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Scott Millwood



**The Urgent Need  
for Regulation  
of Satellite  
Mega-constellations in  
Outer Space**

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# The Urgent Need for Regulation of Satellite Mega-constellations in Outer Space

 Springer

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*For my son, who lives among the stars*

# Foreword

This book will not be uncontroversial. And that is precisely the gift of its author, who I met when he embarked upon a sabbatical year studying the Masters of Air and Space Law at Leiden University, where I teach space law to students from all over the world. As a mid-career student, he brought his experience in the telecommunications industry, and passion for international affairs, to his analysis of outer space law. What impressed me—and something Scott only revealed to me in incremental terms—was his history of making documentary films about our relationship with nature.

The storyteller who has become a space lawyer weaves a narrative in this book, of the geopolitical landscape in which a serious conflict is emerging between the space activities of commercial actors and astronomy.

The launch of mega-constellations made up of tens-of-thousands of satellites into orbit has raised concerns about the extent to which States responsible for the oversight of commercial ventures in the New Space era will comply with the duty of due regard and the obligation to avoid interference with the activities of other States.

Space law, as a branch of public international law, has always provided room for creative legal thinking. But the rapid expansion of commercial activities, particularly in Low Earth Orbit, is now giving rise to major challenges, sustainability issues, and geopolitical tensions that will require breakthrough solutions and disruptive thinkers.

This timely book offers a new perspective on how mega-constellations might be regulated to protect astronomy. It will not only appeal to legal and astronomical experts, but all readers with an interest in outer space, for the craft of the author lies in making these disciplines accessible to all. He is convincing in his opinions, frank in his assessments, and unafraid to challenge the astronomical community to defend the public interest in science.

This approach is to be welcomed. As the first book of its kind to explore the application of international law to mega-constellations, it will make an important contribution to current discourse. It offers a unique insight into the hidden factors driving the race for dominance in outer space.

I cannot imagine this book having been written by anyone else, and I am sure it will break new ground in legal thought on the regulation of mega-constellations.

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# Preface

This book seeks to contribute to public discourse by highlighting the emerging issue of interference with science, as the infrastructure for an Orbital Internet is established in Low Earth Orbit (LEO) by new commercial space-actors. It explores the intersection of space law, telecommunications, and defence, positioning its analysis within current and historic geopolitical developments, including the race for 5G, for the battle to dominate the space domain is actually a battle to shape the Internet-of-Things (IoT). Casting a wide lens, it seeks to understand the forces driving the launch of mega-constellations, in order to propose legal and regulatory solutions to the interference they pose to science.

It arrives at the conclusion that the establishment of a comprehensive governance framework, reflecting the principles of the Outer Space Treaty (OST), will be necessary to ensure the “global commons” does not collapse as an Orbital Internet is established. This book argues that attempts to treat the “Dark Sky” as subject to cultural heritage protections, and erect a human right to starlight, are misplaced. The challenge is not so much an environmental one, as a question of governance. It will therefore require a governance solution. In pursuit of a new framework, this book argues that the principle of State Responsibility requires greater national supervision, with an urgent need for incorporation of impact assessment processes at national regulators, in order to mitigate the interference mega-constellations pose to the space activities of others. It advocates for a new strategy of “*international regulatory coordination*” as the fastest means of addressing what is an urgent problem. It envisions in such regulation a renewed role for the precautionary principle and the doctrine of proportionality, for it is simply common sense that the 10,000% increase in space objects in LEO, resulting from just four mega-constellations launched by US Tech Giants, will exponentially increase the technical and geopolitical risks. This is not sustainable. This book makes pragmatic recommendations on how regulatory processes might be bolstered to ensure the common, and sometimes conflicting, interests of stakeholders can be managed.

This work is by its very nature an extended essay. It does not claim to be definitive and nor should the reader understand it as such. A new “space race” is

unfolding at a rapid pace, and new developments in the nature of constellations continue to be announced on a weekly basis. Instead, I invite the reader to consider the issues in the geopolitical context in which the race to dominate LEO has emerged, and draw lessons from history that might be applied to protecting the interests of science. To assist the reader, the *Outer Space Treaty* (1967)—a short, eloquent text reflecting the shared values of humanity in outer space—is included in the Appendix.

I embarked upon the research that forms the basis of this book in 2019, shortly after photographs of SpaceX’s launch of the first tranche of Starlink satellites alerted the world to its potential impact. The book’s narrative spans the 3 years since, in which astronomers and international stakeholders grappled with the question of “what is to be done?”. It necessarily charts a course through the dramatic developments in these years, during which the Russian invasion of Ukraine in 2014 escalated into a devastating war. In the interests of its narrative arc, this book documents events in a relatively linear manner, with the most recent developments of 2022 detailed in the final chapters.

As a European, I am most interested in how EU institutions, and organisations representing astronomers, should respond. I hope this book will serve leaders in this sector, by providing insight into the application of outer space law. More than anything, the challenge of mega-constellations calls for astronomers to reinvigorate the diplomacy of science, in order to influence future regulation and ensure astronomy remains a critical activity in outer space.

Netherlands, Leiden

Scott Millwood

# Acknowledgements

The research that forms the foundation of this book was initially undertaken at the International Institute of Air and Space Law (IIASL) at Leiden University, under the supervision of Associate Professor Tanja Masson-Zwaan, in partial fulfilment of the requirements for the degree of Master of Advanced Legal Studies in Air and Space Law, in 2020. I am most grateful to Prof. Masson-Zwaan and the staff of IIASL for their support.

I extend my sincere gratitude to members of national delegations to the United Nations Committee on the Peaceful Use of Outer Space (UNCOPUOS) and the scientific community that participated in interviews or were prepared to share their views, including: Prof. Dr. Ewine van Dishoeck (*IAU President, Professor of Astronomy, Leiden University*), Prof. Dr. Hansjörg Dittus (then *Member of the Executive Board of the German Aerospace Centre, DLR Space Research & Technology*), Prof. Dr. Heino Falcke (*Professor of Astroparticle Physics and Radio Astronomy Research, Institute for Mathematics, Astrophysics and Particle Physics (IMAPP), Radboud University, Nijmegen*), Piero Benvenuti and Constance Walker (*Chairs, IAU Working Group Dark Skies/Mega-constellations SATCON 2020*), Dr. Marco Langbroek (*Space Situational Awareness consultant at Leiden Observatory*), Dr. Martin Millon (*Space Research Institute at the École polytechnique fédérale de Lausanne (EPFL), Switzerland*), Gabriel Swiney (*US State Department*), Joe Sandri and Jim Turner (*The Balance Group*), Dr. Andrew Williams (*European Southern Observatory*), the team at the UK Space Agency, Martijn Geers, and the many astronomers who engaged in a vibrant discourse.

I am especially indebted to Prof. Michael Byers, Professor & Canada Research Chair in Global Politics and International Law at the University of British Columbia, for his feedback on an early draft and generosity in the exchange of ideas.

The photograph of the launch of SpaceX's Starlink, which alerted the world to the impact on astronomy, is provided courtesy of Dr. Marco Langbroek from Leiden Observatory (Fig. [1.1](#)). Rafael Schmall's photograph of the Albireo star interrupted by lines of satellites, entitled "Prison of Technology", won the Insight Investment Astronomy Photographer of the Year 2020 Award for best photograph in the

“People and Space” category (Fig. [3.1](#)). The first image of a black hole (Fig. [3.2](#)), a project initiated by Prof. Falcke’s institute at Radboud University in the Netherlands, is included courtesy of the organisations that collaborated on that project. I am grateful for their generosity in allowing these works to be reproduced here.

I acknowledge the support I have received in scholarships from the European Space Agency (ESA) and the Netherlands’ Stichting Space Professionals Foundation (SSPF) in recent years, which allowed me a mid-career immersion in all things outer space.

Finally, I extend my deep appreciation to the Executive Editor of Law, Dr. Brigitte Reschke, at Springer, who immediately recognised the contemporary legal and regulatory questions raised in this book and who, together with the Springer team, supported it through to publication.

My sincere hope is that this book will contribute to public debate about the impact of mega-constellations on astronomy, and the sustainability of activities in Earth’s orbit.

# Recommendations

## **This book recommends that nations:**

- (1) recognise that mega-constellations in Low Earth Orbit (LEO), to support Internet services, will **interfere with optical and radio frequency techniques** used by astronomers to study the universe
- (2) recognise the **geopolitical impact** of the proliferation of mega-constellations in LEO, and the role that a strategically formulated **diplomacy of science** might play in ensuring the sustainable and peaceful use of outer space
- (3) urge the International Telecommunication Union (ITU) to **treat spectrum in LEO and Medium Earth Orbit (MEO) as finite resources** in order to ensure equitable access to all nations
- (4) recognise that interference with astronomy by mega-constellations **drives up the cost of science** and that it is science, and therefore the public, that bears the cost of this interference
- (5) recognise the **impact on major investment** in high-value Earth-based astronomical infrastructure, and equip astronomy organisations with the regulatory expertise to protect their interests
- (6) encourage astronomical organisations, including the International Astronomical Union (IAU), European Southern Observatory (ESO), and North American observatories, to develop **regulatory strategies in order to shape the future regulation of mega-constellations**
- (7) incorporate **Impact Assessments, including environmental impact assessment**, in the application process for launch and operational licences at the US Federal Communications Commission (FCC) and other agencies, adopting a model of “international regulatory coordination”
- (8) facilitate development of a “**proportionality principle**” in assessment processes, as the disproportionate scale of mega-constellations dramatically increases the risks, and consider national standards to minimise the number of satellites in mega-constellations

- (9) establish **regulatory processes allowing public stakeholders to make submissions**, bringing risks of interference to the attention of the regulatory authority as the application for an operating licence is assessed
- (10) require **disclosure of whole-of-project plans** for mega-constellations at the point of initial licence application, so whole-of-project impact can be assessed before launches commence

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