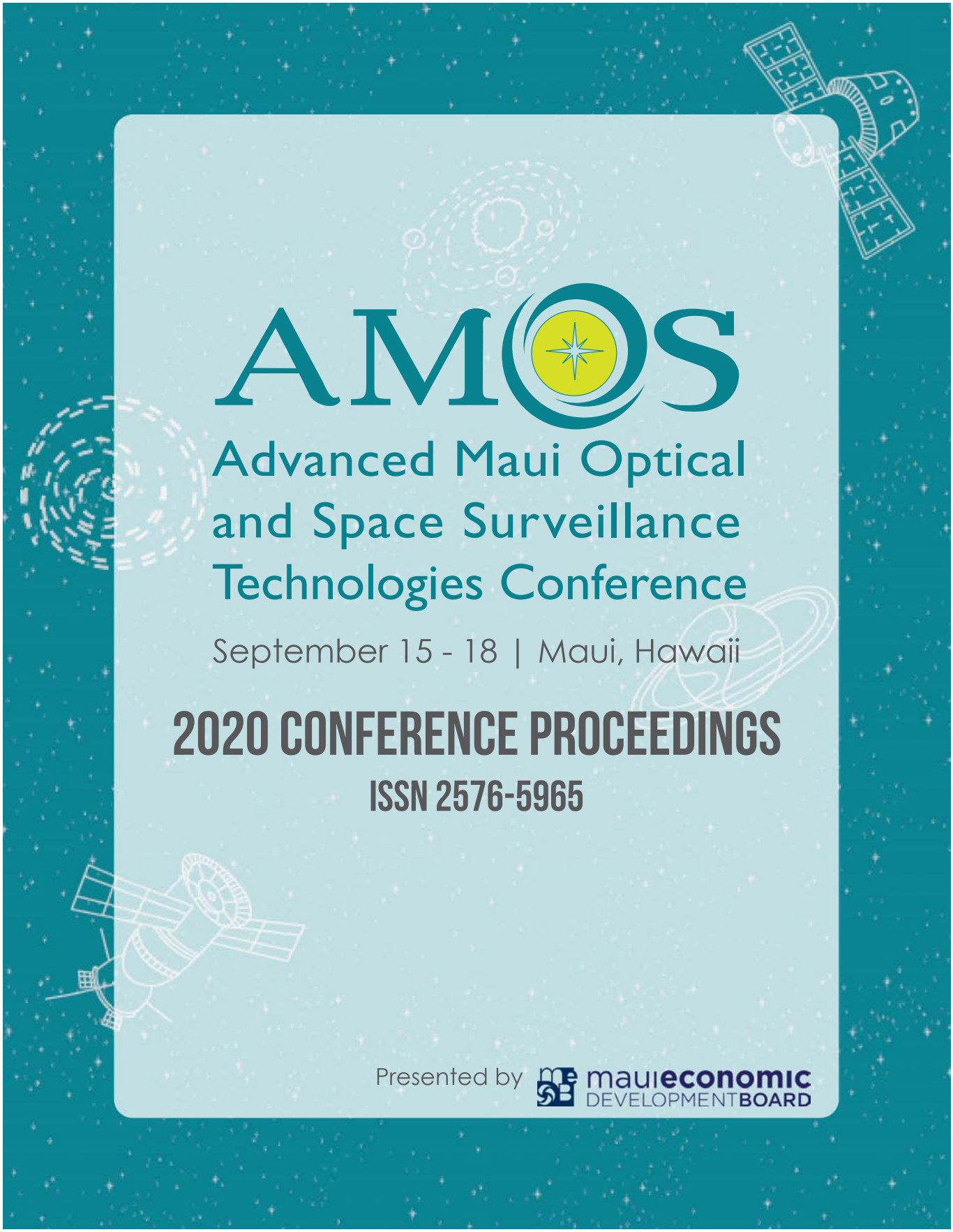
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PREFACE

This volume consists of papers from the oral and poster presentations of the conference held virtually September 15-18, 2020 from Maui, Hawaii. The number and quality of the papers received attest to the increased recognition and exposure of the conference in the scientific and technical communities.

Some of the many topics contained in this year's proceedings included adaptive optics and imaging, astrodynamics, atmospherics and space weather, cislunar SSA, machine learning for SSA applications, non-resolved object characterization, optical systems and instrumentation, orbital debris, space-based assets and space situational/domain awareness.

A unique addition to this volume comprises of the Opening Remarks from Day 2 of the Conference. The presented wholistic approach to space sustainability and international norms of behavior is pertinent across all sectors of the AMOS audience, including military, industry, academia, and policy, as well as all nations regardless of space capabilities.

We would like to express immense appreciation to the global SSA Community for their perseverance in continuing to advance this important field of study amidst a worldwide pandemic. In particular, we thank the technical and session chairs, the 885 participants, conference sponsors and exhibitors, presenters, forum panelists, and authors who contributed to making the 21st, and first virtual, AMOS Conference a success.

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21st Advanced Maui Optical and Space Surveillance Technologies (AMOS)

Conference Day 2: Opening Keynote, 17 September 2020[1]

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Disclaimer: minor variations between this script and the actual keynote may occur. In addition, this is not a peer-reviewed academic paper and some references may be incomplete.

[Introduction and greetings]

Good morning, afternoon and evening.

My name is Quentin Verspieren, researcher at the Graduate School of Public Policy of the University of Tokyo, and research fellow at the Japan Space Forum. Before starting with my remarks, I would like to express my pleasure to be given the opportunity to open the second day of such a wonderful conference. But most of all, I want to warmly thank the AMOS team and the Secure World Foundation for their invitation and trust.

My remarks will serve as an opening to the following policy forum on "challenges and opportunities in developing norms of behaviour". I will therefore propose in this talk a few reflexions on various elements, from a policy perspective, not a technical one. I will touch upon the history of STM, the role of the military and more generally national security actors, and on the place of emerging nations in STM regime making. Overall, I will try raise questions rather than provide answers, which could be done by a large number of experts much wiser than I am.

[Origins of STM]

Most people consider that the concept of space traffic management is fairly recent, from the end of the 20th century. In fact, the first reference to "space traffic rules" was made in 1932 by a Czechoslovak jurist called Vladimir Mandl, in what is known as the first monograph on space law, written in German.[2] The reason I mention

[1] This keynote is partially inspired from the speaker's doctoral dissertation: Quentin Verspieren, 'A Reluctant Space Safety Services Provider: The Role of the Military in Space Traffic Management' (Doctoral Thesis, Tokyo, Japan, Graduate School of Public Policy, The University of Tokyo, 2020).

[2] In German: "Raumverkehrsregeln". In: Vladimir Mandl, *Das Weltraum-Recht. Ein Problem Der Raumfahrt* (Mannheim, Berlin, Leipzig, Germany: J. Bensheimer Verlag, 1932), 27; An English translation was later commissioned by NASA: Vladimir Mandl,

this is that quite often in international space law and in particular for issues related to space traffic management, we are reinventing the wheel every 20 to 30 years, because of our lack of awareness of past efforts. Let me illustrate this statement with a few examples.

In 1957, French jurist Eugène Pépin identified five elements that would require the creation of "regulatory rule[s]" for "circulation" in outer space: (1) the ascension of rockets through sovereign airspace, (2) the re-entry of rocket bodies, (3) unintentional collisions between orbiting satellites, (4) the need for identification of satellites in case of accident and (5) the avoidance of harmful radio-interference.[3] Most of the prominent experts at the time shared these views, in particular on the latter point.[4]

Then, for around 30 years, STM – which was not called STM at the time – fell into oblivion until Lubos Perek presented his paper *Traffic Rules for Outer Space* during the 25th International Colloquium on Space Law held in Paris in 1982. These rules, although more detailed, roughly correspond to Pépin's five elements, with a noticeable addition being the mitigation of space debris.[5]

At the time however, STM studies were still in the realm of theory. It was only from the very end of the 20th century that the desire and need to define and actually implement traffic rules became tangible. On 24 July 1996, French military satellite Cerise, operated on behalf of the French Armed Forces by UK company Surrey Satellite Technology suddenly started to spin out of control. Unable to evaluate the cause due to its lack of space surveillance capabilities, France had to request support from NASA and from the UK Space Track Network, which identified that the satellite was damaged by a piece of debris from an abandoned third stage of Ariane 1 rocket launched ten years earlier in 1986, making Cerise "space's first confirmed victim of a hit-and-run accident".[6] A few years later – although there is no evidence of causality, the concept of space traffic, associated with the desire to manage it, made a real and definite comeback. In 1999 and 2001, the American Institute of Aeronautics and Astronautics (AIAA) organised the 5th and 6th *International Space Cooperation* workshops titled respectively *Solving Global Problems* and *Addressing Challenges of the New Millennium*. These two workshops were the starting points for various initiatives aimed at developing new ideas on STM. They focused on "orbital management, collision avoidance, relevant orbital debris issues, and regulatory framework needs".[7] A key outcome of the 2001 workshop was the establishment of an STM working group at the International Academy of Astronautics (IAA). This working group gathered for five years and produced one of the cornerstones of space

'Outer Space Law: A Problem of Astronautics', NASA Technical Memorandum, trans. Kanner (Leo) Associates (National Aeronautics and Space Administration, 1984).

[3] Eugène Pépin, 'Legal Problems Created by the Sputnik', *The McGill Law Journal* 4, no. 1 (1957): 68.

[4] Examples include, among many others: Myres S McDougal and Leon Lipson, 'Perspectives for a Law of Outer Space', *The American Journal of International Law* 52 (1958): 417; Eugène Pépin, 'Les Problèmes Juridiques de l'espace', *The McGill Law Journal* 6, no. 1 (1959): 40; Rolando Quadri, 'Droit International Cosmique', in *Scritti Giuridici: I. Diritto Internazionale Pubblico* (Milano, Italy: Dott. A. Giuffrè Editore, 1988), 552 originally published in the following; Rolando Quadri, 'Droit International Cosmique', in *Recueil Des Cours de l'Académie de Droit International de La Haye*, vol. 98, 1959.

[5] Lubos Perek, 'Traffic Rules for Outer Space' (International Colloquium on the Law of Outer Space, International Institute of Space Law, 1982).

[6] Mark Ward, 'Satellite Injured in Space Wreck', New Scientist, 24 August 1996, https://www.newscientist.com/article/mg15120440-400-satellite-injured-in-space-wreck/.

[7] Graham Gibbs and Ian Pryke, 'International Cooperation in Space: The AIAA-IAC Workshops', *Space Policy* 19 (2003): 59–60.

traffic management literature: the 2006 *IAA Cosmic Study on Space Traffic Management*.[8]

The lesson I want to share with these examples is that STM is already an old field and that we are losing a lot of time, resources and energy trying to solve issues that have already been solved in the past, the most emblematic being the recurring debate over the limit between air and space, core of the *spatialist-functionalist* debate dear to space lawyers with air law background. The current discussions on an 'ICAO for space' or on the definition of a 'near space zone' between airspace and outer space were already discussed and considered obsolete in the 1950s. To go even further and show the importance to look at legal history, when John Cobb Cooper was proposing in the 1950s to define the limit between airspace and outer space,[9] the very same Eugène Pépin blamed him for reviving a debate from the 1910s.[10]

So, one modest piece of advice to all of us: let us learn STM history. It spans over 90 years but is limited in content, so it is not such a big effort. But it would allow all of us to stop reopening long closed debates.

[Military role and influence]

The second focus of these remarks is on an important actor, often overlooked in, at least, academic STM literature. I will start with three – rhetorical – questions:

1. Who is the second largest satellite operator in the world, with around 190 satellites, accounting for 8.5% of all satellites in orbit? These are late 2019 figures of the Union of Concerned Scientists. The answer is the US Armed Forces.[11] Not far below are the Chinese and Russian militaries. Taking the example of China, a recent report of Frank Rose at the Brookings Institution estimated that the Chinese government currently operates no less than 120 intelligence, reconnaissance and surveillance (ISR) and remote sensing satellites.[12]
2. Who has the unrivalled ability to monitor outer space? The number one is, again, the US military, followed by the Russian Armed Forces and most likely, the Chinese ones.
3. Who is purposely excluded from most academic studies on STM? Again, the answer is military and national security actors, which are naturally ruled out as agents of conservatism, or "interfering factors which might hinder the establishment and operational effectiveness of a space traffic management regime" as the 2006 IAA cosmic study says.[13]

It is critical to go beyond the *cliché* that the military does not care about the sustainability of outer space, *cliché* that I am sure most of you fully reject. But even more, I believe that we need to put the military back at

[8] Corinne Contant-Jorgenson, Petr Lala, and Kai-Uwe Schrogl, 'Cosmic Study on Space Traffic Management' (Paris, France: International Academy of Astronautics, 2006).
[9] McDougal and Lipson, 'Perspectives for a Law of Outer Space', 424–25.
[10] Pépin, 'Legal Problems Created by the Sputnik', 69–71.
[11] The UCS operates the largest satellite database based on public sources, available at: 'Union of Concerned Scientists Satellite Database', ucsusa.org, accessed 22 January 2020, https://www.ucsusa.org/resources/satellite-database.
[12] Frank A Rose, 'Managing China's Rise in Outer Space', Global China: Assessing China's Growing Role in the World (Washington, DC: Brookings Institution, April 2020), 7, https://www.brookings.edu/research/managing-chinas-rise-in-outer-space/.
[13] Contant-Jorgenson, Lala, and Schrogl, 'Cosmic Study on Space Traffic Management', 12.

the centre of STM international regime-making discussions. Now, I understand that it is an extremely complex topic. I have focussed almost exclusively on it for the last three years, and I have more questions than answers.

Continuing on the attachment of military and national security actors to the safety and sustainability of the space domain, on which they are so dependent, I want to point out that progress has been made to ensure cleaner activities, in terms of debris mitigation. The US Air Force for instance has strongly improved its compliance with the US Government Orbital Debris Mitigation Standard Practices. Actually, in tomorrow's orbital debris session, I will be unveiling new data, obtained through a Freedom of Information Act request, detailing the evolution of the Air Force's compliance with the Orbital Debris Mitigation Standard Practices.[14] Overall, the improvement of military practices in outer space has been driven by an incremental cultural shift within the military. Once more, I will use the example of the US military. In 1964, Morris Janowitz published a book titled *The Professional Soldier* in which he explained that the military would evolve into what he called a "constabulary force" through the modification of its skill structure. He forecasted that among military officers, the gap would widen between, on the one hand, generalist "military managers", and on the other hand, highly specialised "military technologists", either trained via specialised programs in military academies or recruited from civilian universities through the Reserve Officers Training Corps (ROTC) program.[15] More than a forecast, this was a prophecy for what concerns American space-related forces: most of the prominent US space generals where trained or recruited like this: General Shelton, who opened this conference last year graduated in astronautical engineering at the Air Force Academy and the embodiment of the space general, General Hyten was recruited from Harvard through the ROTC program. In the US Armed Forces, such "space military technologists" as Janowitz would say, are often nicknamed "pure space officers" because in addition to their initial training, they often had a coherent space career path.

These officers have a strong, intimate and passionate knowledge of outer space, and are well aware of the importance of the safety and sustainability of the space domain. They go well beyond their natural military reflexes, like secrecy and classification, to contribute to the development of good and responsible practices. Other countries are consciously or unconsciously following this path. My own country, France, has released a new defence space strategy last year putting emphasis on the fostering of a new generation of responsible space officers, through specialised programs in military academies and related universities, as well as through the establishment of a space academy.[16] This is why I urge my colleagues in academia and government to give these military experts the place they deserve in the definition of international norms of behaviour in outer space. Military and national security actors have their own ways at looking at space safety and sustainability and would bring a unique and interesting perspective to the discussions. I will mention three points.

[14] Quentin Verspieren, 'The US Air Force Compliance with the Orbital Debris Mitigation Standard Practices' (21st Advanced Maui Optical and Space Surveillance Technologies (AMOS) Conference, Maui, Hawaii, 2020).
[15] Morris Janowitz, *The Professional Soldier* (New York: The Free Press, 1964), 425.
[16] 'Stratégie Spatiale de Défense : Rapport du groupe de travail « Espace »' (Paris, France: Ministère des Armées, July 2019), https://www.defense.gouv.fr/content/download/563618/9727385/Strate%CC%81gie%20spatiale%20de%20de%CC%81fense%202019.pdf.

The first point concerns operations and semantics: talking about managing space traffic is inappropriate. When addressing STM policymaking, 99% of the time consists in discussing standards for joint operations and communication, data sharing, guidelines for debris mitigation, non-binding rules of the road, etc. As such, STM has little to do with management but rather with communication, coordination, cooperation and standardisation. Semantics is important. The way we address an issue is closely related to our unconscious understanding of the issue, which in turns is heavily dependent on how we name it. We need to identify another term for STM in order to stop believing that management, in the sense of control, can be achieved. SPD-3 has unfortunately written into stone the term of STM,[17] but I am confident that we will progressively move forward. In particular, I noticed that in most of their recent public speeches, officials of the Office of Space Commerce have gradually replaced STM by the more neutral expression of "space safety and sustainability".[18] This is a good step forward.

The second point concerns transparency, which has significantly improved, even at the DoD. I will not re-explain all the advances made in terms of declassification, removal of objects from the restricted list of the SATCAT, [19] etc. I want however to share two enlightening anecdotes from the maritime and space domains. (1) The first anecdote was shared by a friend working for AGI, the famous private SSA service provider. In 2019, Russian satellite Luch-Olymp was navigating in close proximity to an American geostationary military communication satellite of the WGS constellation. However, after the USSTRATCOM released the orbital elements of WGS satellites, including the one supposedly spied on, Luch suddenly changed its course and went far away from the WGS satellite. As my friend said: "It was almost like the Russians going: 'oh, we didn't know you were right there, we will move away now that we see that you're there'". It shows how transparency on one's own assets can serve to expose an adversary's hostile behaviour. (2) The second anecdote concerns incidents having happened to the US Navy in Asia-Pacific in 2017. In June and August 2017, two different US Navy destroyers collided with massive civilian vessels, provoking important material damages, but most importantly the deaths of 17 US Navy sailors. The reason was that large container ships mostly navigate with instruments and that following the usual Navy practice, the destroyers were not broadcasting their AIS (basically name, position, course of the ship) and were therefore practically invisible to other civilian vessels. During a subsequent Senate hearing, Chief of Naval Operations Admiral Richardson announced that in crowded areas of the seas, for instance the Malacca Straight, US Navy ships would now turn their AIS on. He added that, in these heavily trafficked areas, using the AIS does not contravene operational security as Navy ships are anyway directly visible

[17] Executive Office of the President, 'Space Policy Directive-3 of June 18, 2018: National Space Traffic Management Policy', *Federal Register*, Presidential Memorandum, 83, no. 120 (18 June 2018): 28969–76.
[18] 'Remarks from AMOS Conference 2019', Office of Space Commerce, 20 September 2019, https://www.space.commerce.gov/remarks-from-amos-conference-2019/; Diane Howard, 'OSC Remarks at UN General Assembly', Office of Space Commerce, 31 October 2019, https://www.space.commerce.gov/osc-remarks-at-un-general-assembly/; Kevin M O'Connell, 'O'Connell Remarks to U.S. Chamber of Commerce', Office of Space Commerce, 3 December 2019, https://www.space.commerce.gov/oconnell-remarks-to-u-s-chamber-of-commerce/; Kevin M O'Connell, 'Remarks from SSA Workshop in Japan', Office of Space Commerce, 28 February 2020, https://www.space.commerce.gov/remarks-from-ssa-workshop-in-japan/.
[19] 'USSTRATCOM Expands SSA Data on Space-Track.Org', Air Force Space Command, 10 October 2018, https://www.afspc.af.mil/News/Article-Display/Article/1658619/usstratcom-expands-ssa-data-on-space-trackorg/.

from other ships. I think that this example can easily find a parallel in crowded LEO orbits, where secrecy is mostly impossible, and where transparency would significantly improve safety while not hampering national security utilisation.[20]

The third and most important point concerns norms of behaviour. During my interactions with military experts, I identified an underlying debate: what type of behaviour are we trying to promote? The answer of most military experts that I met was "safe behaviour", as opposed to "appropriate behaviour". While "safe behaviour" embodies the idea of shared values and understanding for the preservation of outer space based on an objective scientific evaluation of risk, "appropriate behaviour" constitutes unacceptable limitations to the freedom of – military – activities in outer space based on subjective considerations. To paraphrase James March and Herbert Simon, "norms of safe behaviour" follow a logic of consequence whereas "norms of appropriate behaviour" follow a logic of appropriateness, literally.[21] I however need to point out and regret the confusion raised by the US Defense Space Strategy of June 2020 which instructs the DoD to "partner with the Department of State (DoS) to work closely with allies and partners in order to develop common understandings of appropriate behaviour in space".[22] I do believe that this phrasing is a mistake.

Finally, when we talk about norms of behaviour, we are talking about non-binding instruments, so how can they have an impact? Norms of behaviour are efficient as long as the largest number of actors believe they are and transcribe them in their national laws and regulations. Most of the established powers understand their importance, of course also understanding the needs of exceptional violations for imperious reasons, such as national security. What is more complex is the role, understanding and support from emerging and non-space actors.

[Emerging nations]

Concerns from emerging space nations or even non-space nations about STM regime-making are various. These countries are anything but a coherent bloc. Here are examples of concerns that I could hear from emerging and non-space actors. The first one is very straightforward: "will we be able to use space in the future?" In other words, will the space environment be usable? The second concern is that STM rules may limit their ability to develop a space program. This concern is the space version of the 'right to pollute for development' type of argument that we usually hear from developing nations in environmental policy discussions on Earth. The third concern relates to inclusion: "Will we be part of rulemaking even if we are currently absent from space?".

Let us address all these points together, starting with the first one: will space be usable by future space powers? And let us be very clear: everyone has interest in pursuing space sustainability, in the sense that no one

[20] Quentin Verspieren and Hideaki Shiroyama, 'From the Seas to Outer Space: The Reverse Dynamics of Civil-Military Situational Awareness Information and Responsibility Sharing', *Space Policy* 50 (November 2019), https://doi.org/10.1016/j.spacepol.2019.07.003.
[21] James G March and Herbert A Simon, *Organizations*, 2nd ed. (Cambridge, UK: Blackwell Publishers, 1993), 8.
[22] 'Defense Space Strategy: Summary' (Arlington, Virginia: Department of Defense, June 2020), 8.

has interest in the degradation of the space environment, *a fortiori* leading powers. So, apart from understandable concerns, I do not see any real opposition between established and future space powers on this point.

However, it is important to be clear on what we mean by sustainability: sustainability of the environment for everyone, or sustainability of existing activities by a tightening of rules that may hamper the development of newcomers. The second part of this sentence is what drives the main concern of emerging or future space actors: the US, Russia, China, France, the UK all developed their programs through trial and errors, which resulted in numerous failed missions and subsequent debris generation. Let us be clear, these countries are at the origin of most of space debris. They are not spontaneous creations of nature. I concur with Professor Moriba Jah when he pushes for the use of the term of 'anthropogenic space debris'. Therefore, seeing this, emerging nations feel like being cheated, denied the right for error. They feel that STM is a smoke screen for policies aiming at maintaining the *status quo* of primarily American domination in space.

Even beyond historical responsibility, which is a complex issue, in order to secure the adherence of emerging and future space powers to international norms of behaviour in space, established powers should engage into massive capacity building. By showing emerging and future space actors that, with support from established powers, they can develop a space program while skipping or attenuating the impact of the trial-and-error phase, we will be able to reach widespread support for norms of behaviour ensuring the safety and sustainability of outer space. In short, in order to ensure worldwide norm diffusion, or proliferation, it is key that leading space powers include, reassure and accompany emerging and future space powers in their development.

[Conclusion]

Time is now running out, and I hope that you end up these remarks with more questions than answers, which was my purpose. In addition, I want to stress that establishing or even discussing the establishment of an international STM regime without the participation of the most powerful actors in space, the armed forces of world leading powers, can only result in either limited or, on the contrary, unrealistic proposals. But I know that this is something that my dear friends at the Secure World Foundation understand better than anyone, and I cannot wait to see the wonderful panel Victoria has prepared for our delight. Thank you very much for your attention.

2020 AMOS CONFERENCE PROCEEDINGS

SPACE SITUATIONAL AWARENESS/SPACE DOMAIN AWARENESS

Co-chaired by **Moriba Jah**, University of Texas Austin and **Danielle Wood**, Massachusetts Institute of Technology

ASTRODYNAMICS

Co-chaired by **T.S. Kelso**, ComSpOC Corp and **Marek Ziebart**, University College London

MACHINE LEARNING APPLICATIONS OF SSA

Co-chaired by **Justin Fletcher**, Air Force and **Nathan Toner**, Centauri

ADAPTIVE OPTICS & IMAGING

Co-chaired by **Geoff Andersen**, Air Force Office of Scientific Research and **Michael Hart**, University of Arizona; HartSci LLC

NON-RESOLVED OBJECT CHARACTERIZATION

Co-chaired by **Emily Lambert**, L3 Harris and **Tamara Payne**, Applied Optimization, Inc.

ATMOSPHERICS/SPACE WEATHER

Co-chaired by **Thomas Berger**, University of Colorado at Boulder and **Marcus Holzinger**, University of Colorado at Boulder

OPTICAL SYSTEMS & INSTRUMENTATION

Co-chaired by **Sue Lederer**, NASA Johnson Space Center and **Darren McKnight**, Centauri

ORBITAL DEBRIS

Co-chaired by **James Blake**, University of Warwick and **Heather Cowardin**, NASA Johnson Space Center

SPACE-BASED ASSETS

Co-chaired by **Brandon Cesul**, Centauri and **Elizabeth Cunningham**, Air Force

CISLUNAR SSA

Co-chaired by **James Frith**, Air Force Research Laboratory and **Jaime Stearns**, Air Force Research Laboratory

POSTERS

APPENDIX