personality as a species suggests some of us won’t put up with that situation indefinitely. True, the human family is mixed. Some stay home, fix what doesn’t work, or learn to live with nearly intolerable political or environmental conditions. But others break away to make new places, never planning to return. We spread. We have done so since leaving Africa to populate Europe, Asia, and the New World, and since then we have repeated the process over and over again.

The trends in environmental and political conditions on Earth are as important a part of a scenario for space colonization as the technology story, and an important part of understanding ourselves. Along with learning how our bodies respond to space, we need to predict how our societies will respond to a deteriorating environment, increasing political and religious conflict, and widening wealth disparities.

The inspiring and discouraging qualities that make people such interesting animals are already mixing to create the movement toward space. Billionaires are building spaceships to go farther than any man or woman has gone before, at the same time as they make money selling tickets for joyrides beyond the atmosphere.

We’ve met brilliant young engineers at commercial space companies who are driving down the cost of access to space. They are putting in long hours to make spaceflight a part of everyday life and thinking several steps beyond. They don’t work so hard just for a paycheck. These young aerospace workers speak the language of Star Trek, attacking huge technical challenges with the dexterity and attitude of hackers. They’re unfamiliar with failure and utterly sure they are on the way to space.

Spending time with these people, it’s not hard to imagine a day when a huge spaceship will prepare for departure from the end of a long, retractable corridor connected to a commercial space station orbiting the Earth. The scenario may sound like science fiction. But doesn’t the future often sound like science fiction—until it suddenly arrives?

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From a leading planetary scientist and an award-winning science writer, a propulsive account of the developments and initiatives that have transformed the dream of space colonization into something that may well be achievable.

We are at the cusp of a golden age in space science, as increasingly more entrepreneurs—Elon Musk, Richard Branson, Jeff Bezos—are seduced by the commercial potential of human access to space. But Beyond Earth does not offer another wide-eyed technology fantasy: instead, it is grounded not only in the human capacity for invention and the appeal of adventure but also in the bureaucratic, political, and scientific realities that present obstacles to space travel—realities that have hampered NASA's efforts ever since the Challenger disaster.

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(With 8 pages of color illustrations)

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We're complementary opposites. Amanda brings the science and the wonder, but also an awareness of how technology unsteadily unfolds. Charles brings the skepticism of one who has studied human tragedy on Earth, but also the optimism of one who loves the nature in us all. Amanda would eagerly accept a one-way ticket off the Earth to fulfill her drive for adventure and her vision for the future. Charles can hardly sit still through a red-eye flight and cannot imagine saying good-bye to the snow, sea, and fresh air of this world.

We'll never be rich enough to send everyone off to another celestial body, but it isn't hard to imagine a day when governments or the very rich begin thinking of a spaceship as a lifeboat—or an ark. People are already thinking that way. In 2008, the Svalbard Global Seed Vault opened, deep inside a frozen mountain on an island halfway between Norway and the North Pole, to preserve millions of plant lines in case of disaster or apocalypse. An off-world colony would likewise shield a store of human genes out of the way of any earthly harm.

But, unlike seeds, human beings don't stay the same when you put them in safe storage. An extraterrestrial colony might begin as an annex to Earth, preserving our species, but it would develop into a world of its own, with its own culture, government, and future. Within a generation the Earth could be a foreign place to children born under an orange sky. For them, the smell of recycled air, not fresh breezes, would carry the nostalgic sense of home.

We envision their sky as orange because our scenario for this future leads us to Titan. Why Titan? We have screened each of the places colonists could go to find one where the requirements of human safety and sustenance can be met without direct support from Earth and without end. The process of constructing a scenario led us to this wet, energy-rich object in the outer solar system.

We aren't exactly predicting that a colony will be built there, and we certainly don't know when it will happen. A scenario is a way of organizing an investigation of the future, not a prediction. This powerful exercise generates a thought experiment that anyone can run in his or her own mind, using the hard information we provide. As you come with us through this journey into a possible future, you will find all the facts for your own thought experiment to see if your reasoning brings you to Titan, too.

The book's structure reflects this interplay of hard science and intriguing projections. Alternating sections cover reality and the future scenario. Sections labeled "Present" report the technology and ideas that already exist and tell the stories of the real people bringing space closer. Sections labeled "Future" project a scenario that responds to forces and opportunities that seem to us likely, as well as some whimsical predictions. The book interweaves these two modes to create an integrated picture of what's known and where that knowledge could lead. Readers are free to reach their own conclusions.

Building a self-sustaining space colony is several decades and technology steps away. But many space scientists and engineers think about it, because it represents the kind of adventure that brought them into the field in the first place. And because it raises fascinating questions about today's technology, research, and space industry. Indeed, the goal of moving people to a new planet is the strongest justification for a manned U.S. space program.

We've started with the current state of space science, then asked how we could get to another celestial body and build a colony there, where we would go, and why it might really happen. To be credible, the scenario must respond to these three questions—how, where, and why—with answers that are based in today's reality. That's why the book uses alternating sections: so the present can inform the future for each of the three questions.

The question of how addresses the technology of both advanced propulsion and the design of conventional spacecraft as they become commonplace. As the business of spaceflight becomes assimilated into our everyday lives, economics holds the key. The commercial spaceflight industry is transforming our sense of possibility. Using Silicon Valley's money and innovative confidence, it will soon bring mass space products to the market. This industry looks something like the computer business did when Steve Jobs and Bill Gates

were leaving their garages: ready for a rapid spread beyond the confines of expensive, centralized government projects and into making space travel safe, repeatable, and affordable. As that happens, the cost of lifting materials to weightlessness will fall dramatically, transforming the practicality of every space endeavor.

The question of where brings out the many insights of planetary science, as well as space health, psychology, reproductive issues, and the interlocking needs of energy, shelter from radiation, and adaptation to low-gravity life. Colonists need a place they can survive and support themselves, indefinitely.

This “where” question has two steps: asking what human society needs for survival and picking the best spot in the solar system to meet those needs. Titan’s hydrocarbon hills and lakes can provide unlimited fuel. Water and its constituents of hydrogen and oxygen make up half of Titan’s mass. With water and energy we can make food, process materials, and power cities.

That leaves the question of why, which asks for plausible reasons to leave the Earth permanently.

This isn’t a Lewis and Clark journey of discovery, probing the unknown and returning home to fame and glory. Space colonists are more like the anonymous pioneers who headed west in covered wagons to build homesteads. The trip won’t be fun and they aren’t coming back. Life will be hard and dangerous for at least the first generation. Some exceptional people might be willing to go merely to be the first, but creating a colony will require more than adventurers. A colony will need people, a lot of them, with specialized abilities and the resolve to settle and build. Most of all, it will need a sponsor willing to pay the enormous cost of launching the endeavor. In some ways, the “why” question is the biggest of all.

Often, the colonies of the past justified their cost either by sending something of value back to the mother country or by giving the colonists themselves a way to get away from something bad back home. As for the first reason—making money—the business case for living in space remains murky. Space mining could produce materials that don’t exist on Earth or are extremely rare here. Heat-shocked graphite asteroids laced with diamonds. Moon deposits of a helium isotope, He-3, implanted by the solar wind, that could power fusion reactors.

But fusion reactors don’t exist yet and interplanetary payloads currently are worth more than diamonds (and we probably don’t need that many diamonds anyway). Indeed, no resource we know of justifies the cost of a mission, let alone a colony. The business proposition for colonization could improve with cheaper space travel, a big find by space prospectors, or a new technology that requires materials not found on Earth. For us as authors, these possibilities remain hazy, so in our scenario we have chosen another motivation to drive space colonization: the need to get away from the Earth.

Human beings can’t go west anymore. Our planet is full. Our personality as a species suggests some of us won’t put up with that situation indefinitely. True, the human family is mixed. Some stay home, fix what doesn’t work, or learn to live with nearly intolerable political or environmental conditions. But others break away to make new places, never planning to return. We spread. We have done so since leaving Africa to populate Europe, Asia, and the New World, and since then we have repeated the process over and over again.

The trends in environmental and political conditions on Earth are as important a part of a scenario for space colonization as the technology story, and an important part of understanding ourselves. Along with learning how our bodies respond to space, we need to predict how our societies will respond to a deteriorating environment, increasing political and religious conflict, and widening wealth disparities.

The inspiring and discouraging qualities that make people such interesting animals are already mixing to create the movement toward space. Billionaires are building spaceships to go farther than any man or woman has gone before, at the same time as they make money selling tickets for joyrides beyond the atmosphere.

We've met brilliant young engineers at commercial space companies who are driving down the cost of access to space. They are putting in long hours to make spaceflight a part of everyday life and thinking several steps beyond. They don't work so hard just for a paycheck. These young aerospace workers speak the language of Star Trek, attacking huge technical challenges with the dexterity and attitude of hackers. They're unfamiliar with failure and utterly sure they are on the way to space.

Spending time with these people, it's not hard to imagine a day when a huge spaceship will prepare for departure from the end of a long, retractable corridor connected to a commercial space station orbiting the Earth. The scenario may sound like science fiction. But doesn't the future often sound like science fiction—until it suddenly arrives?

Most helpful customer reviews

26 of 30 people found the following review helpful.
Interesting concept but flaky science, alot of hype and magical thinking, ignores all other space concepts
By Wikileaker
Beyond Earth is an interesting project but with some major problems in its science. To make these easier to find, first allow me to mention four other books having to do with long-duration spaceflight that the beginner will benefit from more: The High Frontier: Human Colonies in Space, Prospects for Interstellar Travel), The Starflight Handbook, and Entering Space: Creating a Spacefaring Civilization. The first two are rather expensive, but that's because they're classics and for good reason.

I really wanted to like this book because there is a dearth of literature on settlement of the Solar system's periphery. But Beyond Earth has too many science problems, the biggest one having to do with the idea of burning Titan's atmospheric methane (5% CH4) for power production. (since Dr. Hendrix provides the scientific expertise for the book, I will address her contributions to it directly). It should be obvious that without free oxygen available, it will be rather difficult to combust methane. Dr. Hendrix suggests that electricity supplied by a nuclear fission reactor can be used to crack water to supply the oxygen. Well, yes, this will work, BUT seems a needlessly complex way to supply power when it can be tapped directly from the fission reactor. Keep in mind that at each step (electrolyzing water and burning methane) there will be losses and inefficiencies that the Titan colony can hardly afford. And burning methane will produce CO2, not a good thing unless one needs to make dry ice bricks.

The entire idea of relying on nuclear fission to power the colony itself needs to be thought out better. In my reading experience, all authors fail to emphasize that at Saturn's distance, if the heat supply gives out, then the colonists will FREEZE SOLID. I'm talking meat popsicles! This is something that must always be kept in mind when considering the reliability of the colony's heat supply. The authors cite the experience of the US Navy's nuclear submarine fleet to support their contention that nuclear fission plants can be relied on. But these vessels go out on patrols only for a duration of 6-9 months at a time, get depot-level maintenance when in port between patrols, and rely on a vast infrastructure of supporting industry. The Titan colony needs power continuously, in perpetuity. Then there is the little problem of obtaining fission fuel (uranium or plutonium). Obviously this will have to be imported because it is practically nonexistent at Saturn. Lastly, in

order to expand the colony on a permanent basis, nuclear reactors will need to be imported from Earth for a very long time. Without that vast industrial infrastructure, nuclear just does not scale easily.

The book fails to mention solar power as a viable alternative or supplement. This is probably because of the thick haze that blankets Titan. Solar power could be gathered by orbital powersats and beamed down (Dr. Hendrix mentions that there are some radiofrequencies that will penetrate the atmosphere down to the surface). For those who doubt that solar is a workable option at Saturn's distance from the sun, I would refer them to Dyson's Infinite in All Directions in which he describes a civilization in the Kuiper Belt that gathers the faint sunlight with arrays of metal mirrors many miles long. Keep in mind that a mirror deployed in space can be foil-thin (even atoms-thin). The gathered sunlight can be focused on a turbogenerator for electricity production, or the mirrors can be used to concentrate sunlight on photovoltaic cells. Gathering sunlight at Saturn is much more expensive than at Earth (Saturn's sunlight is 1.35 percent the intensity of Earth's sunlight, or 18.36 watts per square meter averaged over the Saturian year) but it can work, and it is dependable and easily scalable. The only question is how electricity can be transported to Titan's surface. If microwave beams cannot be used then the energy would have to be transported down to Titan via a chemical intermediary.

Then there's the so-called Q-Drive which Dr. Hendrix proposes to use for propulsion to Titan. Her description is lacking in technical detail, only that "quantum particles" are produced somehow from the quantum vacuum, and ejected as reaction mass. This supposedly permits the spacecraft to accelerate without propellant -- the reaction mass is "manufactured" in flight. I did some research on this and I was led to the Wikipedia article titled "Quantum Vacuum Thruster". It seems there is some controversy if this concept is for real or not. I've studied a little physics and my opinion is the Q-Drive resembles the fabled "perpetual motion devices" that patent examiners sometimes let slip through their approval process. Seems like the authors are trying to get something for nothing, and the beginner student of physics learns very quickly that never happens. You can't even break even. Little things like "entropy" and "conservation laws" always get in the way. The author Mauldin of the book I mentioned at the start Prospects for Interstellar Travel) laments that it seems so unfair we have to work so hard building up a decent speed and then have to expend more time and energy braking at the destination, and then the spacecraft winds up with the same momentum state that it started with! Bummer but that's reality, folks! Strange, I recall reading in Beyond Earth that the authors said they were going to limit their technical discussions to established science. I'll just finish by remarking that I believe that the "Q" in Q-Drive really stands for "quack".

What's really galling is that there are so many other valid ideas for fast space propulsion that they could have put in the book. Maybe they felt they just had to be different. Or that their friend Sonny White is so enthusiastic about this wondrous Q-Drive that they just had to put it in. Too bad for the reading public, I hope no innocent schoolchildren or some wide-eyed teenager finds this book in a library and gets disillusioned when they find out it was all a bunch of hokum.

The authors take pains to disparage all locations other than Titan as worthy destinations for human colonization. They dismiss Mars simply because it is bombarded by cosmic radiation and meteoroids due to its thin atmosphere. Colonists there will have to shelter in hardened shelters, or underground (or lava tubes, which the authors can be commended for mentioning). This is not an insurmountable obstacle, and would be far easier to deal with than Titan's killer cold. Titan residents are going to be spending nearly all their lives in their hot-air-balloon habs. Perhaps the authors should have interviewed some Antarctic researchers and inquired how much they enjoyed being outside their shelters (oh I forgot, the Antarctic scientists evacuate for the winter! Bummer the Titan people can only retreat to orbit). Back to Mars: it's got plenty of rocks, metals, oxygen and water. it's warm, solar energy is freely available, and Mars is far closer to the metal-rich asteroid belt. It has two natural satellites which will be advantageous as stepping-stones for exploration (via

telepresence) and establishment of a colony. Mars has an eerily earthlike 24 hour rotational day/night cycle. Mars has nearly three times Titan's gravity (38 percent of a gee rather than 14%). Since nobody knows just how much gravity is necessary for long-term human health and reproduction, this last factor is probably a decisive advantage for Mars over Titan.

The moons of Jupiter are also probably more viable than Titan. The outermost Big Three (Europa,Ganymede,Callisto) all are now known to have underground oceans of liquid water. Since it's liquid we can be sure things are pretty warm down there. The icy roof provides excellent radiation shielding. And contrary to what they said in Beyond Earth, there IS plenty of rock/metal in the Galilean moons. The mean density of Io is 3.5 g/cm3 and Europa is 3.0 g/cm3, so there is plenty of something there much denser than water (1.0 g/cm3). (Io is minable at its poles). Even Callisto has a mean density of 1.83 g/cm3, and as a bonus it's almost completely undifferentiated, so there are lots of the heavy elements near its surface. The only real problem with the Jovian moons is the low gravity, about that of our Moon (though it helps keep the water pressure to a manageable level).

Another thing I wish the authors had made room for was material on the other moons of Saturn. Saturn does have a most handsome collection of medium size moons far smaller than Titan and the Galilean giants, but still far bigger than the space rocks of Jupiter in the 10-300 km range. The Titan colonists will have a great many mining opportunities on these low-gee motherlodes for the metals which they will need so badly.

The authors of Beyond Earth do not even consider the possibility of space stations as colonies as described in Gerard O'Neill's The High Frontier: Human Colonies in Space. Yes, building city-size habitats in free space will be expensive and difficult. But this solves ALL the problems of a permanent colony in space. Any level of gravity can be provided for, as much shielding against space radiation can be provided for, as much area and volume as needed can be provided for. Lesser gravity and near-zero gravity will assist many manufacturing activities. Access to abundant solar energy and the material resources of the Belt is fast, easy, and inexpensive. It was a gross oversight to ignore the possibilities of space habitats. After publication of O'Neill's book, Isaac Asimov termed this perspective "planetary chauvinism". And it's a mistake when considering the possibilities of solar colonization..

Lastly, a thing that I found annoying was the author's subscription to the too-popular conceit that the universe absolutely must be teeming with alien intelligences. I myself could have done without the prattle about the Fermi paradox. There are plenty of reasons why the Earth may be the only home for intelligent life (personally, I believe even this statement is debatable at best). 'Nuff said on this topic, I will simply refer the reader to the outstanding Rare Earth: Why Complex Life is Uncommon in the Universe.

I rate Beyond Earth two stars because it does contain some interesting material on the politics of space development. The color photos are nice. The authors were right to point out that there is much unknown about the long-term hazards of space travel, and that more research into it should be furthered. Importantly, they make clear it's a far better idea to clean up the mess we are making of our Earth than to undertake space colonization on an involuntary, forced basis. After all, it may prove impossible for all we know. As for the idea that the only plausible impetus for expanding out into the solar system would be global environmental catastrophe, the authors could have saved quite a few pages by simply stating the rationale that Elon Musk of SpaceX has for his effort to establish a permanent human presence on Mars -- it's just not a good survival strategy for the human species to keep all our eggs in one planetary basket. It's just something we gotta do, no matter what. Big rocks do fall out of the sky from time to time. But don't fret so much kids, the dinosaurs didn't see it coming either.

2 of 2 people found the following review helpful.

The basic premise and writing is good, but it is a bit too slanted in ...
By Michel Poulin
The basic premise and writing is good, but it is a bit too slanted in order to support nearly exclusively the authors' proposition that Titan, rather than Mars, should be colonized by humans in the future. Some actual facts are kind of 'overlooked' so that they would not impinge the authors' pet project. Also, the idea of writing sub-chapters showing what the future could bring was not a bad one, but too often described oversimplistic scenarios, or scenarios that are not very believable, in order to support the authors' views. Overall, not a bad book but not a great one either.

12 of 15 people found the following review helpful.
Bad science
By Pär Tyskling
Interesting ide with titan but the author got it all wrong. He believes you can extract unlimited energy by burning the local hydrocarbones with oxygen extracted by electrolyting water. Makes no sense at all. The energy requiered to do the electrolysys process is the same or higher than what you gain from burbing that fuel. The hydrocarbones on titan is of no use to us energy wise. Taking away to main speaking point of the whole titan argument renders the book completely useless. Sorry but that is the science

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BEYOND EARTH: OUR PATH TO A NEW HOME IN THE PLANETS BY CHARLES WOHLFORTH, AMANDA R. HENDRIX PH.D. PDF

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Review
“Refreshing….delightfully different from any other book I’ve ever read by human-spaceflight cheerleaders. The authors have put their thinking caps on and broken out of the usual orthodoxy by presenting cogent ideas on why humans should go into space, including their lovely idea of going to and living on obscure (to most folks) Titan….Mr. Wohlforth and Ms. Hendrix gracefully outline not just the mechanics but the philosophy and morality of human spaceflight in their well-structured book….It is decidedly a book that should be read by anyone intrigued by the possibility and feasibility of a future ‘out there.’” —Homer Hickam, The Wall Street Journal

“Long ago I’d come to doubt that humans might ever leave this planet to homestead another. But this impeccably researched, imaginative, and gracefully written book seized me right from its introduction and kept me rapt to the end, rooting for our future. Beyond Earth is epic science writing, the rare kind that I can’t get out of my mind – or my dreams.” —Alan Weisman, author of Countdown and The World Without Us

“An engaging mind game. It’s hard not to get swept up in the authors’ wide-ranging enthusiasm for space exploration and settlement. They find optimism in some surprising places—even in the gloomy prospects for our current planetary home.” —Tom Kizzia, author of Pilgrim’s Wilderness

“This wonderful book imagines the future and, most of all, made me think—a rewarding journey even when I disagreed. As enjoyable as any science fiction, it isn’t fiction, but a fascinating extrapolation of facts leading to a possible future. Everyone should read it.”
—Julian Nott, space scientist, pilot, inventor, and holder of seventy-nine world aviation records in balloons

“Beyond Earth is an important contribution. It’s a thought-provoking introduction to our unlimited future in the outer solar system and beyond.” —S. Pete Worden, Executive Director, Breakthrough StarShot, and Former NASA Ames Center Director

“Beyond Earth goes beyond anything yet written on the subject of space colonization, making clear how what once seemed an adventure is now an urgent necessity. A future human settlement on Titan will keep this book in its library the way early American citizens preserved copies of Common Sense.” —Thomas

Mallon, author of Finale

“The authors successfully combine a visionary approach to space colonization with the practicalities facing the program now. Their conclusion that NASA should focus on ‘stretch technology,’ leaving the rest to the private sector, is controversial but worthy of serious consideration. A welcome contribution to the ongoing discussion of the future of America’s space program.” —Kirkus Reviews

“Promising not to offer another ‘wide-eyed technology fantasy,’ Hendrix and Wohlforth dive into the gritty bureaucratic, political, and scientific hoops humans will have to jump through to make life on other planets a reality. The book also delivers its own form of a mic drop with the argument that it is Titan, not Mars, that will eventually serve as Earth’s next frontier.” —Inverse, Science Books to Read this Fall

“Well researched, the volume takes the compelling approach of discussing current and planned explorations of the solar system, then projects this work into a future scenario narrative that plays out over segments in each chapter….Written in lay language with clear explanations of planetary research, this offering will appeal to readers of environmental or space topics.” —Library Journal

“Planetary scientist Hendrix and writer Wohlforth weave scientific research with fascinating speculation to paint a picture of how and why humankind might spread to other planets….On the whole, the fictional chapters are entertaining, chilling, and put the science in a more human context. The two halves work together to create a striking, reality-based possible future that’s seen through the lens of current knowledge.” —Publishers Weekly

“Highly approachable and enlightening.” —Signature Reads

“Beyond Earth balances possible futures with a raft of facts on advances in spacecraft technology, robotics and space medicine. Crucially, [Wohlforth and Hendrix] parse the push and pull between cautious governments and gung-ho entrepreneurs, concluding that the two may ultimately add up to a propulsive combination.” —Nature

“Beyond Earth does not offer another wide-eyed technology fantasy: instead, it is grounded not only in the human capacity for invention and the appeal of adventure but also in the bureaucratic, political and scientific realities that present obstacles to space travel — realities that have hampered NASA’s efforts ever since the Challenger disaster. In Beyond Earth, Charles Wohlforth and Amanda R.Hendrix offer groundbreaking research and argue persuasively that not Mars, but Titan — a moon of Saturn with a nitrogen atmosphere, a weather cycle and an inexhaustible supply of cheap energy, where we will even be able to fly like birds in the minimal gravitational field —offers the most realistic and thrilling prospect of life without support from Earth.” —The Gleaner

“A warning siren for global climate change. While telling a compelling tale about how a small cadre of brave and/or rich souls could colonize space, the real message here is that our best chance to preserve humanity requires facing up to the challenges here on Earth….Certainly worth a read.” —Cranereaction.com

“This back-and-forth between science and science fiction is nicely done…engaging.” —Hippopress.com

About the Author
CHARLES WOHLFORTH is the author of more than ten previous books. He writes a column for Alaska Dispatch News, hosts a weekly interview program for public radio stations in Alaska (where he lives), and has won the Los Angeles Times Book Prize for Science and Technology, among many other awards.

AMANDA R. HENDRIX, Ph.D., a planetary scientist, worked for twelve years at NASA's Jet Propulsion Laboratory. She has been a scientific investigator on the Galileo and Lunar Reconnaissance missions, a principal investigator on NASA research and Hubble Space Telescope observing programs, and is the author of many scientific papers. As an investigator on the Cassini mission to Saturn, she has focused her research on the moons of Saturn.

Introduction
THE WAY OFF THE EARTH

Someday, people will live on Titan, the largest moon of Saturn. Their energy will come from burning the unlimited supply of fossil fuels on its surface and their oxygen from the water ice that forms much of Titan's mass. The nitrogen atmosphere, thicker than the Earth's, will protect them from space radiation and allow them to live in unpressurized buildings and travel without spacesuits, in very warm clothes with respirators. They will go boating on lakes of liquid methane and fly like birds in the cold, dense atmosphere, with wings on their backs.

This will happen because, at a certain point, it will make sense. Today, the cold, gloomy Titan skies are unappealing and impossibly distant. We do not yet have the technology to put people on Titan. But the technology is coming at the same time the prospects for the Earth are getting worse. In earlier times, human beings struck out for strange and dangerous new places when their homes became intolerable. If humanity doesn't change course on this planet, a new world free from war and climate upheaval could someday draw colonists to Titan in the same way.

The technology required for a space colony is already visible. The largest barriers are institutional. An indifferent political establishment. A space agency, NASA, with a culture that squelches dissent and that lacks a coherent goal for human spaceflight. News media that have sold the public a false understanding of the real challenges of space exploration. Going to another planet will be difficult and, without breakthroughs, unacceptably dangerous.

But the ingredients for a space colony are coming together. Experience building space vehicles has spread to many countries and private industry. An Internet-spawned innovation culture that knows how to make new things fast has turned its attention to space. The concepts needed to get us there have been thought out already.

When the moment comes, it won't be the first time human beings have embarked on a voyage that seemed impossibly difficult, expensive, and technically challenging. Our kind repeatedly built new societies in places so remote as to forbid return. When we do it again, we'll probably have reasons similar to those they had then.

As authors, we have investigated science and technology as well as culture and the environment to construct our scenario about space colonization. We have pondered the fundamental issues facing humanity: our response to technology; our will to explore, expand, and consume; and how we treat one another and treat the world we already have. The most important ingredient for space colonization is the human animal: our cellular response to cosmic radiation, our psychological ability to travel for years through nothingness, and our ecological fitness for a new landscape where no organism has lived before (at least no organism we know of). What are we? How far can we go?

Scientists we interviewed often asked if we were writing science fiction or journalism. We never intended to write a work of imagination, but a skeptic would never have predicted what has already happened. We visited a rocket factory floor where private space industry workers were sewing astronaut suits that Captain James T. Kirk would have been proud to wear. Our scenario is not based on a love of cool inventions and inspiring visions. It relies on our knowledge of people's tendency for dumb decisions, selfish drives, and messy politics. Recognizing these predictable truths makes it easier to see how technology could unfold, and more interesting and funnier, too.

We've had tremendous fun thinking and arguing about how this will happen. The work developed while we laughed together for many hours on Skype, Amanda at her office or kitchen table in Los Angeles and Boulder and Charles in a home office facing his snow-buried boat in Anchorage or in the Alaska wilderness.

Amanda works with space technology every day. She has practiced to become an astronaut and has managed equipment to capture the scenery of a world on the other side of the solar system. She has also navigated the bureaucracy of big science, a universe of meetings, travel, and egos like any modern organization. Laboring over the myriad details of new ideas, she has helped make the miracle of space exploration real.

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The book's structure reflects this interplay of hard science and intriguing projections. Alternating sections cover reality and the future scenario. Sections labeled "Present" report the technology and ideas that already exist and tell the stories of the real people bringing space closer. Sections labeled "Future" project a scenario that responds to forces and opportunities that seem to us likely, as well as some whimsical predictions. The book interweaves these two modes to create an integrated picture of what's known and where that knowledge could lead. Readers are free to reach their own conclusions.

Building a self-sustaining space colony is several decades and technology steps away. But many space scientists and engineers think about it, because it represents the kind of adventure that brought them into the field in the first place. And because it raises fascinating questions about today's technology, research, and space industry. Indeed, the goal of moving people to a new planet is the strongest justification for a manned U.S. space program.

We've started with the current state of space science, then asked how we could get to another celestial body and build a colony there, where we would go, and why it might really happen. To be credible, the scenario must respond to these three questions—how, where, and why—with answers that are based in today's reality. That's why the book uses alternating sections: so the present can inform the future for each of the three questions.

The question of how addresses the technology of both advanced propulsion and the design of conventional spacecraft as they become commonplace. As the business of spaceflight becomes assimilated into our everyday lives, economics holds the key. The commercial spaceflight industry is transforming our sense of possibility. Using Silicon Valley's money and innovative confidence, it will soon bring mass space products to the market. This industry looks something like the computer business did when Steve Jobs and Bill Gates were leaving their garages: ready for a rapid spread beyond the confines of expensive, centralized government projects and into making space travel safe, repeatable, and affordable. As that happens, the cost of lifting materials to weightlessness will fall dramatically, transforming the practicality of every space endeavor.

The question of where brings out the many insights of planetary science, as well as space health, psychology, reproductive issues, and the interlocking needs of energy, shelter from radiation, and adaptation to low-gravity life. Colonists need a place they can survive and support themselves, indefinitely.

This "where" question has two steps: asking what human society needs for survival and picking the best spot in the solar system to meet those needs. Titan's hydrocarbon hills and lakes can provide unlimited fuel. Water and its constituents of hydrogen and oxygen make up half of Titan's mass. With water and energy we can make food, process materials, and power cities.

That leaves the question of why, which asks for plausible reasons to leave the Earth permanently.

This isn't a Lewis and Clark journey of discovery, probing the unknown and returning home to fame and glory. Space colonists are more like the anonymous pioneers who headed west in covered wagons to build homesteads. The trip won't be fun and they aren't coming back. Life will be hard and dangerous for at least the first generation. Some exceptional people might be willing to go merely to be the first, but creating a colony will require more than adventurers. A colony will need people, a lot of them, with specialized abilities and the resolve to settle and build. Most of all, it will need a sponsor willing to pay the enormous

cost of launching the endeavor. In some ways, the “why” question is the biggest of all.

Often, the colonies of the past justified their cost either by sending something of value back to the mother country or by giving the colonists themselves a way to get away from something bad back home. As for the first reason—making money—the business case for living in space remains murky. Space mining could produce materials that don’t exist on Earth or are extremely rare here. Heat-shocked graphite asteroids laced with diamonds. Moon deposits of a helium isotope, He-3, implanted by the solar wind, that could power fusion reactors.

But fusion reactors don’t exist yet and interplanetary payloads currently are worth more than diamonds (and we probably don’t need that many diamonds anyway). Indeed, no resource we know of justifies the cost of a mission, let alone a colony. The business proposition for colonization could improve with cheaper space travel, a big find by space prospectors, or a new technology that requires materials not found on Earth. For us as authors, these possibilities remain hazy, so in our scenario we have chosen another motivation to drive space colonization: the need to get away from the Earth.

Human beings can’t go west anymore. Our planet is full. Our personality as a species suggests some of us won’t put up with that situation indefinitely. True, the human family is mixed. Some stay home, fix what doesn’t work, or learn to live with nearly intolerable political or environmental conditions. But others break away to make new places, never planning to return. We spread. We have done so since leaving Africa to populate Europe, Asia, and the New World, and since then we have repeated the process over and over again.

The trends in environmental and political conditions on Earth are as important a part of a scenario for space colonization as the technology story, and an important part of understanding ourselves. Along with learning how our bodies respond to space, we need to predict how our societies will respond to a deteriorating environment, increasing political and religious conflict, and widening wealth disparities.

The inspiring and discouraging qualities that make people such interesting animals are already mixing to create the movement toward space. Billionaires are building spaceships to go farther than any man or woman has gone before, at the same time as they make money selling tickets for joyrides beyond the atmosphere.

We’ve met brilliant young engineers at commercial space companies who are driving down the cost of access to space. They are putting in long hours to make spaceflight a part of everyday life and thinking several steps beyond. They don’t work so hard just for a paycheck. These young aerospace workers speak the language of Star Trek, attacking huge technical challenges with the dexterity and attitude of hackers. They’re unfamiliar with failure and utterly sure they are on the way to space.

Spending time with these people, it’s not hard to imagine a day when a huge spaceship will prepare for departure from the end of a long, retractable corridor connected to a commercial space station orbiting the Earth. The scenario may sound like science fiction. But doesn’t the future often sound like science fiction—until it suddenly arrives?

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