The Monetisation of Space

Our Sustainability and Expansion in Space

frontiers | Frontiers in Space Technologies

The monetisation of space

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The defining obstacle to our expansion into outer space is not technological, but conceptual. While our engineering ingenuity has already enabled extraordinary feats — from lunar landings to Martian rovers and artificial intelligence—our financial and monetary economics remain shackled to inadequate assumptions that prohibit the sustainable expansion of our footprint in outer space and drag us ever closer to the edge of an ecological catastrophe on Earth. Today, neither billionaires, corporations, nor governments are able to fund our multi-planetary or multi-habitat future. I argue that our expansion into outer space requires a fundamental rethink of our financial value framework, mathematics, and monetary architecture. To unlock the massive investments needed for outer space development and settlement, we must first integrate space as a foundational dimension of value in finance—heretofore built around risk and calendar time. The introduction of space as an analytical dimension in finance is a first step that leads to a new principle of value, the Space Value of Money (SVoM), which, in turn, triggers a profound change in our mathematics and architecture. These transformations make the *monetisation of space* possible, i.e., the creation of money based on space value creation. The monetisation of space is translated into systemic change through the introduction of new financial instruments designed for central bank purchase. Public Capitalisation Notes (PCNs) are proposed as a viable alternative that can help fund our sustainable multi-planetary future.

KEYWORDS

space, risk, time, money, finance, investment, multi-planetary, sustainability

LIVING IN SPACE INITIATIVE

LIS INITIATIVE

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Dr. Armen V. Papazian

13th of November 2025

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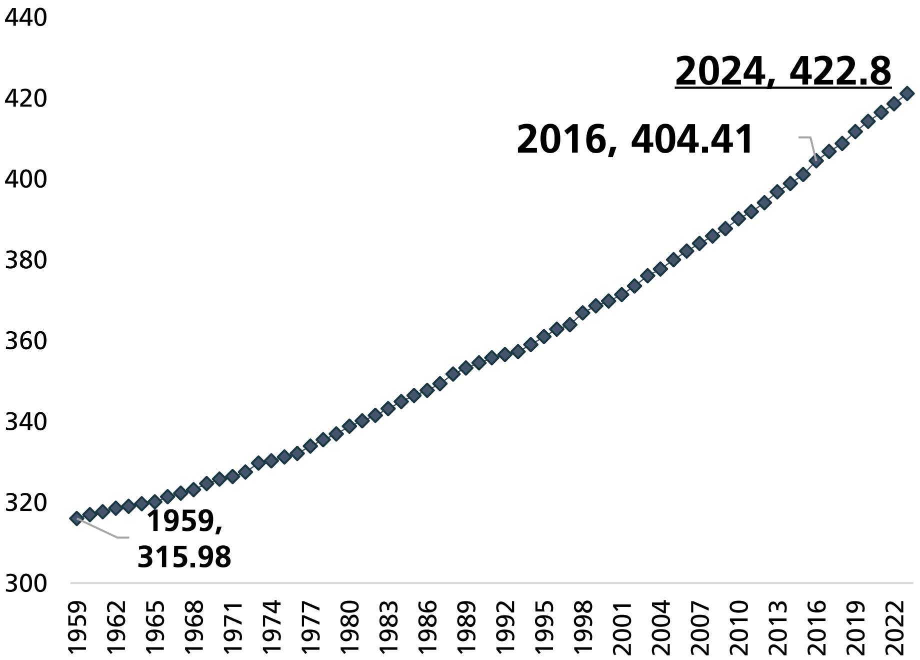
HUMAN PRODUCTIVITY

Configuration E101

Financial and Monetary Economics

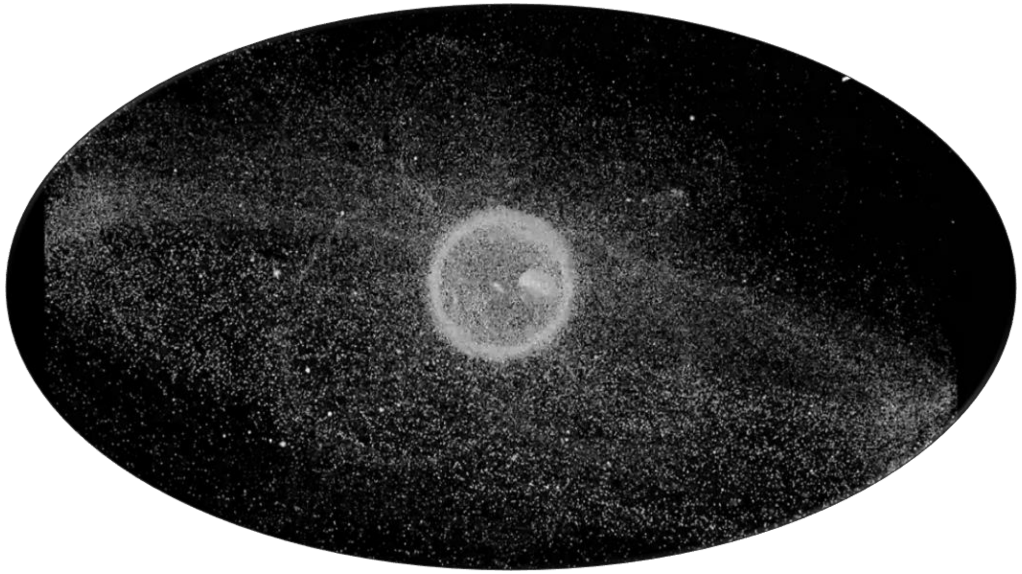
The five offshore plastic accumulation zones in the world's oceans

Source: Author, using Ocean Cleanup (2024), and map from CIA (2023)



Atmospheric CO2, yearly mean, mole fraction in dry air (ppm)

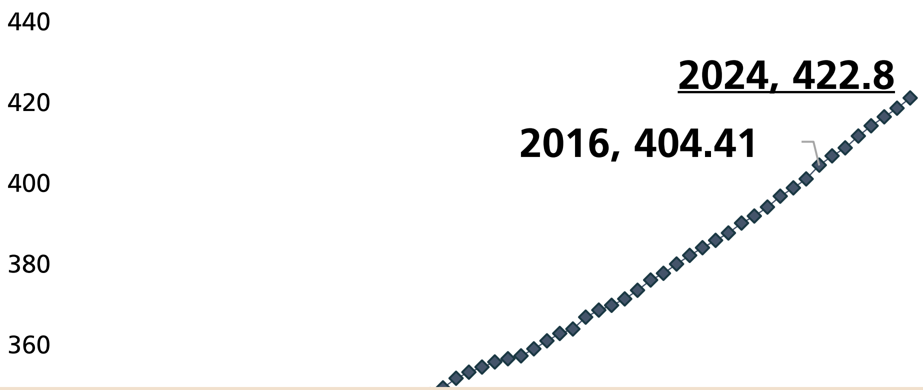
Source: NOAA (2024)

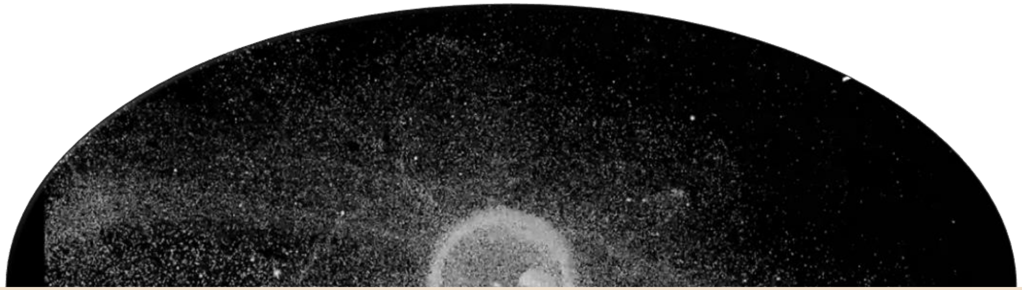


Outer Space Debris Simulation >1mm

Source: ESA (2019)

The five offshore plastic accumulation zones in the world's oceans
Source: Author, using Ocean Cleanup (2024), and map from CIA (2023)





Human productivity is effectively careless, and we are littering every environment we touch.

January 2024:

“Busiest start to a year since the Space Age dawned in 1957”

(Space Foundation 2024)

Total Orbital Launches, and by country, from Q1/2023 to Q2/2025

Source: Papazian (2024) compiled and updated using BryceTech (2025)

		Q1/2023	Q2/2023	Q3/2023	Q4/2023	Q1/2024	Q2/2024	Q3/2024	Q4/2024	Q1/2025	Q2/2025	TOTAL	Percentage
USA	**92.48%**	27	25	32	30	36	42	32	44	42	54	364	58.24%
China		14	11	20	22	14	16	16	22	17	19	171	27.36%
Russia		6	3	4	6	5	3	3	6	4	3	43	6.88%
India		2	2	3	0	2	0	1	2	1	1	14	2.24%
Japan		2	0	1	0	3	0	2	2	1	1	12	1.92%
Europe/France/Germ		0	1	1	1	0	0	2	1	2	1	9	1.44%
Iran		0	0	1	0	2	0	1	1	0	0	5	0.80%
N Korea		0	1	1	1	0	1	0	0	0	0	4	0.64%
S Korea		0	1	0	1	0	0	0	0	0	0	2	0.32%
Israel		1	0	0	0	0	0	0	0	0	0	1	0.16%
Total		52	44	63	61	62	62	57	78	67	79	**625**	100.00%

A dozen countries (out of 195) are enabling and defining our footprint beyond our atmosphere.

Table 2: GDP of Countries with Orbital Launch Capability, 2024

Source: IMF (2025), except for North Korea, online sources estimate.

Source: IMF World Economic Outlook (2025)	GDP, current prices (Billions of U.S. dollars) 2024	Orbital Launches Q1/23 -Q2/25 Total
United States	29298.025	364
Europe	27203.017	9
China, People's Republic of	18749.759	171
Germany	4684.182	Europe
Japan	4019.382	12
India	3909.892	14
United Kingdom	3644.636	0
France	3160.902	Europe
Russian Federation	2173.225	43
Korea, Republic of	1875.388	2
United Arab Emirates	552.325	0
Israel	542.285	1
Iran	416.676	5
North Korea (DPRK) (Estimated)	34.9	4

Building orbital access capability is about policy prioritisation, and <u>not</u> economic size.

Number of Spacecraft and Upmass Carried by Launch Provider from Q1/2023 to Q2/2025

Source: Papazian (2024) compiled and updated using BryceTech (2025)

	Q1/2023		Q2/2023		Q3/2023		Q4/2023		Q1/2024		Q2/2024		Q3/2024		Q4/2024		Q1/2025		Q2/2025		TOTAL	
Name of Provider	**Number**	**Kg**	**Number**	**Kg**	**Number**	**Kg**	**Number**	**Kg**	**Number**	**Kg**	**Number**	**Kg**	**Number**	**Kg**	**Number**	**Kg**	**Number**	**Kg**	**Number**	**Kg**	**Number**	**Kg**
Space Exploration Technologies (SpaceX)	763	233,114	648	214,095	519	381,278	590	382,080	525	429,125	659	530,488	518	362,087	680	540,678	780	477,570	1,060	639,282	6,742	4,189,797
China Aerospace Science & Technology Corp. (CASC)	31	23,965	49	23,069	24	24,560	31	40,810	27	29,426	23	35,534	56	30,350	78	65,996	58	44,791	50	53,230	427	371,731
Roscosmos	6	23,093	2	8,100	4	17,475	7	25,612	24	13,782	13	12,820	4	415	60	24,458	8	12,450	4	11,272	132	149,477
Rocket Lab	7	427	1	21	9	416	1	100	10	508	9	285	7	1,212	7	2,283	20	602	8	515	79	6,369
United Launch Alliance (ULA)			1	5,000	3	6,000	2	1,200	7	1,285	2	19,000	3	200	1	123			54	31,050	73	63,858
Galactic Energy	5	179			15	1,280	2	265			13	810	7	3,860	4	1,500	19	1,360	4	200	69	9,454
CAS Space			26	912					5	890			5	608	26	5,400			6	920	68	8,730
Indian Space Research Organisation (ISRO)	39	5,466	4	2,722	11	5,817			2	2,744			1	60	4	1,210	1	2,250	1	1,696	63	21,965
GK Launch Services			49	3,168																	49	3,168
ExPace	4	200	1	20	9	425	8	400	5	350	4	616	4	450	1	200	1	100			37	2,761
Arianespace			4	5,963	2	6,950	12	806					12	14,760	1	250	1	3562	1	1,131	33	33,422
Chinarocket Co. Ltd.							1	200	9	575			8	4,200			10	1200			28	6,175
Mitsubishi Heavy Industries Launch Services					4	3,050			4	4,755			2	175	1	150	1	4900	1	2,600	13	15,630
Landspace					1	1	3	150							2	255			6	923	12	1,329
Firefly Aerospace					1	200	1	250					8	3,900					1	450	11	4,800
Korea Aerospace Research Institute (South Korea)			8	202																	8	202
Virgin Orbit	8	35																			8	35
Iranian Space Agency									3	40					3	1,000					6	1,040
Space One (Canon/IHI)									1	100					5	2,280					6	2,380
I-Space			1	100			1	250					3	258							5	608
Korean Committee of Space Technology (North Korea)			1	5	1	250					1	100									3	355
Orienspace									3	300											3	300
Northrop Grumman Space Systems					1	8,051													2	500	3	8,551
China Manned Space Agency							1	8,100			1	8,082									2	16,182
Islamic Revolutionary Guard Corps									1	50			1	34							2	84
ABL Space Systems	2	22																			2	22
Japan Aerospace Exploration Agency (JAXA)	2	3,500																			2	3,500
China National Space Administration			1	8,082																	1	8,082
Iranian Revolutionary Guards Air Force					1	10															1	10
National Aerospace Technology Administration							1	250													1	250
South Korea Ministry of National Defense							1	100													1	100
Space Pioneer			1	8																	1	8
Israel Defense Forces	1	260																				
Blue Origin																	1	500				
Relativity Space	1	5																			1	5
Isar Aerospace Technologies Gmbh																	0	0			0	0
Total	**869**	**290,266**	**797**	**271,467**	**605**	**455,763**	**662**	**460,573**	**626**	**483,930**	**725**	**607,735**	**639**	**422,569**	**873**	**645,783**	**900**	**549,285**	**1,198**	**743,769**	**7,894**	**4,931,140**

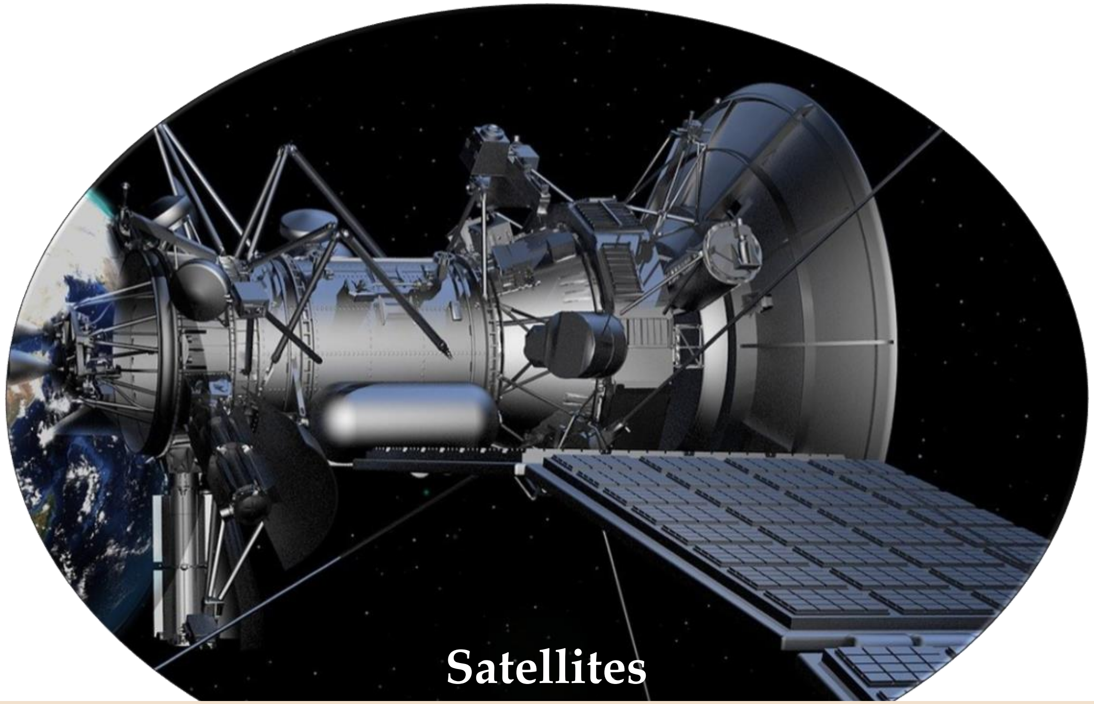
7,894 4,931,140

36 providers, public and private, civil and military

MAY 2025: 11,700

2030: 100,000

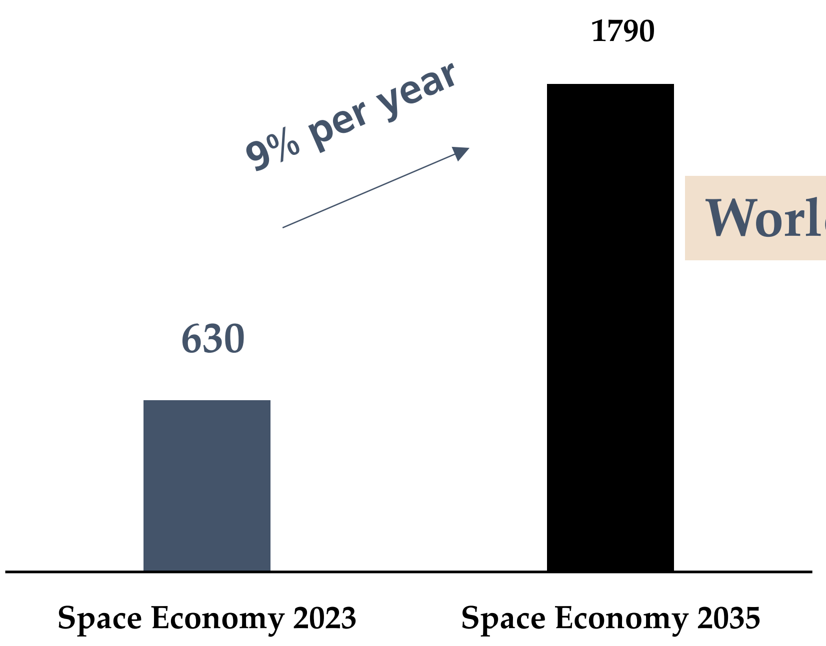
Using space-based infrastructure to deliver goods and services on Earth and for national security.



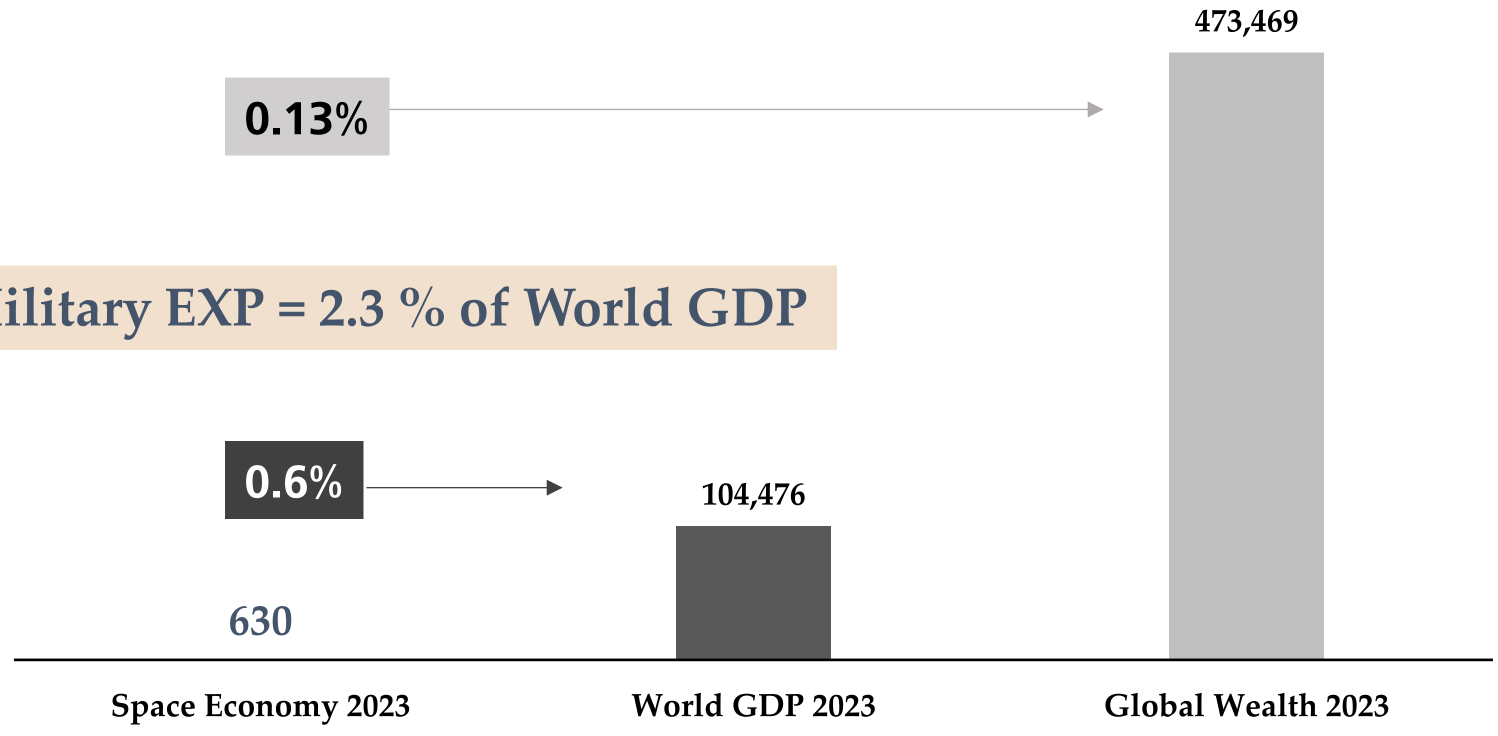
Space Exploration Applications at 2.5% (WEF-McKinsey, 2024)

Human productivity is effectively still Earthbound.

Global 'Space Economy', 2023 - 2035, $Bn
Source: WEF-McKinsey (2024)



Relative to World GDP 2023 and Global Wealth 2023, $Bn
Source: IMF (2024), UBS (2024)

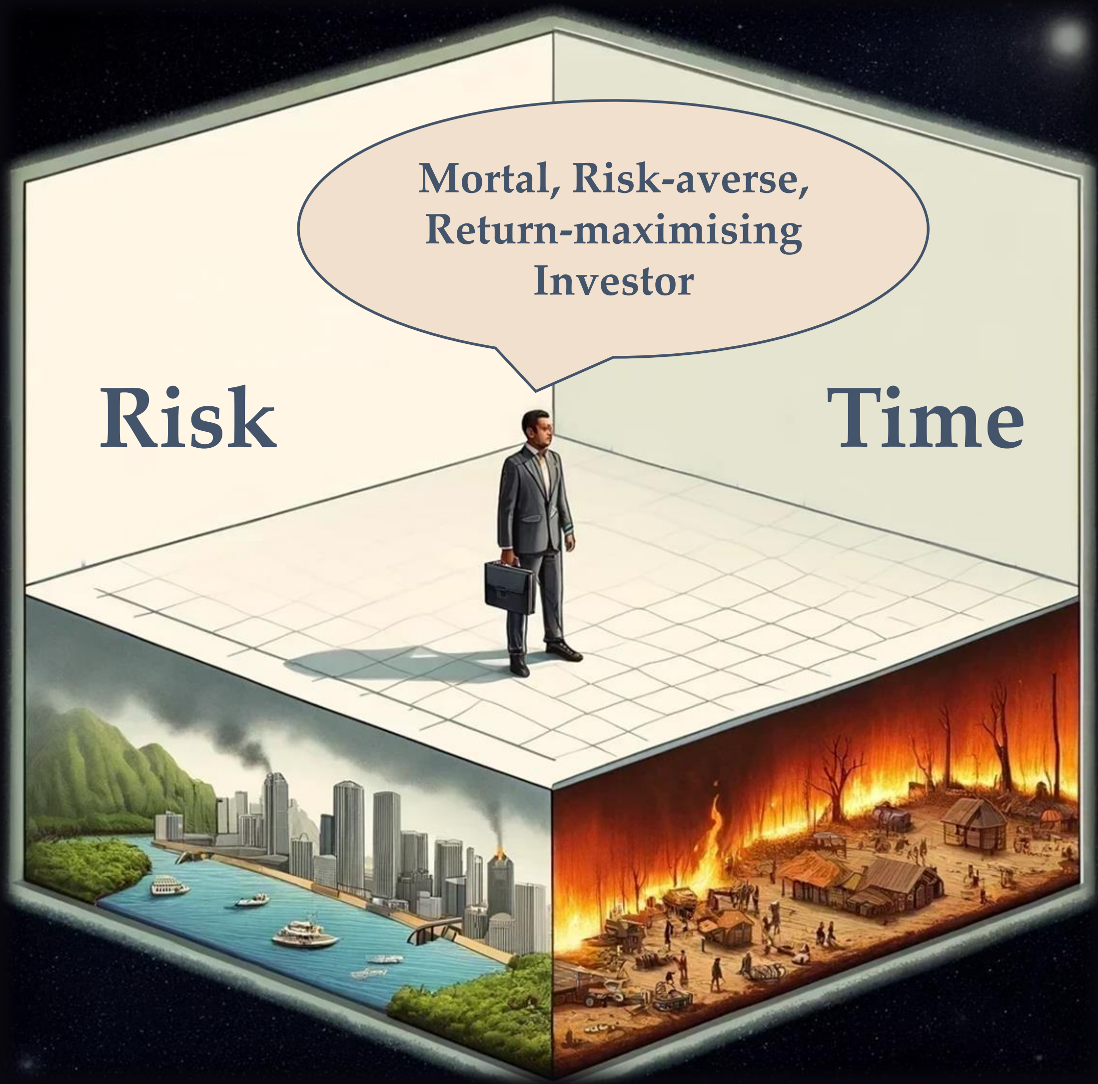


Humanity spends more on protecting itself from itself than on building its collective future in outer space.

HUMAN PRODUCTIVITY

CARELESS & EARTHBOUND

Financial value framework
Financial mathematics
Monetary architecture



Financial value framework
Financial mathematics
Monetary architecture

Space, <u>our physical context</u>, is missing.

Key Equations of Value and Return in Finance

Sample Bond Valuation Equations

$$Bond\ Value = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} + \frac{P}{(1+r)^n}$$

$$Bond\ Value = \sum_{t=1}^{n\times m} \frac{C_t}{\left(1+\left(\frac{r}{m}\right)\right)^t} + \frac{P}{\left(1+\left(\frac{r}{m}\right)\right)^{n\times m}}$$

Elements

- n = Maturity or Number of Periods
- m = Number of Compounding
- t = Moving time
- r = Discount Rate or Yield to Maturity
- P = Par Value of Bond
- C_t = Coupon Payments

Sample of Stock and Firm Valuation Equations

$$P_0 = \frac{D_1}{r-g}$$

$$P_0 = \sum_{t=1}^{n} \frac{D_t}{(1+WACC)^t} + \frac{P_n}{(1+WACC)^n}$$

$$P_0 = \sum_{t=1}^{n} \frac{D_t}{(1+WACC)^t} + \frac{D_{n+1}}{(WACC-g).(1+WACC)^n}$$

- P_0 = Stock price
- g = Constant Growth Rate in Dividends
- r = Constant Cost of Capital
- D_1 = Next Year/Period Dividend
- P_n = Terminal Value= (D_{n+1}/WACC-g)
- D_t = Dividend at t
- D_{n+1}=Dividend at n+1
- WACC = Weighted Average Cost of Capital
- g = Constant Growth Rate in Dividends
- $FCFF_t$ = Free Cash Flow to Firm at t

Sample of Asset Pricing Models

$$R_i = R_f + \beta_i \times (R_m - R_f) \qquad \beta_i = \frac{Covariance_{R_i,R_m}}{Variance_{R_m}}$$

$$E(R_i) - R_f = b_1\big(E(R_M) - R_f\big) + s_i E(SMB) + h_i E(HML)$$

- R_i = Return on security i
- R_f = Risk Free Rate
- β_i = Beta= Systematic Risk Proxy
- Rm = Return on market
- $E(R_i) - R_f$ = Expected Excess Return Stock i
- $E(R_i)$ = Expected Return on Stock i
- R_f = Risk Free Rate
- $E(R_M)$ = Expected Return on Market
- $E(R_M) - R_f$ = Exp. Market Risk Premium
- $E(SMB)$ = Expected Size Premium
- $E(HML)$ = Expected Value Premium
- b_i, s_i, h_i = Factor Sensitivities or Loadings

Modigliani Miller Corporate Value & Capital Structure Model

$$V_j = (S_j + D_j) = \frac{\bar{X}_j}{\rho_k}$$

$$i_j = \rho_k + (\rho_k - r)\frac{D_j}{S_j}$$

- Vj = Value of Firm j
- Sj = Market Value of Common Shares of j
- Dj = Market Value of Debts of j
- Xj = Expected Return on the Assets owned by the company
- ρk = Capitalisation Rate for shares in class k

Black and Scholes Option Pricing Model

$$C = SN(d) - Le^{-rt}N(d - \sigma\sqrt{t})$$

$$d = \frac{\ln\frac{S}{L} + \left(r + \frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}}$$

- C = Value of Call Option
- Nd = Normal Distribution Function
- t = Time to Maturity
- L = Exercise (Strike)Price of Option
- σ = Standard Deviation of Return on Stock
- r = Risk Free Interest Rate
- S = Current Stock Price or Asset Price

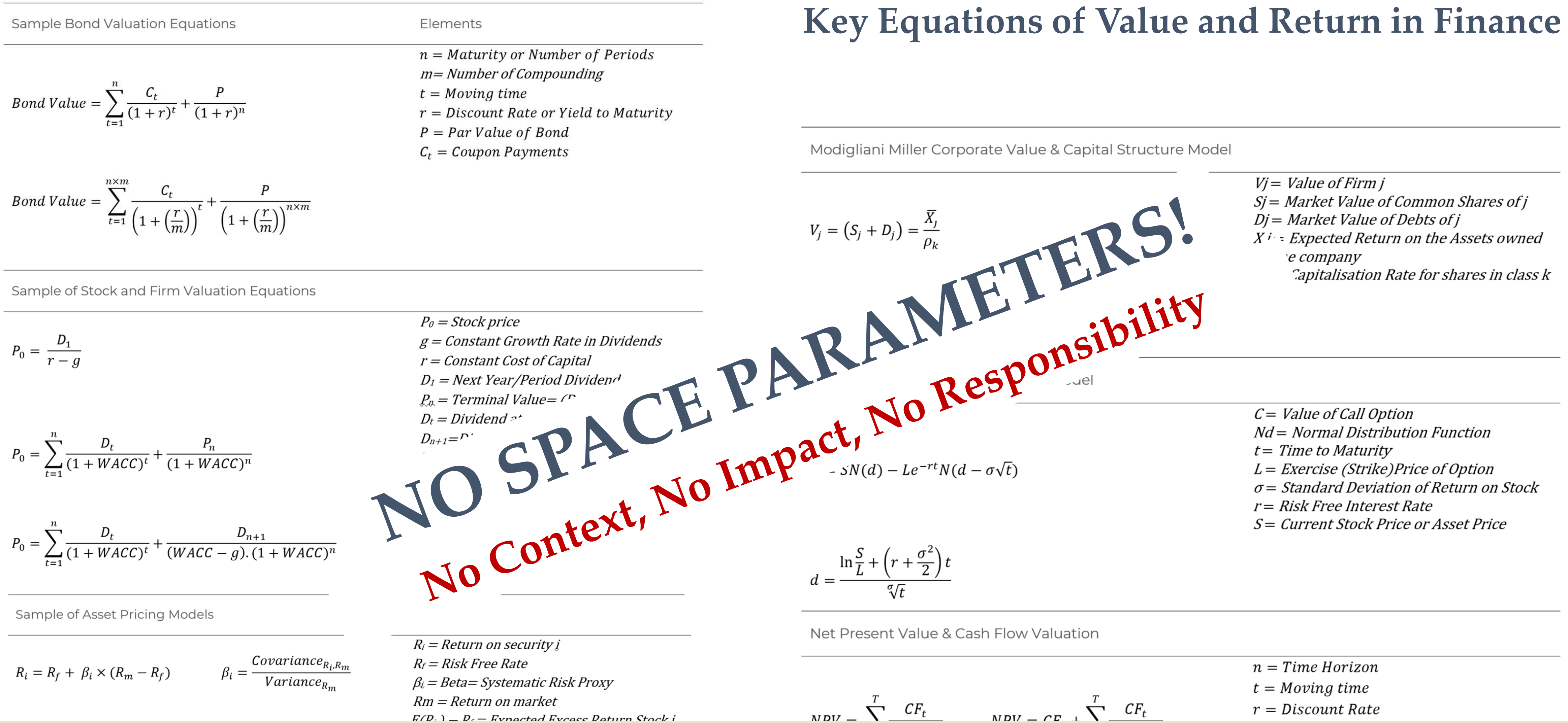
Net Present Value & Cash Flow Valuation

$$NPV = \sum_{t=0}^{T} \frac{CF_t}{(1+r)^t} \qquad NPV = CF_0 + \sum_{t=1}^{T} \frac{CF_t}{(1+r)^t}$$

$$Net\ Present\ Value = -II + \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t}$$

- n = Time Horizon
- t = Moving time
- r = Discount Rate
- II = Initial Investment
- CF_t = Future Expected Cash Flows at t

Key Equations of Value and Return in Finance



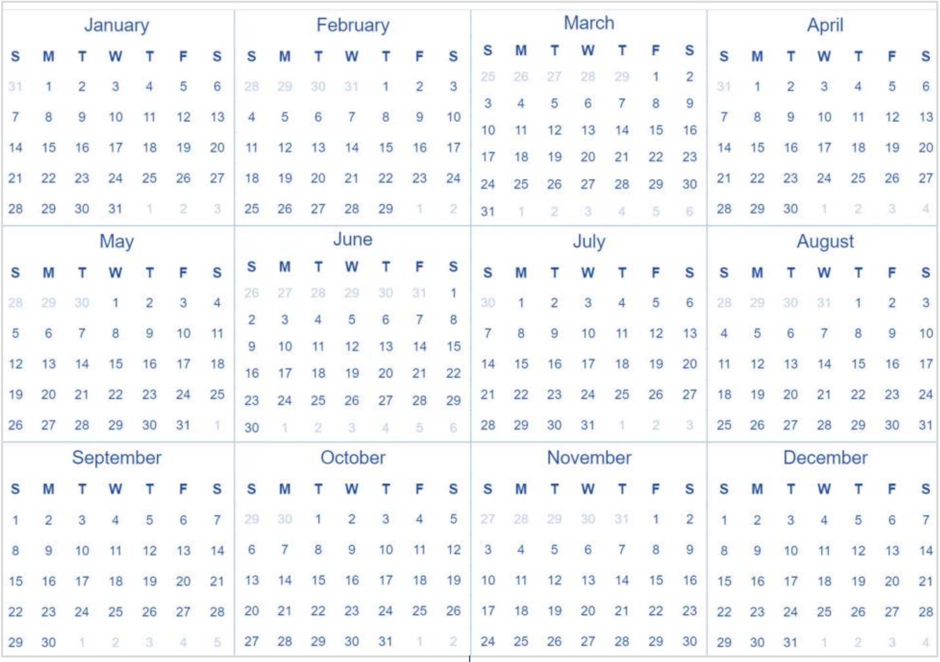
A spaceless financial value framework & mathematics
constrain the public and private parts of the outer space economy.

All forms of fiat money are created through or backed by debt instruments.

<u>Quantitative Easing (QE):</u> Purchase of bonds with
Freshly created central bank reserves

$$Bond\ Value = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} + \frac{P}{(1+r)^n}$$

RISK **TIME**

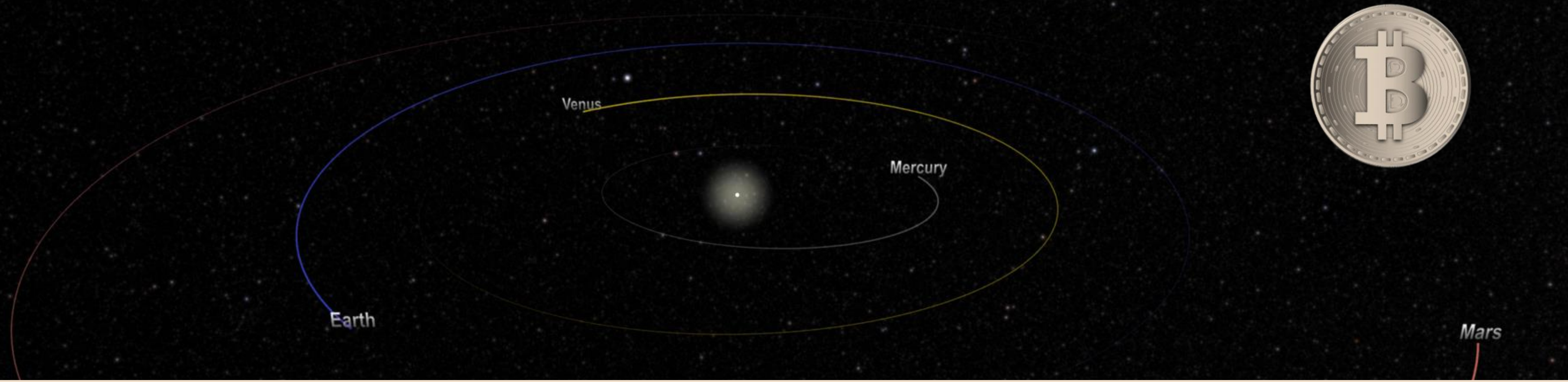


Rotation 24 hours = **1day**
Revolution 365 days = **1 year**

Video Credit: NASA https://svs.gsfc.nasa.gov/4790/

The monetisation of risk and calendar time

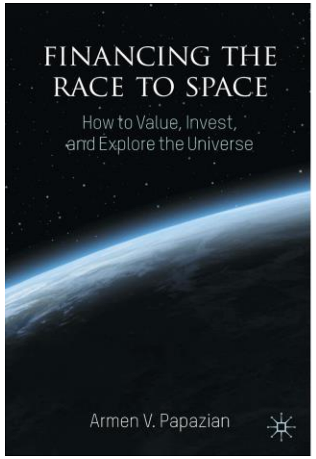
Cryptocurrencies do <u>not</u> address the issue

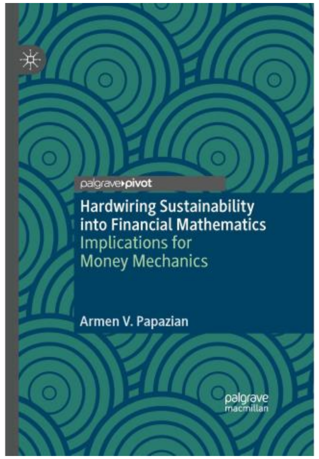


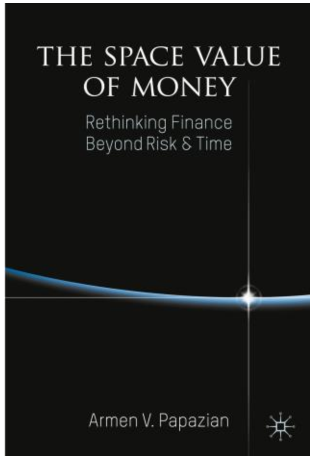
A debt-based monetary architecture monetises the fixed movements of Earth in space but not Earth itself, not Space.

Space layers
Source: Papazian (2024)

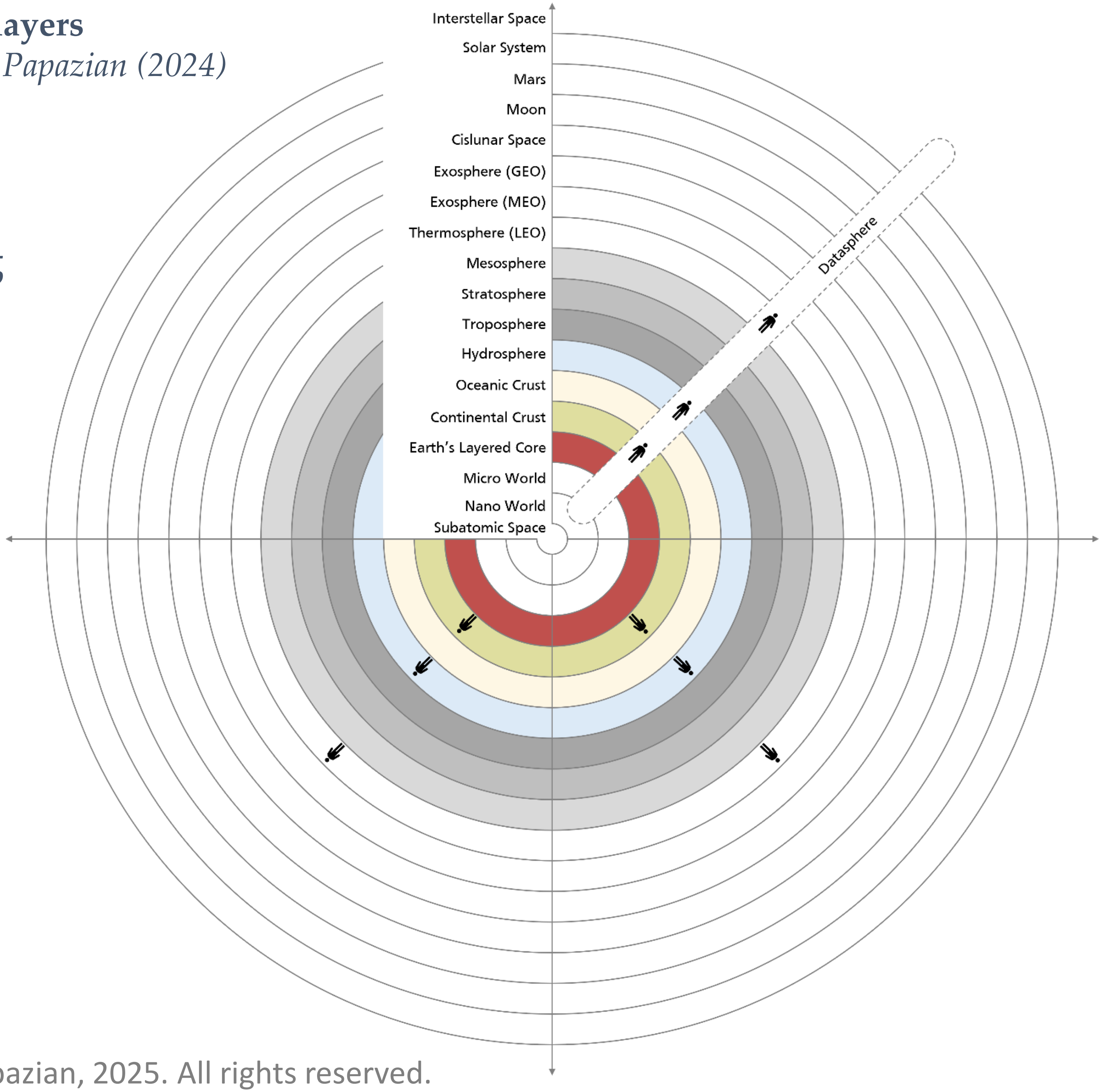
Space, our physical context, stretching from subatomic to interstellar space and every layer in between and beyond.







The Space Value Of Money

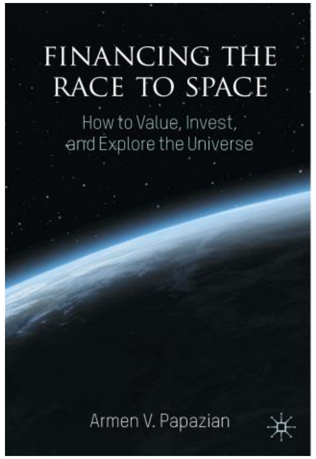


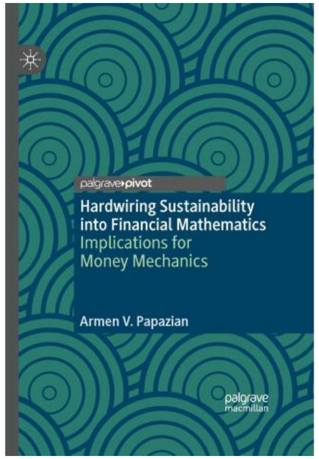
Equations of Impact and Space Value

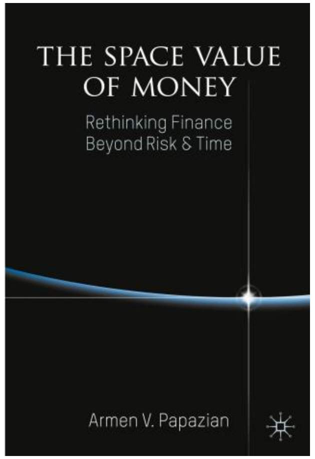
Source: Papazian (2024)

Impact Aspect	Net Space Value	$g \times (PI_{T,S,P} + BI_{T,S,B} + HCI_{T,S} + RDI_{T,S,N} + NAI_{D,S,A} + NMI_T)$
PLANETARY	Pollution Impact	$PI_{T,S,P} = \sum_{t=1}^{T} \sum_{s=1}^{S} \sum_{p=1}^{P} Q_{pst} \times C_{pst}$
	Biodiversity Impact	$BI_{T,S,B} = \sum_{t=1}^{T} \sum_{s=1}^{S} \sum_{b=1}^{B} A_{bst} \times R_{bst}$
HUMAN	Human Capital Impact	$HCI_{T,S} = f \times \sum_{t=1}^{T} \sum_{s=1}^{S} E_{st} + T_{st} + H_{st} + I_{st} + C_{st} + S_{st}$
	R and D Impact	$RDI_{T,S,N} = \sum_{t=1}^{T} \sum_{s=1}^{S} \sum_{n=1}^{N} h_n \times RD_{tsn}$
ECONOMIC	New Asset Impact	$NAI_{D,S,A} = \sum_{s=1}^{S} \sum_{a=1}^{A} k_a \times BVA_{asD}$
	New Money Impact	$NMI_T = (II \times DR \times BLR) + mm \times (II + X_T - M_T)$

Coefficients	Fairness	f
	Health	h
	Transition	k
	Governance	g



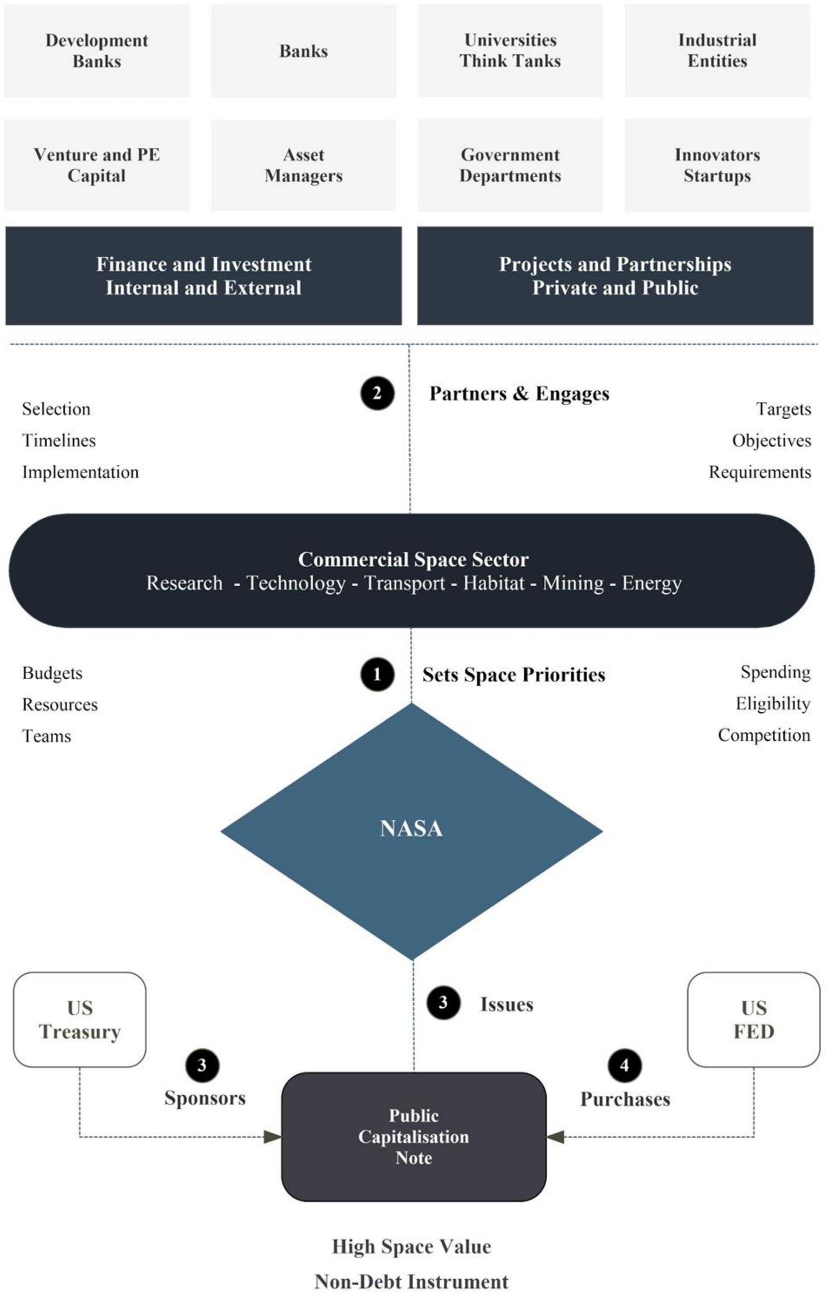


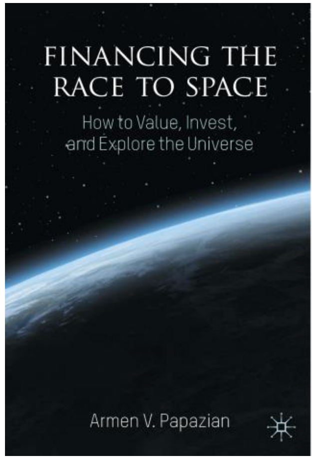


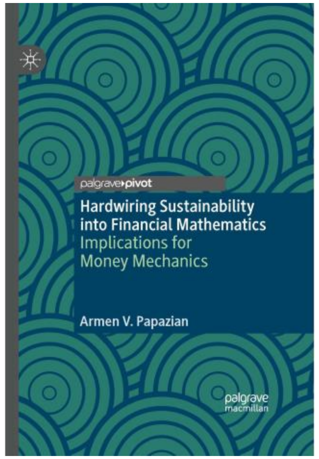
The Space Value Of Money

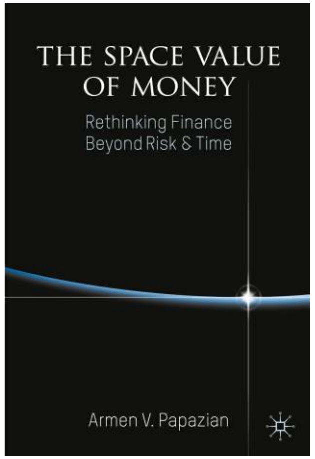
Public Capitalisation Notes – NASA PCN

Source: Papazian (2024)









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Thank You!

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