Managing a metaproblem: Space debris

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Given the new plans for going to Moon or Mars, and the growth of the market for satellites, both private and military, the aerospace industry is booming. However the exponential increase in the quantity of trash in orbit around Earth jeopardizes its growth — a situation typical of what has been called a metaproblem, which requires coordination among many different actors. The problem of space debris has three interdependent momentums, each requiring different forms of action: *contain* the present situation to keep it from deteriorating; *stimulate* the invention of solutions for the future; and *clean up* existing debris to eliminate the legacy from the past. Four ways to settle this problem are identified with the help of scenario planning, each taking account of the variety of actors (public and private) and of possible forms of coordination (market and regulations).

On 10 February 2009, a declassified Russian military satellite, Cosmos-2251, rammed the telecommunications satellite Iridium-33 head-on at an estimated speed of more than 11,000 km/second. The collision probably produced more than 3000 pieces of debris (estimates vary). This was the first large-scale accident in space recorded. Since the start of the space age in 1957, the quantity of space debris has increased exponentially. This has been called Kessler's syndrome (KESSLER & COUR-PALAIS 1978): each accident produces a multitude of new pieces of debris, which might well cause other collisions in a chain reaction. At present, there are reported to be in space: 34,000 objects above 10 cm in diameter, 900,000 above 1 cm, and 128 million above 1 mm. An object of one millimeter (*e.g.*, a flake of paint) can, given its speed in space, cause major damage to a satellite in orbit. In proportion to the increasing number of observation and communication satellites, the risk of collisions is rising.[1]

Detection systems can help to foresee collisions with large objects. On Monday, 2 September 2019, the European Space Agency (ESA) modified the trajectory of one of its satellites, Aeolus, in order to avoid a collision with a satellite in the Starlink constellation of SpaceX, Elon Musk's corporation. This was the first time that the ESA had to perform such a maneuver to avoid collision with an operating satellite. Previously, such maneuvers were made to avoid debris or derelict satellites. Many smaller objects elude detection; and the proliferation of debris will soon make such maneuvers more difficult and probably less effective. The costs resulting from this proliferation of debris can mount, in terms of human lives (for astronauts and people on ground) and in economic terms (were sophisticated satellites to be destroyed).

This problem shows how the pursuit of individual strategies (for launching ever more satellites) can tend toward a collective catastrophe (no longer being able to travel in space). In this sense, Earth orbits have become the stage of a new "*tragedy of the commons*" as described by Garret Hardin (1968, p. 1244): "*Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all.*"

This sort of situation has been described as a "*meta-problem*" (CARTWRIGHT 1987). Managing it calls for the involvement of diverse actors with contradictory values who use various means of action. Questions related to the environment, sustainable development, human rights or corruption fall into this category. The case of space debris can be used to see how such problems are produced and eventually placed on the agenda so that efforts will be made to manage them. By extending Cartwright's analysis, we notice that such problems characteristically have three interdependent but separate dimensions. First of all, the most urgent problems have to be handled to prevent, for example, that the firing of an antiballistic missile or a collision with a satellite in operation not cause a new catastrophe that would be fatal to activities in space. Farther ahead, the situation will be durably stabilized only if stakeholders deeply change their comportment

[1] This article, including quotations from French, has been translated by Noal Mellott (Omaha Beach, France). All websites were consulted in August 2021; and a few bibliographical references have, with the editor's approval, been completed.

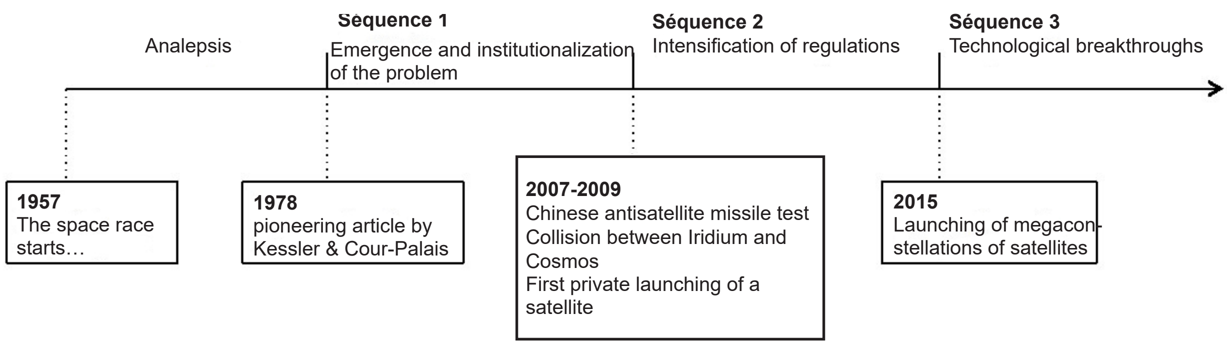
Table 1: Methodology

A varied bibliographical corpus has been consulted for this article. There is a wide range of sources about space debris: reports, publications of international organizations, legislative texts, official chronicles…. not to mention the scientific publications we consulted (KESSLER & COUR-PALAIS 1978, ALBY *et al*. 2007, BONNAL 2016) in various disciplines, such as economics (SALTER 2016), sociology (SAINT-MARTIN 2016) and law (CHADDHA 2013). To discover the major points of information in this abundant corpus, we adopted the snowball sampling method (PATTON 2002, MILES & HUBERMAN 2018).

Fifteen interviews were conducted to complete the information collected. We met with the representatives of each of the big players in the aerospace industry who are implicated in the problem of space debris: industrialists (ecodesign, commerce, engineering), space agencies, startups (specialized in risk analysis or debris removal), universities (CubeSats, research on power lasers) and legal services. Thanks to these nondirective interviews, lasting from 75 minutes to 3 hours, we grounded the hypotheses formulated during our research and tested the possibility and plausibility of the scenarios that we had worked out ("*using interview material to revise theory*": PIORE 2006, p. 22).

What characterizes a metaproblem is its multidimensionality and high uncertainty. Analytically, its complexity can be broken down into its constituent dimensions. The literature has identified two dimensions in the space debris metaproblem: MITIGATION (no longer producing more debris) and REMEDIATION (cleaning up existing debris). Our approach brought to light a third: CONTAINMENT (forestalling imminent catastrophes). By shedding light on these three dimensions, we broached the question of uncertainty with the help of scenario planning, which has often been used to analyze environmental problems. To design the scenarios, two axes of critical uncertainty were constructed out of an analysis of the material collected and of the interviews: private/public actors and regulation/market.

Table 2: The storyline



— what has been called MITIGATION. Finally, Earth orbits will have to be cleaned of the debris accumulated there since the start of the space age — the dimension of REMEDIATION.

By showing how the space debris metaproblem arose, how it has developed and how various actors have started reacting, this article explores possible, plausible scenarios for managing it. A generalization to other types of metaproblems, such as plastic wastes in the oceans, is imaginable.

The metaproblem, a narrative analysis

Let us start with a history of space debris in order to understand how this metaproblem emerged and has taken shape over time. On the basis of this narrative, we shall analyze this problem in its three dimensions. For this history, the study of the chronologies reported in the literature on this topic (KESSLER 1993, SALTER 2016, BONNAL 2016, SAINT-MARTIN 2016) helped us establish a storyline (*cf*. Table 2) with three periods between two tipping points (ABBOTT 2001, ABELL 2004, DUMEZ 2016). The first sequence is the appearance of the scientific problem and the first attempts to find a solution. A few major collisions tipped this history into its second sequence, characterized by more intense regulatory activities. We have now probably entered a third sequence characterized by technological breakthroughs that will make the problem much worse in the coming years.

Sequence 1: Emergence and institutionalization of the problem

The first satellites remained in space once they stopped operating. When manned flights started, boosters were retrieved on the ground and analyzed for evidence of impacts from meteorites. To their amazment, the NASA scientists (in particular Donald Kessler) reported finding particles of aluminum. Since such particles are not present in space, they had to have come from man-made objects.

In 1978, a pioneering article — often said to be the starting point of the history of space debris — was published in the Journal of Geophysical Research. Its title is "Collision frequency of artificial satellites: The creation of a debris belt" (KESSLER & COUR-PALAIS 1978). At the time, its purely statistical approach served as proof of an exponential effect, a phenomenon now called "Kessler's syndrome" (KESSLER 1993). Since space debris are being produced faster than the atmosphere can get rid of them, they risk colliding with other objects and producing more fragments. In space, mass counts for very little: a piece of debris does not have to be heavy to wreak damage. An object 1 cm in diameter has a power of destruction equivalent to a car running at 130 km/h on the earth's surface.

Officially recognizing the gravity of this problem, NASA asked Kessler to head the Orbital Debris Program Office, a new division based in Houston. A group of scientists specialized on space debris formed around Kessler. In 1993, they set up the Inter-Agency Space Debris Coordination Committee (IADC), an international, interagency organization with the mission "to exchange between member space agencies, to facilitate opportunities for cooperation in space debris research, to review the progress of ongoing cooperative activities and to identify debris mitigation options" (IADC 1993, p. 1). The most frequently cited definition of space debris comes from the IADC: "all man-made objects including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are nonfunctional" (IADC 2020, p. 6).

NASA, JAXA and the CNES (respectively the American, Japanese and French space agencies) soon adopted their first standards. At the turn of the new century, the IADC (2020) and COPUOS (United Nations Committee on the Peaceful Uses of Outer Space) published guidelines and codes of conduct.

During this first sequence, which lasted nearly thirty years, the space debris problem was discovered and gradually "institutionalized" (ALBY et al. 2007, SAINT-MARTIN 2016, VON DER DUNK & TRONCHETTI 2015).

On 11 January 2007, the Chinese army performed an antisatellite missile test that destroyed an old weather satellite. This event alone increased by 25% the quantity of debris in space. Two years later, Iridium and Cosmos collided, as mentioned in the introduction. These two events amounted to a tipping point that signals a new phase in the history of space debris. In the meantime, China has become responsible for nearly 42% of space debris, as compared with 27.5% for the United States and 25.5% for Russia. The space community has recognized the gravity of this problem and its possibly tragic consequences. The problem now to be addressed is for this community to find a fitting solution.

Sequence 2: More regulations

The second sequence was marked by two distinct trends that occurred in combination. On the one hand, as shown, the quantity of debris in orbit suddenly increased following the two events in 2007 and 2009. On the other hand, private businesses moved to center stage in the aerospace industry. SpaceX, Elon Musk's firm, was founded in 2003. After several failed launches, its Falcon 1 became, in 2009, the first private spacecraft to place a satellite in orbit. The combination of these two independent trends set off reactions in matters of regulation, both among nation-states and private actors.

More and more governments were adopting national legislation about space debris. Although they did not mention this issue, major international treaties did stipulate that countries are responsible for their activities in space. With private firms entering the business of launches, governments — given the state's ultimate liability — sought for coverage by regulating their private operators' space activities. For instance, France passed the Act on Space Operations in 2008. These private firms tried to take part in this process of regulation.

In 2011, an ISO standard on the management of space systems reflected this determination to set up a private form of regulation. Drafted by space agencies, member states, the space and insurance industries, and jurists, this standard drew heavily on the IADC's technical guidelines. It could have been effective had it had a ripple effect or had reputation been a major issue for all stakeholders. Unfortunately, the influential players in this field have still done little to apply it.

Meanwhile, startups were forming that saw space debris as a market opportunity. Set up in 2013 by a Japanese entrepreneur, Astroscale is trying to sell services for orbital debris removal. Its canvassing of the big firms that launch megaconstellations of satellites are starting to make the cash register ring. Nevertheless, this firm is still having difficulty drafting a long-term business plan.

In 2013, the space debris issue dropped out of the orbit of specialists and came down to ground with the release of Alfonso Cuarón's Gravity. In a sequel to this movie, the mass media started reporting on this topic.

During this second sequence, the international community accepted that space debris was a problem to be managed collectively. Despite this visibility in the media and the efforts made to draft regulations, research programs on space debris did not come up with any precise, effective solution. Worse yet, new menaces were looming as this sequence came to a close.

Sequence 3: Technological breakthroughs, and the problem worsens

During the period starting in 2015, the situation became worse because of three factors: plans for nanosatellites, programs for megaconstellations, and the continuance of tests by the armed forces in some countries.

A constellation is a group of mostly low Earth orbit (LEO) satellites that are coordinated to cover the largest area possible on the ground. These constellations usually collect positioning and observation data via remote sensing. They are mainly used in telecommunications, climatology, meteorology and cartography.

For example, a constellation like Galileo, the EU's navigation satellite system, has 30 satellites. In 2015, several private satellite operators (e.g., OneWeb and SpaceX) disclosed plans for megaconstellations that will guarantee perfect Internet coverage and broadband access everywhere on the planet. Since Sputnik, 8850 objects have been placed on orbit; but SpaceX will be launching 12,000 LEO satellites for Starlink.

These new programs carry quite real dangers. They will suddenly increase the number of satellites in orbit and, as a consequence, the risk of collisions. Moreover, most of these satellites do not have motors powerful enough to perform maneuvers to deorbit them or control them when they reach the end of their life cycle or no longer work.

Meanwhile, more and more miniaturized satellites (CubeSats) are being launched. Thanks to their standardized components, these small cubes (10 cm x 10 cm x 10 cm) are manufactured at a low cost. At the start, CubeSats were developed by universities so that students could make and steer their own satellites. Nowadays, private firms as well as space agencies are taking an interest in them for commercial reasons. A CubeSat's small size keeps its position from being precisely detected, especially when it stops transmitting. At the end of its life cycle, this small device can become an uncontrollable, extremely dangerous projectile.

Finally, in recent years, many military maneuvers have been conducted in violation of the most basic safety rules, the destruction of an Indian satellite by a missile test on 27 March 2019 being an example thereof. Shows of force, the need for legitimation as a big military power, tacit warnings to neighboring lands… the aerospace industry is the theater of a planetary geopolitics. These activities multiply space debris. They also undermine the efforts made by the scientific community and jurists in favor of regulations.

The metaproblem's three dimensions: Containment, mitigation and remediation

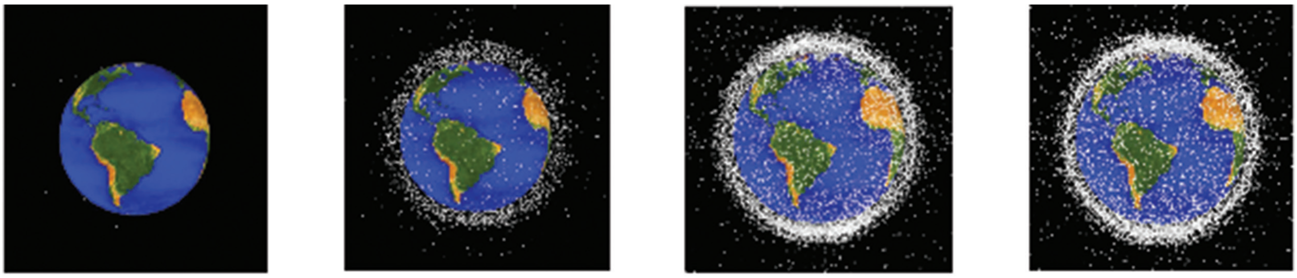
This metaproblem can be analyzed in relation to its three constituent dimensions. These three are both separable (since the parties involved and the requisite forms of coordination differ from one dimension to another) and interdependent (since the metaproblem is seen as a whole). They are related to the metaproblem's time horizon with very deep roots in the past, with implications for a far-off future, and with the urgency of acting in the present. These three dimensions are: containment, mitigation and remediation.

To keep the problem from becoming much worse, the first reaction by stakeholders must be to adopt immediate measures. The problem must be contained right away. In the case of space debris, this means forestalling any new catastrophe. Such an event could result from a collision in space, an explosion in flight or the voluntary destruction of a satellite.

Metaproblems also are of concern in relation to the future. To attenuate risks, the behavior of the parties involved must be modified; and a new dynamics, created. In the literature, this is called "mitigation", which is "aimed at preventing a problem from getting worse" (BAIOCCHI & WELSER 2010, p. 13). Several incentives can serve to encourage stakeholders to follow recommendations. In the case at hand, these parties must stop creating new debris and anticipate the end of operation of their satellites by using better adapted materials that can easily disintegrate in the atmosphere and withstand collisions. Satellites could also be fitted out with little motors for atmospheric entry once their mission has come to an end.

Finally, we must take into account the damage wrought in the past and clean up the wastes. This remediation "aims to reverse events or stop undesired effects" (BAIOCCHI & WELSER 2010, p. 13). This reactive process tries to attenuate the problem but not necessarily eliminate it. Several techniques for removing space debris are now undergoing experimentation: robotic arms, harpoons, lasers…. but they are still hard to implement, and they are expensive.

These three dimensions — contain, mitigate, remediate — correspond to three processes of collective action that can be conducted both separately and together. They must be squarely tackled to solve the metaproblem of the proliferation of debris in orbit around Earth. Which scenarios are possible and plausible in response to these three necessary actions?



1960 1980 2010 2015

Figure 1: The number of reported objects in orbit (of a diameter of more than 10 cm in low Earth orbit and of 1 m in geostationary orbit)
Source: https://orbitaldebris.jsc.nasa.gov/modeling

The scenario approach

Major treaties have rejected the militarization, as well as the private or public ownership, of space. The last treaty adopted on space (1984) has referred to Moon as a "*common heritage of mankind*". From the start of the space age, outer space has been conceived to be a commons. However, this conception has never been fully applicable. Military strategies have been extended into space, and private operators have been developing business activities there. When the first treaties were signed during the 1960s, there was not yet an awareness that space debris was a tragedy of the commons. Nonetheless, this realization would very gradually take shape, as our narrative account has shown.

Garret Hardin (1968) proposed two solutions to what he called the "*tragedy of the commons*". The first was for the state to be coercive, capable of controlling and sanctioning the behavior of other parties. In the case at hand, that would imply strong international cooperation between governments. However the specialized jurists whom we met and who participated in UN work groups were extremely pessimistic about this possibility, even in the medium term. The second solution would be to privatize the commons, each owner having an interest in taking care of his share. However this option runs counter to the fundamental principle, which figures in the first treaty, of free access to space. Ostrom (1990) has proposed another solution for forests and irrigation systems, namely: the management of the commons by local communities. However this approach, which implies a set of sanctions and the official recognition of these communities, is not scaled to the global nature of the space debris problem. Besides, there is no possibility to impose sanctions.

Paradoxically, this tragedy can apparently not be managed by adopting the solutions (state, market, community) proposed by Hardin and Ostrom. Instead, it is necessary to imagine combinations thereof — similarly to what Fournier (2013, p. 438) has called "commoning:" "*We see the commons not only as a finite pool of resources but also as a social process of production and organization.*" The phrase "*social process of production and organization*" is accurate: although it fits the problem, it remains too vague. As we came to think that many such processes might be at work, we adopted an approach based on scenarios (SCHWARTZ 1991, SCHOEMAKER 1995, PINKHAM & CHAPLIN 1996, WIEBE *et al*. 2018). Scenario planning normally has two aspects: "*A common approach to scenario-building is to choose two driving forces that are both very important and uncertain or unpredictable. For each of these two 'critical uncertainties', one then assumes two different but plausible future outcomes. Combining the two outcomes for the two forces yields a scenario matrix of four different futures.*" (PINKHAM & CHAPLIN 1996, p. 3).

Identifying two axes of critical uncertainty

The diversity of actors and of forms of coordination are the two axes of "critical uncertainty" in the space debris metaproblem. The actors can be public or private, whereas the alternative forms of coordination are through regulations or through the marketplace. Identifying these two axes was the first step toward building scenarios (cf. Figure 2).

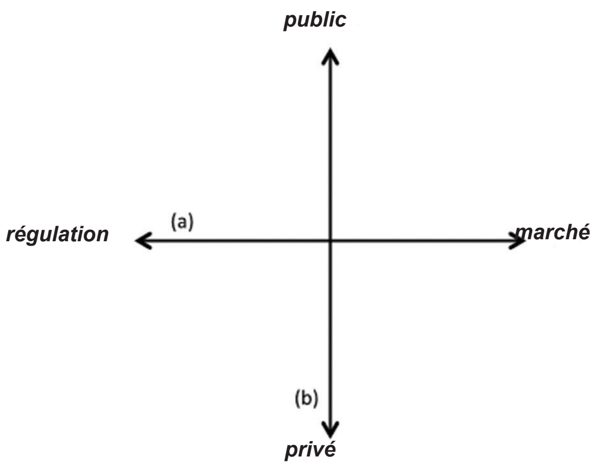


Figure 2: The two axes of critical uncertainty: *a)* forms of coordination, regulation/market, and *b)* the actors, private/public

Actors: Private or public

A metaproblem is characterized by a combination of varied objectives and interests with different time horizons (CARTWRIGHT 1987, p. 93). Outer space is a sector where both private and public actors are busy. Though coexisting, these two sorts of players pursue different interests. As a function of their activities, actors of the one or the other sort take the lead and undertake initiatives.

Historically, state and public authorities have been dominant in matters, whether civilian or military, related to space. A public space agency is in charge of orchestrating the nation's activities in space. The importance of these agencies varies depending on the country. In France and the United States, for example, these agencies have a role in designing and launching objects in space. Nowadays, the private sector is actively expanding its aerospatial activities. It includes historical firms (like Airbus or Arianespace) as well as influential newcomers (such as SpaceX or Blue Origin) along with several small, more specialized players — what has been called the "*new space*" (PASCO 2017). Thanks to their considerable financial means, these firms are able to react fast to changes in the market. They are probably more sensitive than governments to "naming and shaming". In contrast, governments have limited room for maneuvering given their implication in geopolitics. Unlike states, these firms pursue short- or medium-term goals for earning a profit, goals that might be in contradiction with sustainability (WEEDEN & CHOW 2011). The following question cropped up. Which sort of actor can take initiatives for containing, mitigating or remedying this metaproblem and assume leadership for the implementation of the solutions imagined?

Forms of coordination: Regulation or the marketplace?

Given this problem's three dimensions, the actors can resort to several organizational processes. On the one hand, public or private standards and regulations could be used to orient behaviors. On the other hand, the creation of a market could coordinate actors around the equilibrium price between supply and demand. In practice of course, these two forms of coordination are combined: the market needs rules, and regulations are intended for market oversight. Often however, the one dominates the other, as the balance of power shifts toward the one side or the other, toward the market or toward regulatory activities.

Two major forms of regulation can be distinguished. "*Hard law*" can be used nationally or internationally. What characterizes it is its "*dimensions of obligation, precision, and delegation*" (ABBOTT & SNIDAL 2000, p. 422). While it can both reduce the costs of transactions and reinforce the credibility of actors and their strategies, it has, as a counterpart, that it dictates behavior and restrains freedom. On the international scale, a treaty is the most coercive form. In contrast, soft law (best represented by standards) is a form of self-regulation without coercion. It can even be considered to be a form of organization (BRUNSSON *et al*. 2012). The grounds of soft law might be a metaorganization, *i.e.*, an organization that discusses and issue standards, its members being organizations (AHRNE & BRUNSSON 2008, BERKOWITZ & DUMEZ 2016), often private actors from the marketplace (trade groups). The multiplication of standards sometimes runs counter to the initial objective of simplifying rules (BÜTHE & MATTLI 2013). This phenomenon has been described as "*meta-standardization*", which means that: "*convergence happens at the level of core criteria and overarching principles ('rules of the game'), whereas variety remains at the level of specialized attributes allowing standards-setters to maintain their own identities*" (REINECKE *et al*. 2012, p. 792).

Opposite regulation, the market is considered to be a form of coordination, whereby rival organizations or individuals set a price for exchanging property rights. Classical economic theory presents the marketplace and organizations as opposing elements, the latter serving only to make up for "market failure": "*Organizations are a means of achieving the benefits of collective action in situations in which the price system fails*" (ARROW 1974, p. 33). If the market is necessary to come to grips with a metaproblem, it will have to be considered to be an organization (AHRNE *et al*. 2015). Like an organization, its structure and mode of operation vary. Like an organization, it is more or less well organized. Like an organization, it has five dimensions: "*membership, rules, monitoring, sanctions and hierarchy*": "*The concept of market organization is an analytical tool, which can be used for analyzing why and how markets are created, why they get their specific form and how they change*" (AHRNE *et al*. 2015). These authors have even proposed a typology of market organizers: profiteers (for whom creating a market rhymes with profits), buyers, sellers and "*others*" (who take part in creating a market but have no economic interest in doing so, such as NGOs).

Building four scenarios

Four management scenarios were made (cf. Figure 3). The first is regulatory oversight by public authorities, its grounds being the rules of hard or soft law discussed during negotiations between governments and international organizations. The second is private regulation, which relies on the setting of standards and implies forms of cooperation between private parties who often compete with each other. The third concerns the activity itself and not the regulation of it: managing the problem by establishing a public service, a sort of monopoly often associated with the lack of potential profits. The fourth scenario is the classical marketplace, where players seek to earn profit by offering or buying goods and services.

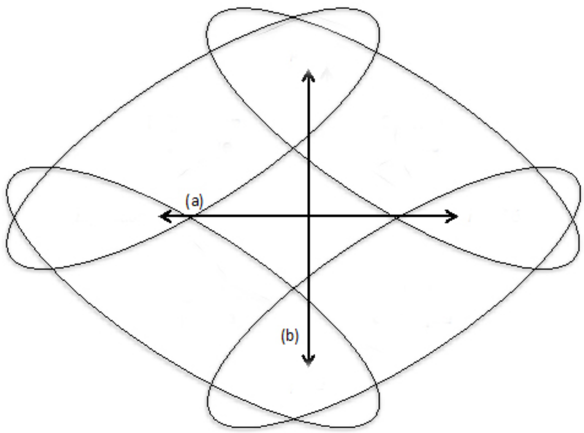


Figure 3: The four scenarios: As a public service, by the marketplace, by private regulations (standards), by public regulations

Managing the metaproblem: Plausible scenarios for…

As stated at the start, the metaproblem has three dimensions: containment, mitigation and remediation. We identified the most plausible scenario(s) for each.

…containment: Public regulation

In the short run, it is necessary to forestall catastrophes by preventing further antiballistic missile tests and averting collisions with big, identified pieces of debris. These two requirements are public issues, given, in particular, their military aspects. They imply the adoption of rules by public authorities. The optimal solution would be the signature of a new international treaty by all countries directly or indirectly present in space (BARRETT 2003). As we have seen however, the jurists involved in negotiations have expressed serious doubts about the United Nations coming up with a new agreement of this sort. In effect, geopolitical conflicts have seemingly paralyzed COPUOS, which only works through a consensus. Given this absence of a united international community, space cannot be managed like a commons. So, the scenario of an international treaty seems impracticable. Only a new catastrophe, like the events in 2007 or 2009, might eventually push the whole international community to act together.

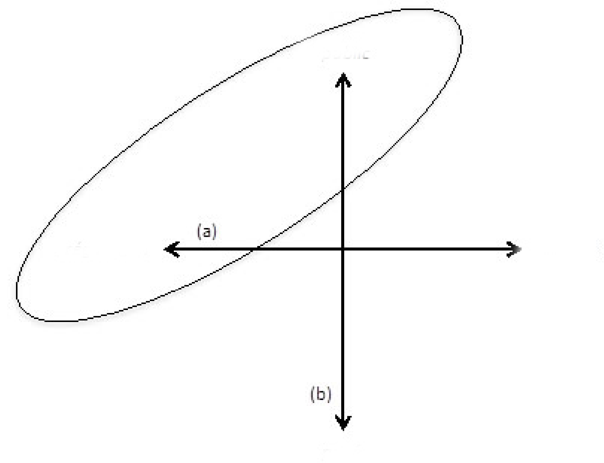


Figure 4: Containment by public regulation

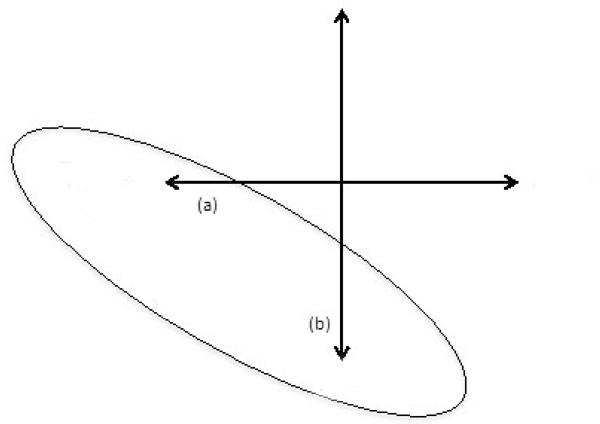


Figure 5: Mitigation by private regulation

We can imagine a scenario, suboptimal but feasible, based on the formation of a virtuous group of the major countries active in space. They would bind themselves, through a charter, to no longer shoot at satellites in space. Of course, rogue states would not be bound by the charter and could continue military exercises, but they would be subject to a naming and shaming that might have an effect.

For space traffic management (the avoidance of collisions), geopolitical tensions are also an obstacle to the drafting of an international treaty for signature by all nation-states. The idea of a virtuous community of stakeholders does not seem applicable to this problem however. After all, we cannot imagine a highway code that would apply only to virtuous drivers!

…mitigation: Private regulation

To put an end to the proliferation of space debris, the players in aerospace must modify long-term behavior patterns. They must be induced to take into account the end of the life cycle of the devices they send into space; and they must do so from the very phase of design (so as to eventually be able to deorbit the devices). This requires changing the rules and, too, developing market-related activities; and it probably entails mobilizing both public and private actors. It is, therefore, hard to choose a single scenario among these four possibilities. Since, in practice, regulation and the market will be combined, the question is to know how far the situation will tilt toward one pole or the other on the coordination axis. Since rule-making is apparently the first, inevitable step toward long-term change, the tilt will initially be toward regulation. A regulatory framework is generally conducive to organizing space activities, whence a second question: will this regulation be public or private? As seen when examining the first scenario, public regulation buckles under geopolitical tensions. So, the first step toward modifying long-term behavior seems to be to set up a private form of regulation (cf. Figure 5).

In the management of a metaproblem, reputation provides powerful leverage for altering private actors' behaviors (FOMBRUN 1996 & 2001, BREITINGER & BONARDI 2019). Firms can be judged as being socially responsible not by nature but in the field where they are active (BASTIANUTTI & DUMEZ 2012). In addition, a firm's reputation can have repercussions on the whole sector, on its collective reputation: "*The reputation of the industry is only as good as the reputation pf individual companies. If one company does something wrong, the whole industry can be judged to have done something wrong*" (quoted by TUCKER 2008, p. 7). This solidarity is an incentive for firms to undertake coordination (WINN *et al*. 2008), which can go so far as to set up a metaorganization. In 2019, a group of private actors (including the historical players in aerospace, specialized startups, insurers and the owners of mega-constellations) met to set up the Space Safety Coalition. All the members of this virtuous private community have pledged to upport best practices for a more sustainable management of their activities in space. This form of private regulation fits into a broader trend in setting standards (which produced the 2011 ISO standard).

This scenario would bolster a private form of regulation. In this case, firms are the driving force in changing behavior patterns through the very rules that they support, all the more willingly insofar as they have made the rules themselves (BRUNSSON & JACOBSSON 2000). These rules are diffused between firms, often through relations with suppliers and subcontractors. They can also come to affect public actors, as the rules adopted by the most virtuous end up being applied on the less virtuous.

…remediation: A public service or a private market?

Solving the cleanup problem, even though it implies the formulation of rules, is an activity. Removing debris from orbit calls for significant advances in technology, and entails developing a market (and not just making standards). Actors will have to be mobilized around a collective, long-term problem with a still uncertain return on investment. We thus imagined two activity-based scenarios: a public service or a classical marketplace. We thought it necessary to explore both so as to compare their strengths and weaknesses.

The first of these two scenarios is the creation of a public market of a monopolistic type. Nation-states could jointly set up an international fund for a new multilateral organization that would be neutral and oversee the cleaning of Earth orbits. This nonprofit organization would become the public street sweeper in space. It would be in charge of deorbiting dangerous smithereens with or without the approval of the country that launched the device. For the first time in the handling of a metaproblem related to sustainable development, joint international action would be undertaken to solve a shared problem. This action would, we assume, engage all actors to make a financial commitment (in proportion to the means of each and the presence of their objects in orbit) as part of a program for pooling costs (with a system of fees similar to air traffic control). Such a highly symbolic initiative would have the advantages of sharing costs between countries and of being a civilian approach to the space debris problem. However most of the interviewees who had taken part in international negotiations of this sort emphasized that this process would be very slow and exhausting. Besides, multilateralism has come to a standstill in the past few years.

For all these reasons, the creation of a private market (the second option) probably represents, in the medium term, a more plausible possibility despite the extremely high investments required. The increased financial risks related to potential collisions will make private firms and their clients aware of the need for solutions. The necessary condition for this scenario is to create and organize this market; this supposes a collective action by firms. Though still relatively small, there are more potential clients and suppliers in this market than a few years ago. We could thus imagine a minimal form of collective action based on informal, intermittent contacts. However this flexible form of market organization would probably prove insufficient, at least for making rules. So, a small group of actors could then take the initiative to set up a metaorganization, since a trade group would probably not suffice to cope with the problem. The metaorganization might, at times, directly coordinate actions and also be a market operator (if only to launch and control the devices used for the cleanup). It could stake out a position as a regulator by drafting rules and monitoring activities. There are very few examples of this sort of setup, but it is a possibility. It would resemble, for example, the Companhia Geral das Vinhas do Alto Douro, which used to organize the Port wine market (DUGUID 2015).

Figure 6 illustrates the two possibilities for coordination by the marketplace that have been discussed. The first requires laborious international negotiations between governments, whereas the second has a more flexible form of coordination with, however, the likely formation of a metaorganization. The second is apparently the more plausible scenario in the medium term. A combination of the two (of a classical market and a public service) in the form of a public-private partnership is, of course, conceivable. In effect, several such partnerships have already taken shape around the issue of space debris. For instance, the ESA and OneWeb signed, in 2019, a partnership with the Japanese start-up Astroscale for managing the end of the life cycle of the satellites launched as part of the Sunrise program.

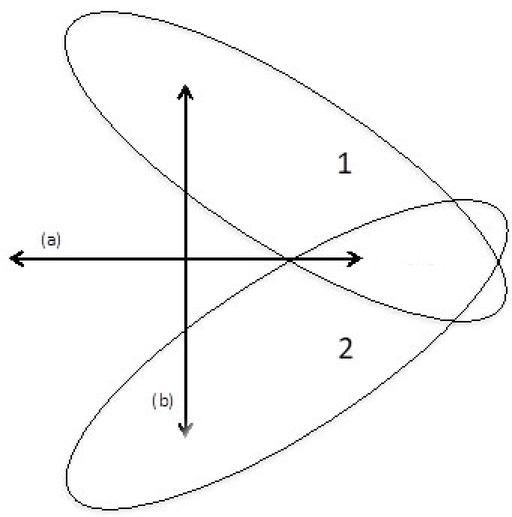


Figure 6: Remediation by a public service or the classical market approach

Conclusion

Managing a metaproblem is a Herculean task. The time horizon extends from the past into a distant future. In the case of space debris, three dimensions emerged. With regard to the past, the Augean stables will have to be cleaned — to get rid of the debris that has accumulated over time in Earth orbit. The many heads of the Lernaean Hydra will have to be tackled — the problems that continually crop up, day to day, have to be lopped to avoid catastrophes. Just as Hercules seized the horns of the Cretan bull and tamed it, the solutions have to be invented that will stabilize and settle the problem in the future by changing behaviors. In practical terms, two axes of critical uncertainty have been identified in relation to this metaproblem: the type of actors (public or private) and the means of coordination (marketplace or regulations). Four scenarios thus appeared as plausible for managing this commons. For each dimension of the metaproblem, one or two of the most plausible scenarios were described that correspond to the characteristics of the situation.

To ameliorate and validate this interpretation of metaproblems, it would be worthwhile making a comparison with a similar case. Applying the same scenarios to, for example, the problems of plastic in the oceans or of the transmutation of nuclear wastes might shed light on points specific to each problem area. Are the three dimensions articulated in the same way? Does the choice of the four poles (private/public actors and market/regulatory coordination) still hold? Answering these questions would prove or disprove the relevance of the analysis presented herein. In addition, it would bring to light the specificity of the metaproblem of space debris in comparison with similar cases.

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