

Financing the Race to Space



Our financial imagination
is as important as our technological imagination
when it comes to extending our reach into the cosmos.
Armen V. Papazian
Starship Congress 2013
Dallas—Texas, USA

Armen V. Papazian

Financing the Race to Space

How to Value, Invest, and Explore
the Universe

palgrave
macmillan

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Space Value Foundation
London, UK

ISBN 978-3-031-73101-3 ISBN 978-3-031-73102-0 (eBook)
<https://doi.org/10.1007/978-3-031-73102-0>

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Cover illustration: shulz

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Is the fulfilment of these ideas a visionary hope? Have they insufficient roots in the motives which govern the evolution of political society? Are the interests which they will thwart stronger and more obvious than those which they will serve?

... At the present moment people are unusually expectant of a more fundamental diagnosis; more particularly ready to receive it; eager to try it out, if it should be even plausible. But apart from this contemporary mood, the ideas of economists and political philosophers, both when they are right and when they are wrong, are more powerful than is commonly understood. Indeed the world is ruled by little else. Practical men, who believe themselves to be quite exempt from any intellectual influences, are usually the slaves of some defunct economist. Madmen in authority, who hear voices in the air, are distilling their frenzy from some academic scribbler of a few years back. I am sure that the power of vested interests is vastly exaggerated compared with the gradual encroachment of ideas.

Not, indeed, immediately, but after a certain interval; for in the field of economic and political philosophy there are not many who are influenced by new theories after they are twenty-five or thirty years of age, so that the ideas which civil servants and politicians and even agitators apply to current events are not likely to be the newest. But, soon or late, it is ideas, not vested interests, which are dangerous for good or evil.

John Maynard Keynes

The General Theory of Employment, Interest and Money. Macmillan.
1936, 383–384

To dream and matter in space...

Foreword

It is my great pleasure to introduce Armen V. Papazian's ground-breaking work, 'Financing the Race to Space.' This book provides a visionary and well-crafted exploration of the monetary and financial frameworks necessary for humanity's pursuit of outer space development, exploration, and settlement.

Papazian's insights are both profound and timely, addressing the complex challenges of financing space endeavours while offering innovative solutions to unlock the investment programs required for future space habitats. His thorough analysis and forward-thinking propositions make this book an essential read for anyone interested in the future of space exploration.

The nuanced discussion highlights the importance of a cooperative approach to space exploration, advocating for a blend of competition and collaboration that can drive humanity forward. Papazian's arguments are compelling, grounded in deep research and presented with clarity and conviction.

As the 695th Lord Mayor of London I have been deeply involved in promoting space sustainability through the Space Protection Initiative. I find Papazian's emphasis on the need for innovative financial instruments, particularly relevant. These concepts align with our ongoing efforts to ensure that our ventures into space are both economically viable and environmentally responsible, particularly our efforts for space debris removal insurance bonds.

'Financing the Race to Space' is a masterful work that challenges and inspires. Armen V. Papazian's book is a must-read for policymakers, investors,

and anyone with a keen interest in the future of space exploration. It is a testament to the power of visionary thinking and a significant contribution to the discourse on sustainable space development.

UK
June 2024

Alderman Professor Michael Mainelli
The Right Honourable The Lord Mayor
of London

Preface



Image Credit: NASA, Voyager 1, 1990, 3.7 bn miles (6 bn km) from the Sun.

“Look again at that dot. That’s there. That’s Earth. On it lived all those you will never meet and have never heard of, the species that ravaged its own home from under its own feet. In crafted confusion, they served imaginary debts and very real greed, failed to expand their reach, and suffocated themselves to oblivion—on a mote of dust suspended in a sunbeam.”

Sarl Cagan

Alien Astronomer*

* This quote is by the author—a satirical warning inspired by Carl Sagan’s famous paragraph in *Pale Blue Dot* (Sagan, 1994): “Look again at that dot. That’s here. That’s home. That’s us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every ‘superstar,’ every ‘supreme leader,’ every saint and sinner in the history of our species lived there—on a mote of dust suspended in a sunbeam.”

I felt compelled to write this book. While some of the arguments I discuss have been shared in two previous publications, *The Space Value of Money* and *Hardwiring Sustainability into Financial Mathematics*, the main theme, propositions, and style of this work are different and unique. I have also updated some of the concepts and included new material to make the arguments clearer and more relatable. Unlike the first two, both written for professionals and academics in finance, this book is designed to share the key insights of my research with a much wider audience.

I must clearly state from the outset that this book is entirely based on my own work and writing. I have not used any AI (Artificial Intelligence) tool. This is important and relevant for two main reasons. The first one is to address broader intellectual property concerns and to ensure the reader is aware that the words in this book have not been chosen through a series of probabilistic decisions. I have selected them based entirely on their ability to express the insights that preceded them. When necessary, words have been replaced and refined, sentences have been improved, to embody the ideas in their most authentic form.

This brings me to the second more philosophical reason. In my view, the most critical challenge of Generative Pre-Trained Transformers (GPT) and the Large Language Models (LLMs) they rely on is the asymptotic and probabilistic nature of their intelligence. As such, however vast their data sets, however fast their processors, however extensive their training, however precise their memory, and however functionally and mechanically useful the machines may be, we are the ones who must invent the new equations upon which our improved future will be built. We must feed the machines, and indeed we do, directly and/or indirectly, consciously, or not.

I am not in a position to venture a guess regarding the timelines and capabilities of Artificial General Intelligence (AGI), but I can comfortably state that, for the foreseeable future, the purposeful, intentional, and creative application of human imagination will continue to be the driving force of human progress. This may change with the arrival of artificial intentional imagination (AIIM).

While AI is a defining element of our current and future progress, and relevant to the technological advances we will achieve on our way to the stars, it is not a core theme of this discussion. In other words, the above paragraphs are the extent of everything AI related in these pages.

This book lays down the monetary and financial foundations for a species actively pursuing outer space development, exploration, and settlement and offers the keys to unlocking the massive investment programs needed to invent, manufacture, deploy, and maintain the new habitats of the future.

The reference to the ‘race to space’ in the main title aims to contextualise the subject for a wider audience. Personally, I believe humanity’s outer space expansion should be a co-competition, i.e., a form of cooperative competition, not a race. Interestingly, the title can also be read to mean ‘financing the *human race* to space,’ which is exactly what this book is about. Furthermore, although the title refers to space, this book is about achieving meaningful milestones in *outer space*. This is an important nuance given that I define space as our physical context of matter, irrespective of constitution, composition, density, dynamics, and temperature, stretching from subatomic to interstellar space and every layer in between and beyond, where outer space, however vast, is but a segment.

In a molecular field of matter (and energy), where our imagination is a primary force of motion and transformation, everything we do and create on planet Earth is a direct function and result of our interpretations of ourselves and the universe. Our bodies, our planet, our solar system, the Milky Way,

and the entire observable universe are part of the space within and through which we act upon interpretation. Thus, what we do, invent, and achieve in this vast molecular context comes down to our own creative imagination, and our willingness to work and sacrifice for its realisation. This is true for all of us, individually and as a global collective. While I do not delve into philosophical discussions on the nature of reality, this is an important starting point as it determines the realm of what we consider possible.

Wherever one may be on planet Earth, or on the International Space Station (ISS), or Tiangong Space Station (TSS), at this very moment, and always, one is in between stars—above one's head and underneath one's feet. This is the true and authentic *where* of the human experience—a tangible given, more real than the entire taxonomy of our projected beliefs, whether economic, financial, monetary, or other. Indeed, however limiting our interpretations of our reality may be, whether on the level of the individual, a collective, or humanity as a whole, our context suggests otherwise.

Sandwiched between stars, to explore the universe our technological imagination must be matched with a commensurately bold and empowering financial imagination. We transcend our limiting interpretations in technology every day, and it is high time we find the new concepts through which we can address the debilitating assumptions of our financial and monetary economics.

At the edge of an ecological catastrophe, on Earth, in space, we must find a way to transform and remove the intellectual and structural impediments to our evolution and the survival of our children. Ultimately, our struggle is not with carbon in the air, with plastic in the oceans, with sewage in the rivers, or with the debris in orbit. It is also not with gravity. Our truest challenge is human mediocrity, in all its shapes and forms, in ourselves and around us, reducing our planet into a consumable of our own confusion, and the universe into a failed version of itself.

Indeed, it is entirely possible that there are other more enlightened civilisations in the universe who have no need for money and do not require monetary incentives to guide their own productive power. It is also entirely possible that they do not need to be persuaded to value the ecosystem they inhabit, and thus, they do not need to be stopped from destroying their own home. As such, from their perspective, the entire content of this book can be considered a worthless evolutionary compromise.

As individuals, nations, and humanity, we are in the grip of our own interpretations and misinterpretations, and we must rethink and reimagine

ourselves to improve the world and extend our reach. This book aims to offer an alternative path that can empower us with the tools and concepts that can achieve both, our sustainability on Earth and expansion in outer space.

UK
July 2024

Armen V. Papazian

Acknowledgements

I owe thanks and gratitude to a number of institutions and individuals who have supported this project. Given that this work is partly based on two previous publications, *The Space Value of Money* and *Hardwiring Sustainability into Financial Mathematics*, the acknowledgements and support I have received for both books are relevant to this publication as well.

I am grateful to:

City of London Corporation for supporting my work and taking part in the launch of *Handwriting Sustainability into Financial Mathematics*.

King's College Cambridge University for continuously inspiring my work and partnering in the launch of *The Space Value of Money* and *Handwriting Sustainability into Financial Mathematics*.

Judge Business School Cambridge University for giving me the platform to express the early insights discussed in this book and partnering in the launch of *The Space Value of Money* and *Handwriting Sustainability into Financial Mathematics*.

The Chartered Institute for Securities and Investment for supporting my work and sponsoring the launch of *Handwriting Sustainability into Financial Mathematics*.

Palgrave Macmillan for continuously supporting my work, ensuring its worldwide distribution, and partnering in the launch of *Handwriting Sustainability into Financial Mathematics*.

Federated Hermes Limited for sponsoring my research during the writing of *The Space Value of Money* and the launch event of *Handwriting Sustainability into Financial Mathematics*.

Institute of Chartered Accountants in England and Wales for hosting and supporting the launch of *Handwriting Sustainability into Financial Mathematics*.

Tech Nation for providing me with the sponsorship that allowed me to continue working on this book as well as *The Space Value of Money* and *Handwriting Sustainability into Financial Mathematics*.

National Space Society for endorsing an earlier paper on the topic and supporting my work.

Space Renaissance International for endorsing an earlier paper on the topic and inviting me to lecture on some of the key ideas discussed in this book.

18th SDG for Space Coalition for endorsing an earlier paper on the topic.

Space Value Foundation for continuously supporting my work and ideas, and for advocating for their adoption.

I owe special thanks to the 695th Lord Mayor of London, Alderman Professor Michael Mainelli, for accepting the invitation to write a foreword. I am inspired by his words and grateful for his support.

I owe special thanks to Dr. Gillian Tett, OBE, Karlton D. Johnson, Tracy Vegro, OBE, and Adrian Webb for reading an early draft of the book and providing reviews.

I owe special thanks to Prof. Gishan Dissanaiké, Lt Col. Peter Garretson, Dr. Keith Carne, Dr. Saker Nusseibeh, CBE, Dr. Pascal Blanqué, Daud Vicary, Domenico Del Re, George Littlejohn, Dr. Matteo Cominetta, Eoin Murray, Giotto Castelli, Prof. Christine Hauskeller, Prof. Aram A. Amasian, and Dr. Jonathan Bonello for their support, for reading and providing reviews.

I owe special thanks to Tula Weis for her unwavering support, she has played a vital role in bringing this book to light, and to Susan Westendorf, Geetha Chockalingam, and Melvin Lourdes Thomas for a swift and highly professional production of the book.

I am grateful to the following individuals for their direct and/or indirect contributions, recently or in the past:

Prof. Dame Sandra Dawson, Dr. Mark Carney, Dr. Rob Wallach, Prof. Geoff Meeks, Prof. Arnoud De Meyer, Prof. Ha-Joon Chang, Dr. Robin Chatterjee, Dr. Jose Gabriel Palma, Prof. Tony Lawson, Prof. Geoffrey Hodgson, Prof. Pierre-Charles Pradier, Prof. Peter Nolan, Prof. Shailaja

Fennell, Prof. Richard Barker, Dr. Rachel Armstrong, Dr. Richard Obousy, Kelvin F. Long, Dr. Ian J. O'Neill, Amalie Sinclair, Alan Sinclair, Adriano Autino, John Lee, Prof. Pier Marzocca, Prof. Dirk Schulze-Makuch, Prof. Joseph Miller, Charles Radley, Giorgio Gaviraghi, Eric Klein, David Brin, Prof. Edward Guinan, Dr. Cathy W. Swan, Prof. Peter A. Swan, Dr. Jose Cordeiro, Dr. Robert L. Frantz, Prof. Weilian Su, Dr. Mae Jemison, Dr. David Livingston, Michael Laine, Dr. Eric Davis, Marc G. Millis, Paul Gilster, John Davies, Dr. Andreas Hein, Robert Swinney, Patrick Mahon, Robert Kennedy III, Angelo Genovese, Prof. Gregory Matloff, Tony Manwaring, Mary Priddey, Charles Goldsmith, Erin Hallett, Sandie Campin, Ruth Newman, Jane Kemp, Jane Playdon, Myra MacMillan, Maris Kraulins, and Dr. Ivan Collister.

I am also grateful to the many colleagues, students, friends, and family who have contributed to the wealth and depth of my learning and experiences over the years. I have learned so much from so many.

While all must be thanked, mistakes remain my own.

Reviews

The Space Value of Money

“Every once in a while, a book comes along that makes a fundamental contribution that is both profound and practical. A book that every member of the National Space Council, including the NASA Administrator and the Space Force Chief of Space Operations should read. *The Space Value of Money* will be of interest to ESG and impact investors, government regulators, financial theorists, and outer space enthusiasts.”

—Lt Col Peter Garretson, *Senior Fellow in Defense Studies, American Foreign Policy Council*

“No doubt, the pressing environmental challenges we face make the concept of the space impact of investments even more compelling.”

—Dr. Pascal Blanqué, *Chairman of Amundi Institute, Former Group CIO of Amundi Asset Management*

“*The Space Value of Money* brings much needed conceptual rigour, whilst further advocating the case for a new paradigm shift in financial valuation. This work gives us the lasting frameworks that aggregate impact across all spatial dimensions. Dr. Papazian culminates over ten years of research in this rich book, providing the springboard for further innovation and system implementation in this area.”

—Domenico Del Re, *Director, Sustainability and Climate Change, PwC*

“Enthralling and captivating. Papazian offers a clear, thorough, and comprehensive discussion. The Space Value of Money gives us an opportunity to reframe our thinking and to explore what is possible. A great read!”

—Daud Vicary, *Founding Trustee of the Responsible Finance and Investment Foundation*

“Armen has developed a novel way to create financial models that are better suited to dealing with the many parameters required if we are to properly consider environmental factors and sustainability in economics and finance. I have found this engaging and look forward to seeing its future use.”

—Dr. Keith Carne, *First Bursar, King’s College, Cambridge University*

Hardwiring Sustainability into Financial Mathematics

“Dr. Papazian’s *Space Value of Money* concept addresses sustainability in microeconomics and macroeconomics—it critically updates and accounts for the additional dimension. This should be compulsory reading for all students of finance and investing.”

—Eoin Murray, *Head of Investment, Federated Hermes Limited*

“At a time when the climate crisis drives home the point for urgent action, and ESG measurements have come under intense scrutiny, one can hardly overstate the importance of this book. Rigorous and comprehensive, it offers an investment impact measurement methodology and answers the key financial question of our times: how can we fund the transition to a sustainable world? A finance handbook for the future.”

—Dr. Matteo Cominetta, *Head of Macroeconomic Research, Barings LLC*

“In the bewildering and ever-swelling sea of acronyms that now covers the world of sustainable finance, Dr. Armen Papazian’s laser-like focus on the financial mathematics of investment value and return is a most welcome addition to the profession’s navigation skills.”

—George Littlejohn, *Senior Adviser, Chartered Institute for Securities & Investment*

“This is a brave book—it highlights inconvenient truths about the financial mathematics of investment that guides the global flow of capital and offers thought through solutions. It is a must read for anyone concerned with planetary sustainability.”

—Adrian Webb, *Founder & Director, Space Value Foundation*

Financing the Race to Space

“*Financing the Race to Space* is a masterful work that challenges and inspires. Armen V. Papazian’s book is a must-read for policymakers, investors, and anyone with a keen interest in the future of space exploration. It is a testament to the power of visionary thinking and a significant contribution to the discourse on sustainable space development.”

—Alderman Professor Michael Mainelli, *The Right Honourable The Lord Mayor of London, City of London Corporation*

“*Financing the Race to Space* is an inspiring and ground-breaking blueprint for the future of space exploration. Blending visionary thinking with practical financial innovation, it offers transformative insights into funding sustainable space ventures and provides the tools and guidance needed to propel humanity’s most ambitious space endeavours. Papazian redefines the financial paradigm necessary for our leap into the cosmos. Essential and enlightening, a must-read for C-suite executives, investors, and policymakers.”

—Karlton D. Johnson, *CEO and Chairman of the Board of Governors, National Space Society*

“Investors, wisely advised by our members who understand the precepts that Dr. Papazian covers so well in his work, stand to reap the responsible rewards.”

—Tracy Vegro OBE, *CEO, The Chartered Institute for Securities & Investment*

“An extraordinary book that serves us and future generations with realism and optimism.”

—Adrian Webb, *Founder and Director, Space Value Foundation*

“A thought provoking and fresh way to look at finance and economics with a set of ideas that deserve wider debate.”

—Dr. Gillian Tett OBE, *Provost, King’s College Cambridge University, Editorial Board Member, Financial Times*

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About the Author



Armen V. Papazian is a financial economist and author of two books on sustainable finance, *The Space Value of Money* and *Hardwiring Sustainability into Financial Mathematics*. He is a founder and director of the Space Value Foundation. A Doctor of Financial Economics from Cambridge University, Judge Business School, King's College Cambridge, he is an active contributor to the public debate on sustainability in finance. A former investment banker, stock exchange executive, academic, and consultant, Armen combines extensive industry experience with financial institutions and markets, with in-depth research into the theoretical and practical aspects of sustainable finance. He is the first winner of the Alpha Centauri Prize for his work on money mechanics for space presented at the Starship Congress in 2013, in Dallas, TX, USA.

Abbreviations

AGI	Artificial General Intelligence
AI	Artificial Intelligence
AIIM	Artificial Intentional Imagination
APF	Asset Purchase Facility
APT	Arbitrage Pricing Theory
BEA	Bureau of Economic Analysis
BEAPFF	Bank of England Asset Purchase Facility Fund Limited
BOE	Bank of England
CAA	Climate Ambition Alliance
CAPEX	Capital Expenditure
CAPM	Capital Asset Pricing Model
CCL	Commerce Control List
CDO	Collateralised Debt Obligations
CE	Credit Easing
CGFI UK	Centre for Greening Finance and Investment
CGFI-SFI UK	Centre for Greening Finance and Investment, Spatial Finance Initiative
COPUOS	United Nations Committee on the Peaceful Uses of Outer Space
CSRD	Corporate Sustainability Reporting Directive
DBEIS	Department for Business, Energy & Industrial Strategy
DCF	Discounted Cash Flow
DDM	Dividends Discount Model
DDTC	Directorate of Defense Trade Controls
DOJ	Department of Justice
DSIT	Department of Science, Innovation & Technology

EA	Environmental Agency
EAR	Export Administration Regulations
ECB	European Central Bank
EEA	European Environment Agency
EFSF	European Financial Stability Facility
EO	Earth Observation
ESA	European Space Agency
ESG	Environmental, Social, and Governance
EU	European Commission
FCF	Free Cash Flows
FCFE	Free Cash Flows for Equity
FCFF	Free Cash Flows for Firm
FDR	Franklin D. Roosevelt
FED	Federal Reserve
GDP	Gross Domestic Output
GEO	Geostationary Orbit
GHG	Greenhouse Gas
GIS	Geographic Information Systems
GLBA	Gramm-Leach-Bliley Act
GO	Gross Output
GPGP	Great Pacific Garbage Patch
GPS	Global Positioning System
GPT	Generative Pre-Trained Transformers
GSA	Glass-Steagall Act
GSV	Gross Space Value
HRC	Habitat Replacement Costs
IEA	International Energy Agency
IMF	International Monetary Fund
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
ISSB	International Sustainability Standards Board
ITAR	International Traffic in Arms Regulations
LCA	Life Cycle Assessment
LEO	Low Earth Orbit
LLM	Large Language Models
MBS	MORTGAGE-BACKED Securities
MEO	Medium Earth Orbit
MOD	Ministry of Defence
MTSCPCP	Minimum Temporary Survival Condition for a Planet-Consuming Parasite
NASA	National Aeronautics and Space Administration
NHS	National Health Service

NOSD	New Outer Space Deal
NOSS	National Outer Space Strategy
NPV	Net Present Value
NSC	Nihilistic Survival Condition
NSS	National Space Strategy
NSV	Net Space Value
OECD	Organisation for Economic Co-operation and Development
OSC	Office of Space Commerce
OST	Outer Space Treaty
PA	Paris Agreement
PB	Planetary Boundaries
PCN	Public Capitalisation Notes
PM	Particulate Matter
PMCCF	Primary Market Corporate Credit Facility
PNT	Positioning, Navigation and Timing
PPP	Public Private Partnership
PRI	Principles of Responsible Investment
QE	Quantitative Easing
SF	Sustainable Finance
SI	International System of Units
SMCCF	Secondary Market Corporate Credit Facility
SVoM	Space Value of Money
TSS	Tiangong Space Station
UK	United Kingdom
UKSA	United Kingdom Space Agency
UNFCCC	United Nations Framework Convention on Climate Change
UNOOSA	United Nations Office for Outer Space Affairs
US	United States
USML	United States Munitions List
VE	Value Easing
WACC	Weighted Average Cost of Capital
WC	Working Capital

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