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Law and Regulation of Commercial Mining of Minerals in Outer Space

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In a closed society Malthusianism has the appearance of self-evident truth, and herein lies the danger. It is not enough to argue against Malthusianism in the abstract - such debates are not settled in academic journals. Unless people can see broad vistas of unused resources in front of them, the belief in limited resources tends to follow as a matter of course. And if the idea is accepted that the world's resources are fixed, then each person is ultimately the enemy of every other person, and each race or nation is the enemy of every other race or nation. The extreme result is tyranny, war and even genocide. Only in a universe of unlimited resources can all men be brothers.

Robert Zubrin and Richard Wagner[1]

[1] Robert Zubrin and Richard Wagner, THE CASE FOR MARS: THE PLAN TO SETTLE THE RED PLANET AND WHY WE MUST (1997), at 303.

Acknowledgements

The field of space law appealed to me originally as a convenient combination of my casual interest in space and my legal studies. Over the years, however, it grew from a peripheral interest to become a passion and from that passion grew a career path that has been both challenging and rewarding. I still recall that one Thursday afternoon in 1998 at the University of Adelaide when I was at lunchtime seminar on space law and its opportunities presented by Michael E. Davis, now a partner at the law firm of Adelta Legal in Adelaide, Australia. From that time, not content with having introduced me to this new and exciting field of law, Mr. Davis soon became my employer and continues to be an invaluable support, mentor and friend. Mere written words are never enough to express my gratitude to him for all that he has done for me, but I offer them here nonetheless as a very small token of my thanks.

In late 1999, after I was elected a member of the International Institute of Space Law, Mr. Davis introduced me to the late Associate Professor Alexis Goh of the University of Western Sydney as a useful contact in that endeavour. After I moved to Canberra from Adelaide in 2000, she encouraged me to undertake this monograph as a doctoral thesis at the University of Western Sydney and she herself became my extremely supportive supervisor. She had shown tremendous faith and high expectations in my abilities as a doctoral candidate and as a teaching academic, both of which I have tried over the years to meet as much as I can though in truth I know I probably can never meet. She was a generous and understanding boss, an encouraging but critical supervisor, a resourceful and supportive friend without whom this work (and my academic career) would never have become a reality. She is much missed.

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The contribution of Professor David Flint AM of Murdoch University (Australia), Professor Paul B. Larsen of Georgetown University (the United States) and Professor Francis Lyall of the University of Aberdeen (the United Kingdom) in

examining this monograph, which was submitted as a doctoral thesis at Murdoch University, must be recognised.

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It goes without saying, though worth saying nonetheless, that without the continuing support encouragement and love of my family, I can achieve nothing in my life. I am very grateful, even though I may not appear to show it from time to time.

Of course, all faults and shortcomings in this monograph are exclusively my own and I count on the support of my friends and the vindictiveness of my enemies to show me any errors of my work.

Sydney, Australia Ricky J. Lee

List of Abbreviations

AAS	American Astronomical Society
ACP	African, Caribbean and Pacific Group of States
AIAA	American Institute of Aeronautics and Astronautics
AN	Ascending node
ARABSAT	Arab Corporation for Space Communications
AU	Astronomical Unit
COPUOS	Committee on Peaceful Uses of Outer Space
COSPAR	Committee on Space Research
DN	Descending node
ECAS	Eight Colour Asteroid Survey
ECSL	European Centre for Space Law
EEC	European Economic Community
ENPV	Expected Net Present Value
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EUTELSAT	European Telecommunication Satellite Organisation
GATT	General Agreement on Tariffs and Trade
GEO	Geostationary Earth Orbit
HEEO	Highly Elliptical Earth Orbit
IAU	International Astronomical Union
IBA	International Bar Association
IBRD	International Bank for Reconstruction and Development
ICC	International Chamber of Commerce
IISL	International Institute of Space Law
ILC	International Law Commission
IMF	International Monetary Fund
INMARSAT	International Mobile Satellite Organisation
INTELSAT	International Telecommunication Satellite Organisation
ISA	International Seabed Authority
ISRO	Indian Space Research Organisation
ITLOS	International Tribunal for the Law of the Sea

ITU	International Telecommunication Union
LEO	Low Earth Orbit
NASA	National Aeronautics and Space Administration
NEAR	Near Earth Asteroid Rendezvous
NIEO	New International Economic Order
NPV	Net Present Value
OPEC	Organisation of Petroleum Exporting Countries
RLV	Reusable Launch Vehicle
ROI	Return on Investment
SSI	Space Studies Institute
SSPS	Space Solar Power Satellite
UN	United Nations
UNCLOS III	Third United Nations Conference on the Law of the Sea
UNCTAD	United Nations Conference on Trade and Development
UNESCO	United Nations Education, Scientific and Cultural Organisation
UNIDROIT	International Institute for the Unification of Private Law
USA	United States of America
USACERL	United States Army Construction Engineering Research Laboratory
WIPO	World Intellectual Property Organisation
WTO	World Trade Organisation

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Glossary

Absolute visual magnitude (H)	A measure of a celestial body's intrinsic brightness, measured in the standard V photometric band
Amor Asteroid	Asteroid with perihelion 1.017 AU $< q \leq$ 1.3 AU
Aphelion (Q)	The point on an orbit that is most distant from the Sun
Apollo Asteroid	Asteroid with perihelion $q <$ 1.017 AU and semi major axis $a >$ 1.0 AU
Arjuna Asteroid	Asteroid with Earth-like orbits with low inclination, low eccentricity and orbital periods close to one Earth year
Astronomical Unit (AU)	Unit of length equal to the mean distance between the Earth and the Sun, estimated in 2009 at 149,597,870,700 m
Aten Asteroid	Asteroid with semi major axis $a <$ 1.0 AU and aphelion $Q >$ 0.983 AU
Carbonyl	Compound of a metal with carbon monoxide (CO)
Conjunction	Where two objects are at the aphelion or perihelion at the same time
Earth Minimum Orbital Intersection Distance (MOID)	Minimum distance between closest points on the orbit of the Earth and the orbit of an asteroid or comet, usually given in astronomical units (AU). Potentially hazardous objects to the Earth have an Earth MOID of less than 0.05 AU
Eccentricity (e)	Measure of the circularity of the orbit where the more eccentric an orbit, the more oval shaped the orbit is
Ecliptic	The orbital plane on which the Earth orbits the Sun
Escape Velocity	Minimum speed an object without propulsion needs to have to move away infinitely from the gravity of an object
Hohmann Transfer Orbit	Elliptical orbit that is tangential to two coplanar orbits that is most energy efficient transfer trajectory
Hyperbolic Velocity	The velocity ($\Delta\vec{v}$) of an object relative to Earth or another celestial object when it is outside that body's gravity well

Impulse	Change in velocity ($\Delta\vec{v}$) that is given to an object in a short period of time relative to the total duration of the trajectory
Inclination (i)	The angle between the orbital plane of a particular object and the ecliptic
Kerogen	Solid hydrocarbons found in crude oil
Opposition	Where one object is at perihelion and the other is at aphelion
Perihelion (q)	The point on an orbit which is closest to the Sun
Planetesimal	One of a class of bodies that are theorised to have formed the planets after condensing from diffuse matter early in the history of the solar system
Pyrolysis	Generation of chemicals or free metals by heat decomposition
Regolith	The fragmented rocky debris blanketing the surface of the Moon, some asteroids and other small objects in the Solar System
Semi-major Axis (A)	The longest diameter of an elliptical orbit.
Synodic Period	Period of a body relative to the Earth
Transfer Orbit	The trajectory for an object travelling from one body to another
Trojan	An object which is trapped in a stable orbit 60° ahead of or behind the object as it orbits the Sun
Volatiles	Gases that can be released from comet cores by heating, producing gases such as water, carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), ammonia (NH_3) and hydrogen cyanide (HCN)

List of Reports, Series and Journal Titles

Source	Full title
A. F. L. Rev.	Air Force Law Review
A.S.I.L.S. Int'l. L. J.	Association of Student International Law Societies International Law Journal
A.T.S.	Australian Treaty Series
Abs. Lunar & Planetary Sci. Conf.	Abstracts of the Lunar and Planetary Science Conference
Acta Astron.	Acta Astronautica (Journal of the International Academy of Astronautics)
Acta Juridica	Acta Juridica (Law Journal of the University of Cape Town)
Ad Astra	Ad Astra (Journal of the National Space Society)
Adel. L. Rev.	Adelaide Law Review
Adv. Space Res.	Advanced Space Research
Air & Sp. L.	Air & Space Law
Akron L. Rev.	Akron Law Review
Am. J. Int'l. L.	American Journal of International Law
Am. J. Int'l. L. Supp.	American Journal of International Law Supplement
Am. Soc. Int'l. L. Proc.	Proceedings of the American Society of International Law
Am. U. J. Int'l. L. & Pol'y.	American University Journal of International Law and Policy
Am. U. L. Rev.	American University Law Review
Ann. Air & Sp. L.	Annals of Air and Space Law
Ann. Assoc. Am. Geog.	Annals of the Association of American Geographers
Ann. Rev. Astron. & Astrop.	Annual Review of Astronomy and Astrophysics
Ann. Rev. Energy	Annual Review of Energy
App. Geog.	Applied Geography
Astron. & Astrophys.	Astronomy and Astrophysics

Astron. Gesell. Abs. Ser.	Astronomische Gesellschaft Abstract Series (Astronomical Society Abstract Series)
Astron. J.	Astronomical Journal
Astrophysics J.	Astrophysics Journal
Aust. Int'l. L. J.	Australian International Law Journal
Aust. J. Astron.	Australian Journal of Astronomy
Aust. Y. B. Int'l. L.	Australian Yearbook of International Law
Az. J. Int'l. & Comp. L.	Arizona Journal of International and Comparative Law
B. C. Envt'l. Aff. L. Rev.	Boston College Environmental Affairs Law Review
B. C. Int'l. & Comp. L. Rev.	Boston College International and Comparative Law Review
B. U. Int'l. L. J.	Boston University International Law Journal
Baylor L. Rev.	Baylor Law Review
Berkeley Tech. L. J.	Berkeley Technology Law Journal
Brit. Y. B. Int'l. L.	British Yearbook of International Law
Brooklyn J. Int'l. L.	Brooklyn Journal of International Law
Brooklyn L. Rev.	Brooklyn Law Review
Buff. L. Rev.	Buffalo Law Review
Bull. Am. Astron. Soc.	Bulletin of the American Astronomical Society
C.F.R.	Code of Federal Regulations
Cable News Network	Cable News Network
Cal. L. Rev.	California Law Review
Cal. W. Int'l. L. J.	California Western International Law Journal
Cam. L. J.	Cambridge Law Journal
Can. Y. B. Int'l. L.	Canadian Yearbook of International Law
Cardozo L. Rev.	Cardozo Law Review
Case W. Res. J. Int'l. L.	Case Western Reserve Journal of International Law
Chi. J. Int'l. L.	Chinese Journal of International Law
Colo. J. Int'l. Envt'l. L. & Pol'y.	Colorado Journal of International Environmental Law and Policy
Colum. J. Envt'l. L.	Columbia Journal of Environmental Law
Colum. J. Transnat'l. L.	Columbia Journal of Transnational Law
Colum. J. World Bus.	Columbia Journal of World Business
Colum. L. Rev.	Columbia Law Review
Com. L. J.	Commercial Law Journal
Conn. J. Int'l. L.	Connecticut Journal of International Law
Cornell Int'l. L. J.	Cornell International Law Journal
Cornell L. Rev.	Cornell Law Review
Cosmic Research	Cosmic Research
Crosslink	Crosslink
De Economist	De Economist
Def. Sci.	Defence Science

Denver J. Int'l. L. & Pol'y.	Denver Journal of International Law and Policy
Detroit Coll. L. J. Int'l. L. & Prac.	Detroit College of Law Journal of International Law and Practice
Dick. J. Int'l. L.	Dickenson Journal of International Law
Die Friedenswarte	Die Friedenswarte
E.R.	English Reports
Earth Planets & Sp.	Earth Planets and Space
Earth, Moon & Planets	Earth, Moon and Planets
Ec. & Fin. Rev.	Economics and Finance Review
Ecology L. Q.	Ecology Law Quarterly
Econ. J.	Economics Journal
Emory Int'l. L. Rev.	Emory International Law Review
Emory J. Int'l. Disp. Resol.	Emory Journal of International Dispute Resolution
Energy Explor. & Exploit.	Energy Exploration and Exploitation
Energy Policy	Energy Policy
Envt'l. & Res. Ec.	Environmental and Resource Economics
Envt'l. L.	Environmental Law
Eur. J. Int'l. L.	European Journal of International Law
Fl. Coastal L. Rev.	Florida Coastal Law Review
Fl. Int'l. L. J.	Florida International Law Journal
Fordham Envt'l. L. Rep.	Fordham Environmental Law Report
Fordham L. Rev.	Fordham Law Review
Foreign Aff.	Foreign Affairs
Foreign Policy	Foreign Policy
Foreign Service J.	Foreign Service Journal
Ga. J. Int'l. & Comp. L.	Georgia Journal of International and Comparative Law
Geo. Wash. J. Int'l. L. & Ec.	George Washington Journal of International Law and Economics
Geoadria	Geoadria
Geochim. & Cosmochim. Acta	Geochimica et Cosmochimica Acta (Journal of the Geochemical and Meteoritical Societies)
Georgetown Int'l. Envt'l. L. Rev.	Georgetown International Environmental Law Review
Georgetown L. J.	Georgetown Law Journal
Hague Y. B. Int'l. L.	Hague Yearbook of International Law
Harv. Int'l. L. J.	Harvard International Law Journal
Harv. J. Law & Tech.	Harvard Journal of Law and Technology
Harv. J. on Legis.	Harvard Journal on Legislation
Hastings Int'l. & Comp. L. Rev.	Hastings International and Comparative Law Review

Hastings L. J.	Hastings Law Journal
Herts. L. J.	Hertfordshire Law Journal
Hist. & Tech.	History and Technology
Houston J. Int'l. L.	Houston Journal of International Law
Howard L. J.	Howard Law Journal
Human Rights Q.	Human Rights Quarterly
Hyperfine Interactions	Hyperfine Interactions
I.C.J. Rep.	Reports of the International Court of Justice
I.L.M.	International Legal Materials
I.L.R.	International Law Reports
Icarus	Icarus
Ind. J. Global Legal Stud.	Indiana Journal of Global Legal Studies
Ind. Leg. F.	Indiana Legal Forum
Indian J. Int'l. L.	Indian Journal of International Law
Info. Econ. & Pol'y.	Information Economics and Policy
Int'l. & Comp. L. Q.	International and Comparative Law Quarterly
Int'l. Bus. Lawyer	International Business Lawyer
Int'l. Geol. Rev.	International Geology Review
Int'l. J.	International Journal
Int'l. J. Estuarine & Coastal L.	International Journal of Estuarine and Coastal Law
Int'l. J. Marine & Coastal L.	International Journal of Marine and Coastal Law
Int'l. Lawyer	International Lawyer
Int'l. Leg. Persp.	International Legal Perspectives
Int'l. Org.	International Organisations
Int'l. R. & S. Ab.	Internationalrechtliche und staatrechtliche Abhandlungen
Int'l. Trade L. J.	International Trade Law Journal
Iran-U.S.C.T.R.	Iran-U.S. Claims Tribunal Reports
Isr. L. Rev.	Israel Law Review
J. Afr. L.	Journal of African Law
J. Air L. & Com.	Journal of Air Law and Commerce
J. Astron. & Space Sci.	Journal of Astronomy and Space Science
J. Brit. Interplanetary Soc.	Journal of the British Interplanetary Society
J. Contemp. Leg. Issues	Journal of Contemporary Legal Issues
J. Energy Nat. Res. L.	Journal of Energy and Natural Resources Law
J. Envt'l. L. & Lit.	Journal of Environmental Law and Litigation
J. Geophys. Res.	Journal of Geophysical Research
J. Guid. Con. & Dyn.	Journal of Guidance, Control and Dynamics
J. Hist. Int'l. L.	Journal of the History of International Law
J. Int'l. L. & Bus.	Journal of International Law and Business
J. Japan & Int'l. Econ.	Journal of Japanese and International Economics