Towards a Taxonomy of Safety Zones

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Abstract

This contribution proposes a taxonomy of restrictive properties of safety zones in outer space. Based on similar phenomena mainly in the regulation of airspace and the high sea, and with consideration of existing discourse with respect to safety zones in outer space, six main aspects of safety zones that determine its constraining effect on other space actors are identified. Consequently, this paper proposes a dynamic minimality principle when considering how to scope and size a safety zone along the axes of restrictions outlined in the taxonomy.

1. Introduction

Safety zones on celestial bodies and in outer space remain an important yet frustratingly underexplored phenomenon that has the potential to constrain future space activities significantly. This contribution aims to investigate the range in substantial scope these safety zones may take by reference to established international regimes dealing with the concept of excluding access, such as United Nations Convention on the Law of the Sea (UNCLOS) as well as more localized but prevalent regimes such as safety zones pertaining to air traffic.

On the basis of the above, this contribution suggests a taxonomy of safety zones on celestial bodies and in outer space that may be classified along multiple dimensions of interest. We find that the following characteristics of safety zones are of prime interest: (1) scope, (2) spatial dimensions, (3) duration, (4) disclosure and (5) consultation regimes, and (6) enforcement measures. We also show that each of these represent an axis on which restrictiveness (and as a result, impact on other space actors) can be modulated by the imposing entity.

We argue in favor of a principle of minimality derived from the principles of free use and free access to outer space and celestial bodies, which we apply to all identified axes. We also argue for a dynamic system of evaluation of these characteristics, with subsequent safety zones in a spatial sector that is already

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subject to access and use restrictions having to meet higher standards or exhibit more restraint. With this we also briefly address the implications of such a system to nations that become spacefaring after the introduction of a critical mass of safety zones. We propose this taxonomy to be used as a flexible factor test when assessing, in the totatlity of circumstances, the legality of any future safety zone in outer space

2. Overview over Safety-Related Area Restriction Measures in International Law

In its broadest form, a safety zone is an area of limited access for the purposes of reducing risk of harm.[1] In this paper, we will focus on non-military access- and use-restrictions. Nonetheless, many of these principles are closely connected to states' considerations pertaining to the preservation of their defensive and offensive capabilities. To understand the motivation and use-case of such measures, let us consider these concepts in some other domains of international law.

2.1. Safety Zones in Aviation

The most salient objects of comparison to outer space are areas of restricted access in aviation contexts.[2] Most generally, under the Chicago Convention, states' ability to impose access restrictions are well recognized. For example, states can regulate flights over certain (inaccessible or inadequately equipped) regions,[3] and establish fully prohibited areas for reasons of military necessity or public safety, adhering to "reasonable extent and location [limits], so as not to interfere unnecessarily with air navigation", a measure that needs to be notified to other states and the ICAO.[4] Another type of access restrictions for the purposes of safety is the prohibition of transport of certain carriage through a state's airspace[5], and, as an extension of this, the restriction of use of certain equipment such as cameras.[6] More granularly, states tend to restrict and compartmentalize their air space in line with safety concerns. To this end, access to much air space is either restricted or requires certain operational procedures and equipment. Distinctions are usually made between controlled and uncontrolled airspaces, with special use airspaces (SAOs) serving as context-specific safety zones. Examples of SAOs with decreasing severity of restrictions encompass prohibited, restricted, warning or alert areas,

1 Note that harm reduction works in both ways here, both to avoid factual risk and liability for the entity requiring the safety zone and for the safety of a possible intruder.
2 Interestingly, similar to Art IX OST, Art 2 of the Chicago Convention imposes a due-regard obligation for the safety of navigation of civil aircraft.
3 Art 5 Chicago Convention.
4 Art 9 Chicago Convention.
5 Art 35 Chicago Convention.
6 Art 36 Chicago Convention.

depending on the types of risk encountered. If these zones are temporary, such zones are generally (simultaneously) imposed and communicated unilaterally through the instrument of NOTAM, i.e. a notice to airmen. Finally, some states declare zones outside of their territory as air defense identification zones or similarly named delimitations without any territorial claims.[7]

2.2. Safety Zones in Maritime Contexts

Similarly, the rules governing maritime environments, such as the United Convention on the Law of the Sea (UNCLOS) allow restrictions of access both with respect to the exercise of geographical sovereignty and in international waters beyond. Pertaining to the former, UNCLOS allows the installation of safety zones around "artificial islands, installations, and structures" within a state's exclusive economic zone for the purpose of ensuring safety of both maritime navigation and the assets at risk.[8] Through UNCLOS, these zones are limited to a distance of five hundred meters from the asset in question (unless special authorization is obtained),[9] and must be notified.[10] However, such safety zones may not be established where essential sea lanes are interfered with.[11] With respect to international waters and the seabed that lie beyond the sovereignty of individual states, and with respect to scientific research installations, UNCLOS again foresees safety zones to protect authorized (and peaceful) installations with similar limitations.[12] On a national level and similar to the regulation of the air, states tend to create a gradient of restriction for certain areas (e.g. to ensure environmental protection through the imposition of a precautionary area.) Like the regulation of air space, maritime environments may be subject to different intensity of discouragement such as warning zones / areas or security or exclusionary zones, (often in a military context).[13]

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7 Peter A Dutton, *Caelum liberum: Air defense identification zones outside sovereign airspace*, 103 AM. J. INT. LAW 691–709 (2009). While these are somewhat military in nature, they affect all air traffic and thus affect non-military air operations.

8 Mikhail Kashubsky & Anthony Morrison, *Security of offshore oil and gas facilities: exclusion zones and ships' routeing*, 5 AUST. J. MARIT. OCEAN AFF. 1–10 (2013), http://www.tandfonline.com/doi/abs/10.1080/18366503.2013.10815725.

9 This limit was also included in a precursor treaty, the Convention on the Continental Shelf.

10 Walker A Smith, *Using the Artemis Accords to Build Customary International Law: A Vision for a U.S.-Centric Good Governance Regime in Outer Space Comments*, 86 J. Air Law Commer. 661–700 (2021), https://heinonline.org/HOL/P?h=hein.journals/jalc86&i=697.

11 Art 60 UNCLOS.

12 Art 147 para 2, Art 260 UNCLOS.

13 F Kenneth Schwetje, *Protecting Space Assets: A Legal Analysis of Keep-Out Zones* , 15 J. SP. LAW 131–146 (1987), https://heinonline.org/HOL/P?h=hein.journals/jrlsl15&i=143, Ted Adam Newsome, *The Legality Of Safety And Security Zones In Outer Space: A Look To Other Domains And Past Proposals*, 2016.

2.3. Safety Zones for Culturally Sensitive Areas

Finally, we consider the protection of culturally sensitive areas. While dogmatically different, there is a perceived need for regulating access and use restrictions for culturally historical sites, and this connects to the concept of safety zones in outer space.[14] Such approach requires understanding harm (or harmful interference) as not (only) affecting assets and personnel but a more ephemeral historical or cultural heritage.[15] Some regimes pertaining to the law of armed conflicts protect hostile acts against e.g. historical monuments or places of worship constituting a cultural heritage.[16] Outside of the *ius in bello*, cultural protection is covered by a network of conventions and declarations of diminishing legal power and enforcement due to a more limited set of participating states and the lack of applicable custom.[17] Specific efforts have been undertaken to protecting heritage in inaccessible domains such as underwater.[18] Under these regimes, "immediate danger" for the protected sites must be met with "practical measures" and authorization of activities must be aligned with the notion of site protection;[19] to this end information about such protected sites ought to be notified to other states.[20] These requirements mirror the considerations present in the other domains investigated above.

3. Overview over Existing Approaches to Safety Zones in Outer Space

Safety zones have been discussed in the context of outer space, as they can be derived from principles of space law and the requirements of operational safety and underlying national interests of space actors. As a measure of both exclusion and safety, they are situated squarely in an area of tension. On the one hand, generally accepted tenets of space law discourage exclusivity such as the prohibition of national appropriation of outer space[21] and the freedom

14 Jessy Kate Schingler, *Imagining Safety Zones: Implications and Open Questions*, Sp. Rev. (2020).

15 Rossana Deplano, *The Artemis Accords: Evolution or Revolution in International Space Law*, 70 Int. Comp. Law Q. 799–819, 811 (2021), https://www.cambridge.org/core/product/identifier/S0020589321000142/type/journal_article.

16 See e.g. Art 53 Protocol I Geneva Convention, see also Katerina Papaioannou, *The international law on the protection of cultural heritage*, 3 IJASOS-International E-journal Adv. Soc. Sci. 257–262 (2017).

17 E.g. International UNESCO Convention on the Protection of the World Cultural and Natural Heritage

18 See Convention on the Protection of the Underwater Cultural Heritage (2001). Note that the scope of the convention requires artifacts to have been submerged for at least one hundred years

19 Art 12 CPUCH.

20 Art 19 CPUCH.

21 See e.g. Art. II OST.

of exploration and use. [22] On the other hand, the inherently risky nature of outer space operations requires precautions to avoid damage to space assets and human life and liability of the responsible states, thereby also connecting to the principle of due regard and avoidance of harmful interference.[23] However, even if not appropriating outer space, such measures still de facto extend states' control.[24]

Considerations of safety zones in this context are not new.[25] Recently, they have received increasing public attention, likely due to their inclusion in the Artemis Accords.[26] Under the Accords, a safety zone is an area in which space operations, or an "anomalous event" could "reasonably cause harmful interference".[27] As a result, the installation of a safety zone is considered a measure to *ensure* states' obligations under Art IX of the OST. Under the Accords, the safety zone is unilaterally imposed by a state through notification[28] and is sized and scoped to align with the space operation's peculiarities.[29] This is often referenced as building upon work by the Hague Space Resources Working Group's Building Blocks for the Development of an International Framework on Space Resource Activities.[30] There, the group has, in the context of resource exploitation, called for permission to establish safety zones as area-based safety measures necessary to assure safety to avoid any harmful interference.[31] The working group also endorsed restricting

22 See e.g. Art. I OST.
23 See e.g. Art IX OST.
24 See Art VIII OST.
25 Schwetje, *supra* note 13; Malcolm Russell, *Military Activities in Outer Space: Soviet Legal Views*, 25 HARV. INT'L. LJ 153 (1984). The close ties of original conceptions to e.g. UNCLOS is also visible e.g in White's proposal for a property law regime in the context of outer space Wayne N White Jr, *Implications Of A Proposal For Real Property Rights In Outer Space*, 366 *In* Proceedings, Forty-Second Colloquium On The Law Of Outer Space, At (2000).
26 Schingler, *supra* note 14.
27 See Section 11 (7) Artemis Accords.
28 This imposition is not necessarily public. The accords call for "notification" but making this information public is subject to a test of "appropriateness", in particular with respect to proprietary and export-controlled information. This may create issues when dealing with non-signatory space actors which are not privy to the original notification.
29 Note that Mike Gold, one of the main drafters involved in the creation of the accords has emphasized that they ought to be understood not as a tool of exclusion or "stay-out zone" Smith, *supra* note 10.
30 *Id.*at 685.
31 Fengna Xu & Jinyuan Su, *New Elements in the Hague Space Resources Governance Working Group's Building Blocks*, 53 SPACE POLICY 101386 (2020), https://linkinghub.elsevier.com/retrieve/pii/S026596462030028X.

access to the safety zone for limited time periods, but noted the necessity to not impede free access.[32]

Naturally, this is not the only context in which safety zones are already discussed or implemented. For example, the International Space Station is surrounded by two-hundred kilometers of restricted space.[33] Current debate also covers the protection of culturally and scientifically significant sites. Some states have expressed interest in preserving their Outer Space "heritage" such as artefacts and traces of their space operations,[34] following strides made by the United States to preserve the Apollo Moon landing sites.[35] Of lesser practical relevance but similar purpose is the fact that the Moon Agreement also considers designations as "international scientific preserves" for which "special protective arrangements" may be in order.[36]

4. Main Axes of Classification of a Taxonomy of Safety Zones

We suggest here to understand safety zones as characterized by their constraining effect on different aspects of space operations. These dimensions reflect the existing discourse around and underlying motivation behind safety zones as outlined above. Under this taxonomy, there are six main axes of comparisons: (1) scope, (2) spatial dimensions, (3) duration, (4) disclosure and (5) consultation regimes, and (6) enforcement. On each of these axes, safety zones may display characteristics that lead to the zone being more or less restrictive and constraining to other space actors. A higher degree of restrictiveness would require a more robust justification as a result.

We also identify further characteristics that allow compartmentalization and comparison of safety zones that are not by themselves directly connected to a constraining effect on other space operations *per se*. This section shines light on some of the most salient of these characteristics.

32 The Hague International Space Resources Governance Working Group, *Adoption of the building blocks for the development of an international framework on space resource activities*, 45 Air and Space Law (2020), https://documents-dds-ny.un.org/doc/UNDOC/LTD/V20/008/95/PDF/V2000895.pdf?OpenElement.

33 Melissa de Zwart, *To the moon and beyond: The Artemis Accords and the evolution of space law*, *in* Commercial and Military Uses of Outer Space 65–80 (2021).

34 See e.g. Section 9, Artemis Accords. Note the weaker language for this section.

35 Justin St. P. Walsh, *Protection of humanity's cultural and historic heritage in space*, 28 SPACE POLICY 234–243 (2012), https://linkinghub.elsevier.com/retrieve/pii/S0265964612000938. See also the One Small Step to Protect Human Heritage in Space Act, S.1694 – 116th Congress (2019-2020) or the Nasa Recommendations to Space-Faring Entities (2011), (https://www.nasa.gov/pdf/617743main_NASA-USG_LUNAR_HISTORIC_SITES_RevA-508.pdf).

36 Art 7 para. 3 Moon Agreement.

4.1. Scope

The inherent defining characteristics of a safety zone are the measures and restrictions imposed. As comparisons with similar regimes have shown, there are multiple types of safety measures.

We first consider general access and access notification conditions. At the most restrictive end of the spectrum are safety zones in which access is fully prohibited (for other space actors). Less intensive are the requirements of pre-clearance or authorization of access with an appropriate entity. Naturally, the requirement to announce planned access is less restrictive than the requirement to gain approval by an authority overseeing the safety zone. On the lowest end of this spectrum are zones in which access is not restricted *per se*, but discouraged or qualified through warnings or alerts.

Second, in recognition of the differences of space actors and their operations and assets, it makes sense to consider equipment-specific requirements of safety zones that can modulate access privileges. A type of variable constraint are safety zones that require certain equipment (e.g. for purposes of navigation, communication, or obstacle avoidance) to access, with the intensity of the constraint dependent on availability (as determined by price and access) of the equipment to space operators.[37] On the flipside of this, safety zones may be valid only (or more restrictive) towards space actors that exhibit certain qualities. For example, safety zones may limit access for space vehicles using certain propulsion technology (e.g. for concern of contamination) or carrying certain cargo.[38]

Finally, differences in access privileges may be a result of political or commercial alliances. It seems conceivable that in case of political or military tensions, the state ultimately responsible for a safety zone may choose to exclude space actors of its political adversaries through a sanction regime. Similarly, there are incentives for political or economical allies to invoke exclusivity of space ports or settlements on celestial bodies. We note that the legality and justifiability of such measures under current space law and even the softer instruments such as the Artemis Accords remains questionable at best.[39]

37 For example, the imposition of a safety zone requiring equipment that is inaccessible to other space-faring nations for reasons of pricing or export-restrictions is clearly a stronger constraint than the requirement to have standard radio equipment on board.

38 Again, the restrictiveness of these measures will have to be determined on a case-by-case basis. Prohibiting access of all space vehicles using conventional technology in favor of proprietary technology only available to a small number of space actors is in higher tension with the cooperative tenets of space law and may require stronger justification.

39 The interplay between sanctions and safety zones is left for future research to respect the focus and conciseness of this paper.

4.2. Spatial Dimensions

The spatial dimensions of a safety zone determine its volumetric occupancy.[40] For all practical purposes at the time of writing, space is a limited resource, so the larger the spatial dimensions of a safety zone are, the more impactful its restrictions are.

It makes sense to consider and distinguish both interplanetary space and celestial bodies. Interplanetary space is comparatively vast. As a result, the constraining impact of safety zones are dependent less on their actual size, and more on their location. Comparatively, celestial bodies make up a very small part of accessible outer space. As a result their physicality is subject to much higher scarcity, intensifying the constraining impact of safety zones.

An interesting inverse situation of currently limited practical importance pertains to the spatial dimensions of intergalactic space whose scarcity is arguably decreasing. Under these considerations, safety zones that pertain to certain dimensions (e.g. length, width and depth) become increasingly less intrusive, while safety zones connected to certain celestial markers remain or even increase in intrusiveness to space actors' (intergalactic) operations.[41]

4.3. Duration

Beyond the (three) spatial dimensions, safety zones encompass a fourth temporal dimensions. Ultimately, all safety zones are not permanent,[42] but we can distinguish between safety zones of limited or indefinite periods. The intensity of constraining other space actors on this axis of observation scales with the duration of the safety zone.

Existing discourse about safety zones has recognized this, with most existing or proposed regimes mandating that both spatial and temporal dimensions of a safety zone must be connected and contingent on its necessity,[43] which is in

40 For most purposes, a safety zone will be a three-dimensional shape (not considering its temporal dimension indicated by its duration). Two-dimensional safety zones (i.e. delimited areas) only make sense if there is a ground-like planar surface, and even then, the purpose of the safety zone will usually require that the "airspace" above it is also subject to restrictions.

41 See for this concept in theory Georges Lemaître, *The expanding universe*, 91 MON. NOT. R. ASTRON. SOC. 490–501 (1931).

42 For example, safety zones for human space operations in proximity to earth reach a natural end of usefulness in around one billion years as this area becomes uninhabitable, see e.g. K.-P. Schröder & Robert Connon Smith, *Distant future of the Sun and Earth revisited*, 386 Mon. Not. R. Astron. Soc. 155–163 (2008), https://academic.oup.com/mnras/article-lookup/doi/10.1111/j.1365-2966.2008.13022.x. .

43 E.g. Section 11 para. Artemis Accords call for a determination made "in reasonable manner leveraging commonly accepted scientific and engineering principles", UNCLOS demands "reasonable" and "appropriate" safety zones in light of "applicable international standards" and "reasonably related to the nature and function of the artificial" of the relevant assets.

line with considerations of requirements under space law. This will typically create an implicit obligation (or commitment under certain regimes) to revoke or limit the safety zones if necessity is no longer given.

4.4. Disclosure

In order for safety zones to be effective, they need to be communicated to other space actors.[44] To minimize the impact of a safety zone on other space operations, its extent, scope and any adjacent relevant (or useful) information ought to be up-to-date and easily available for any prospective space actor likely to be affected if impact ought to be minimal. The zone becomes more restrictive on this axis as information is limited (e.g. to certain space actors), not easily available or outdated. While existing regimes generally encourage or mandate full disclosure, the peculiarities of safety zones may be withheld e.g. in the interest of military or security reasons.[45]

4.5. Consultation

Under existing regimes, safety zones are typically imposed unilaterally. However, existing regimes often foresee some sort of consultation process.[46] The restrictiveness of a safety zone under this view is determined by the peculiarities of this consultation process. If consultations are held prior to the imposition of the measures and periodically (or as necessary) revisited, if consultations are accessible to all prospective affected space actors, then the constraining intensity of the safety zone is minimized on this axis. Conversely, limiting access to consultations to specific groups of space actors, abstaining from revisiting consultations in case of changed circumstances (e.g. both the emergence of new affected space actors, a shift within the overall community of space actors or changes to the underlying necessities) increases factual restrictiveness of the safety zone.

4.6. Enforcement

The status of an area in outer space as safety zone is a normative phenomenon. Its translation into the factual domain encompasses means of enforcement that the responsible state or the relevant space actors use to ensure the inviolability of the safety zone. Enforcement can be considered on multiples levels.

We first consider enforcement responsibility. As similar regimes on Earth show, the strongest enforcement of access restrictions comes through the deployment of military assets or other defensive capabilities; this is true both

44 Deplano, *supra* note 15 at 809.

45 Note e.g. the subdued language in Section 11 para. 9 in the Artemis Accords: ”signatories should, as appropriate, make relevant information … available to the public as soon as practicable and feasible, while taking into account appropriate protections for proprietary and export-controlled information”.

46 See e.g. Section 11 para. 11 Artemis Accords.

for military and primarily non-militarily (e.g. for reasons of public safety) motivated safety zones.[47] Of theoretically parallel severity is enforcement through para-military actors or similar (private) security forces engaged by the space actor.

Second, of interest is the means of potential repellency. Again, a gradient of coerciveness and restrictiveness is apparent (regardless of its legality). Of highest severity is enforcement with destructive weaponry. Below this, physical detaining or impounding assets that violate a safety zone represents a de-escalation. Lesser still are practices of interception, escorting and documentation, and the subsequent imposing of claims, fines, penalties lawsuits or general adverse economic or diplomatic behavior against the respective space actor and/or its attributable state. Of least repellency are safety zones that sport no measures of enforcement.

Connected to the above is a safety zone's actual repellency. Physically walling off a settlement on a celestial body, interference with the navigational system of space vehicles or similar measures prevent violation of the safety zone in a factual way but arguably with less force. In this way, the respective zone is both more and less restrictive as comparable zones with conventional enforcement.

5. Additional Safety Zone Characteristics

Not all distinctive elements relate directly to the zone's restrictiveness. We suggest here two main other criteria that are of interest to the discourse at large: the source of risk a safety zone is modelled around and the legality of the safety zone.

5.1. Source of Risk

Safety zones are a measure of exclusion for the purpose of safety for the assets of the imposing entity and the space actors that are affected by it.

We can distinguish widely between military and civil safety zones. In the former, the likely most salient risk lies with the imposing entity, where the integrity of their military assets and their operations is safeguarded and their confidential information is maintained.[48] Within safety zones for non-military, i.e. civil purposes, another distinction lies in the commerciality of the underlying risky activity. Here, we can broadly divide between commercial activities (such as resource extraction, orbiting of commercial

47 For example, military assets enforcing air defense identification zones deal primarily with civilian aircrafts.

48 Of course risk for other space actors exists in these zones as well, e.g. in cases of live-fire exercises, weapon-testing or just for the purposes of space-traffic control.

satellites or space-tourism) and operations for the purpose of research and exploration. Inbetween are safety zones that are of mixed purpose, such as space-traffic related zones in scarce spatial corridors that many space actors must use regardless of their commercial nature.[49]
De jure, commercial activity is arguably not favored by existing sources of space law when compared to scientific or exploratory space operations. This has implications for the justifiability of their respective safety zones.

5.2. Legality

As has already been hinted at in the previous text, the imposition of a safety zone, its characteristics and its enforcement is a matter of fact. It is important to distinguish this from the question of whether the safety zone in question is legal under applicable treaties or custom. We consider it very likely that states (and their space actors) continue to interpret space law in line with national interests when it comes to safety zones. As a result, there may not always be consensus about the legality of a safety zone. Regardless of legal rights and obligations, states may decide to comply with safety zones of another state as a matter of policy. As a result, we urge for a realistic perspective when considering safety zones, compliance and conscious non-observance.

6. Minimality Principle of Safety Zones

As the previous section has shown, states imposing a safety zone have wide-ranging discretion on how they can restrict access. As their efforts move between the end points of the axes identified above, the tension between their justified interests to minimize harmful interference and the interests of other space-faring states changes.

49 Here we may consider particularly areas in close proximity to spaceports, celestial bodies (e.g. regarding "orbit capacity" or other (future) surface-to-orbit mechanisms Cathy W. Swan & Peter A. Swan, *Why we need a space elevator*, 22 Space Policy 86-91 (2006), https://linkinghub.elsevier.com/retrieve/pii/S0265964606000166; M. Palmroth et al., *Toward Sustainable Use of Space: Economic, Technological, and Legal Perspectives*, 57 Space Policy 101428 (2021), https://linkinghub.elsevier.com/retrieve/pii/S0265964621000205..

Table 1. Overview over restrictive measures related to safety zones

	less restrictive	**←→**	**more restrictive**
general scope	warnings, alerts	preclearance, authorization	prohibition of access
equipment requirement	no requirements	readily available equipment, common restrictions	equipment of limited availability, uncommon restrictions.
equality of application	uniform application	discriminative application based on safety-considerations or exigent legal factors	discriminative application based on commercial or political considerations
spatial dimensions	small perimeter		expansive perimeter
spatial location	general interplanetary or intergalactic space	critical space corridors	celestial bodies and their orbits
duration	limited duration		indefinite duration
disclosure	open and exhaustive communication of all relevant information	limited or outdated information	no information
consultation	accessible consultation prior to establishment and in periodic intervals	consultation open to limited group of space actors	no consultations
potential repellency	no repellant measures, documentation, fines, penalties, diplomatic measures	interception, escorting, detainment, impounding	destructive weapons
actual repellency	no repellent measures	technical (defensive) interference	physical obstacles

With this paper we join the (likely) majority in calling for safety zones to be subject to a minimality principle. Safety zones in all domains surveyed encourage or mandate to minimize in particular duration, scope and spatial dimensions of safety zones.

This is in line with the general approach of regimes regulating safety zones. We may recall that safety zones in airspace are subject to reasonable extent-test, to be weighed against air travel interests.[50] Similarly, maritime safety zone regimes foresee their limitation in line with "accepted international standards" or "recommendations by competent international organizations", but under consideration of "recognized sea lanes essential to international navigation."[51] The same is true for the new regime under the Artemis Accords, in which the size and scope of such zones ought to be dependent on "the nature of the operations being conducted and the environment that such operations are conducted in", and ought to "be determined in a reasonable manner leveraging commonly accepted scientific and engineering principles".[52]

The need for scoping a safety zone along the minimal necessary dimensions is hence well established generally and in particular in the context of outer space. The taxonomy outlined in this paper allows for an application of this principle with increased precision. The principle of minimality that ought to regulate sustainable exclusion and limitation of outer space and its celestial bodies applies to all of these taxonomized dimensions. In other words, embedding of safety zones in existing space law as being subject to freedom of exploration and use requires space actors to minimize their restrictive impact on all these dimensions. To this end the factor test of the proposed taxonomy aids in understanding the aspects of safety zones as separate constraining elements and separate points of consideration.

7. Outlook: Marginal Minimality

Insofar space operations continue to become more prevalent and their respective safety zones become more widespread, the cost of safety zones born by the international community at large, changes. As mentioned before space (in particular space of interest) is ultimately a scarce resource, and celestial bodies are scarcer still. As a result, each imposed safety zone (at a given time) reduces the remainder of freely usable space for later space actors in the same domain. At the same time, the subsequent space actor's safety zone will restrict a relatively larger portion of the remaining unrestricted space.

50 See e.g. Art 9 Chicago Convention.
51 See e.g. Art 60 para 4,5,7, 147 UNCLOS.
52 See e.g. Sec. 11 Artemis Accords.

For this reason we argue for a dynamic understanding of the minimality principle under the consideration of an additional meta-aspect of relative restrictiveness. These considerations are twofold: first, dynamically with respect to already existing space restrictions, and second with respect to restrictiveness to future space actors.

Applying the first dynamic principle, the burden of justifiability for further safety zones, particularly if they are not in the interest of the wider space community, ought to be higher if much of the existing orbit of a celestial body or space transit corridor is already subject to restrictions. At the same time, this phenomenon risks to unduly restrict the activities of emerging space actors. If established space actors have already limited large swaths of usable or critical areas in space, new space actors may be deprived of conducting similar space-operations due to the fact that their consequently necessary safety zones may be considered as too restrictive in context. The second dynamic principle we suggest requires then to understand safety zones as more restrictive the more they impede future space actors' activities and their respective security and safety precautions.

8. Conclusion

Recent years have brought increased interest for safety zones in outer space. In this paper, we have given an overview over existing safety zone-esque frameworks in related domains and in outer space. To understand the tension between restriction, due regard and freedom of exploration and use we have proposed a taxonomy to understand the different aspects of safety zones as potentially constraining elements. We have argued that each of these dimensions is subject to a dynamic minimality principle which requires space actors to strive towards minimal impact on all aspects of a safety zone. Due to the scarcity of space and its celestial bodies, this also ought to be done with particular consideration of existing restrictions and the effects this has on future space operations.