SAMPLE

Cosmic Explorers: Space-Based Solar Power

Energy From Orbit

Aira Astralis

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This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

The most plentiful energy source in the solar system is sunlight, and the Earth receives it secondhand, filtered, interrupted, and diluted. Above the atmosphere, the sun shines continuously, unfiltered by clouds, uncut by night, undiluted by the round planet's own shadow, at a strength roughly a third higher than the best surface noon. The idea at the center of this book is simple enough to state in one sentence: put the solar panels where the sunlight is, and send the power to the ground as a beam. The idea is called space-based solar power, and it has been seriously studied, intermittently, for more than fifty years, and this book is its story: the physics, the engineering, the history of the studies and prototypes, the economics, and the honest question of whether it will ever be built.

The reader deserves the shape of the subject at the start. Space-based solar power is not fringe science. Its physics is settled, its feasibility studies number in the dozens, and every serious assessment, from the American Department of Energy's in the 1970s to the international academies' in the 2010s, has reached the same conclusion: there is no law of nature against it. Every assessment has also reached the same second conclusion: the engineering is very hard, the upfront cost is enormous, and the economics have never closed, at least not yet. The subject's history is therefore a history of a gap, between a physics that works and a balance sheet that has not, and the story's interest lies in watching the gap narrow: launch costs have fallen tenfold in the living memory of the idea's advocates, robotic assembly is being proven in orbit for other purposes, and the first power-beaming demonstrations have flown. The question the book tracks is whether the narrowing will reach zero.

The book's structure follows the logic of the idea itself. The first chapters establish the geometry: why sunlight in orbit is so much better than sunlight on the ground, and what the numbers of the resource actually are. The middle chapters describe the machine: what a power satellite would be made of, how the power would be sent down, what the ground would do with it, and how the whole system would be assembled and operated. The later chapters are the record of the human effort: the idea's invention in the late 1960s, the great studies of the 1970s, the dormant decades, the international revival, and the demonstrations, small but real, that have flown in the current century. The closing chapters weigh the obstacles honestly: the cost of lifting thousands of tons to orbit, the questions about the beam's safety, the competition from ground solar, and the economics that must close for the idea to leave the study phase and become infrastructure.

A note on the author's stance, made once and kept throughout: this book is

neither advocacy nor debunking. The subject attracts both, in strength, because it sits at the intersection of energy policy and space enthusiasm, and the reader will meet, in the chapters ahead, both the boosters who have promised delivery dates for five decades and the critics who have called the idea a permanent ten-years-away technology. The book's method is to give the reader the numbers and the history plainly, so that the reader can hold the argument on either side with the facts in hand. The reader will finish with a working command of the physics, the machinery, the money, and the milestones, and can weigh the next announcement, whichever direction it comes from, without help.

The book's intended reader is the general reader with no engineering training, and the chapters have been built accordingly: every number is given in its plain form, every unit is translated into something a person can picture, and every technical term is defined at first use and gathered in the glossary at the back. The reader who wants the studies themselves will find them, from the 1970s reference program to the current national roadmaps, all public, all citable, and the book's aim is to make those documents readable, not to replace them. The subject rewards the effort, the reader will find, because it is one of the few large technologies whose entire literature, fifty years of it, is small enough to hold in the mind at once, and anyone who finishes this volume will have held the whole of it.

One last framing, before the physics begins. Space-based solar power, if it is ever built at scale, would be among the largest engineering projects in history: square kilometers of collectors in orbit, gigawatts of power flowing to the ground, a continuous industrial presence in space to build and maintain it. The idea's fate is therefore not merely an energy question but a question about the species' industrial maturity, whether the factory-in-orbit capability being assembled for other reasons can be turned to the oldest and largest purpose anyone has proposed for it. That is the story the chapters tell, and the reader is invited to watch, with the numbers in hand, as it is decided.

The reader is also owed the book's method, stated once here, because the subject's literature is not tidy. Space-based solar power has been studied for fifty years by agencies, militaries, universities, and consultants, and the studies disagree, in their cost models, by factors of two and three, and the book's practice throughout has been to quote the ranges rather than the points, to name the source of each number's confidence, and to prefer the demonstrated record over the projected one wherever the two are separable. Where the book states a number without a hedge, the number is physics or the record; where it hedges, the number is a projection, and the hedge is the information. The reader who finishes the book will not know the subject's

future, because no one does, but will know exactly which parts of the subject are known and which are opinion, and the distinction, in an age of confident claims, is the book's whole offering.

Chapter 01: The Geometry of Sunlight: Why Orbit Beats the Ground

The case for space-based solar power begins with arithmetic, and the arithmetic begins with the atmosphere. This chapter establishes the resource: what sunlight is worth on the ground, what it is worth in orbit, and why the difference is large enough to have kept an idea alive for fifty years.

Start with the number that governs everything, the solar constant: at the top of the atmosphere, sunlight delivers roughly 1,360 watts to every square meter facing it directly. This is the raw input, the resource before any losses, and it is essentially constant: the sun's output varies by about a tenth of a percent, and the Earth-Sun distance varies the delivery by about three percent across the year, and neither matters to the argument. On the ground, the same square meter receives less, for three reasons, and the three reasons stack. The atmosphere absorbs and scatters part of the light on the way down; a typical clear noon at mid-latitudes delivers on the order of a thousand watts to the panel, and average weather takes more. The sun's angle spreads the light across more ground at morning and evening, diluting the delivery. And the Earth's rotation removes the sun entirely for half of every day, and the weather removes it unpredictably for a further fraction of the rest.

The losses compound into the single number that drives every energy argument: capacity factor, the fraction of theoretical maximum output a power plant actually delivers across a year. A ground solar farm in a sunny desert delivers roughly a quarter of its nameplate rating averaged over the year; a farm in a temperate cloudy climate delivers closer to a tenth. A coal or nuclear plant, running around the clock with maintenance shutdowns, delivers about ninety percent. The comparison is the source of the intermittent-energy problem, the reason grids need storage and backup, and the reason solar on the ground, however cheap its panels have become, buys more than panels: it buys storage, backup, transmission, and the management of all three.

Now the orbit. A satellite above the atmosphere, tilted to face the sun continuously, suffers none of the three losses. The atmosphere is below it, the angle is chosen, and the shadow is nearly avoidable: in geostationary orbit, the fixed perch above a point on the equator, the sun is eclipsed only around the equinox seasons, for minutes a day, and a power satellite there can deliver sunlight-gathered power more than ninety-nine percent of the time, an availability no ground plant of any kind matches. The collector in orbit therefore runs at a capacity factor about four times the desert farm's, and this, in a single line, is the physical case: the same panel, moved to the right

address, produces roughly four times the annual energy.

The reader should register what the four-times factor does and does not mean. It does not mean the power is free; the panel in orbit costs vastly more to place and maintain than the panel on the ground, and the chapters on economics quantify the difference.

The orbit's other practical virtues deserve their sentence before the chapter closes. The collector in orbit needs no washing, no snow-clearing, and no security fence; it degrades in radiation, but at a known rate the designs budget for, and its twenty-year service life, the standard the studies assume, is comparable to the ground plant's. The orbiting panel also sees no dust, and the reader who knows the desert installations' maintenance schedules knows that cleanliness is not a trivial line item. And the satellite's output arrives at the rectenna as a single, steady stream, with none of the millisecond flicker that a large ground-solar fleet's clouds produce, a small fact with real value, because the grid's engineers price the flicker's smoothing as a cost of the ground resource, and the orbit's smoothness is one of the firmness product's quietest features.

It does mean that the comparison to ground solar is not panels-versus-panels but system-versus-system: the orbiting panel delivers firm, continuous power with no storage, and the ground panel delivers intermittent power whose true cost includes the storage and backup that firmness requires. The comparison the reader will meet throughout the book is therefore between a space system's high capital cost and a ground system's firmness penalty, and the honest accounting, deferred to the economics chapter, prices both.

The geometry chapter closes with the second advantage, less often quoted but as real: the orbiting collector is above the weather, the day-night cycle, and the seasons, but also above the land. A power satellite's ground footprint, its receiving antenna, occupies land, but the collector itself, the square kilometers of panels, occupies nothing but vacuum, and the land under a receiving antenna can be farmed or grazed, a fact the engineering chapters return to. The resource case, assembled: sunlight in orbit is continuous, unfiltered, and undiluted, roughly four times as productive as the same hardware on the ground, and the chapters that follow are the record of the fifty-year effort to decide whether the productivity is worth the shipping.

One more framing number belongs here, because it disciplines every later one.

The four-times factor is an annual-energy factor, not a power factor: at any given noon, a square meter of desert panel produces about the same as the same square meter in orbit, and the orbit's advantage is earned overnight and

in winter, when the ground panel makes nothing and the orbital one does not stop. The system's value is therefore concentrated exactly where the ground system's weakness is, in the dark hours and the dark seasons, and the reader who carries the framing will recognize it in the economics chapters, where the space system's delivered kilowatt-hours are priced not against the ground's cheap noon-hours but against the ground's expensive firm-hours, the storage-backed, backup-backed hours that every grid's decarbonization plan spends its real money on.

The geometry's arithmetic deserves one concrete example. A ground array at a temperate latitude collects nothing at night, little at dawn and dusk, and its noon yield falls by half again in winter; the same panel, moved to a sun-synchronous orbit, faces the sun through every season, its day only minutes shorter than its year, and collects several times the annual energy of its earthbound twin. That multiplier, not any property of the panel itself, is the entire case for going up, and every later chapter's cost model begins with the question of whether the multiplier is worth the journey.

End of free sample. The full book is available at putrabooks.github.io

ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.