USE OF THE SENDAI FRAMEWORK IN FUTURE SPACE DEBRIS DISASTERS: LEARNING LESSONS FROM LONG-TERM DATA ANALYSIS OF ORBITAL ASSETS

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ABSTRACT

Risk assessment of anthropogenic objects in earth orbits today mainly focuses on single object pairs, their risk of collision, fragmentation, and their re-entry forecast.

In domains of environmental care, the combination of system empiric and model approach helps understand the overall evolution within "space as a system", its population dynamics, the evolving progress, the impact of disruptions and indications of turning points.

Classical risk management targets the avoidance of the catastrophe and the strength of the system's resilience. Our highly complex, multi-dimensional topic requires a bridging framework to establish a cooperative, holistic and approved management, ensuring visibility and understanding for stakeholders and society.

The Sendai framework provides guidance before, during and after catastrophic events, based on preparations done beforehand. We show that a catastrophe leading to unavailability of space services fulfils similar conditions, and that preparedness and resilience are key elements for a safe and sustainable future in outer space.

1. COLLISION RISK IS NOT A THEORETICAL EXERCISE, BUT A REALITY

The population of anthropogenic objects launched into orbits around the earth has, for a long time, been increasing slowly, but steadily. With a handful of manufacturers and processes for manufacturing satellites that had known turnaround times of months to years depending on the purpose, the amount of increase was quite foreseeable.

Space debris became a problem already at this point, and at least after the first satellite-to-satellite collisions, satellite operators knew collision risk in outer space was not just a theoretical exercise, but had become a reality.

Apart from starting to use data from optical and radar observations to create and maintain object catalogs and to forecast orbital movements, eventually resulting in assessing expected conjunctions and deriving collision probabilities, the space community came up with many proposals for removing (defunct) objects from their orbits. First attempts were made in legislation to foster, if not enforce, sustainable manufacturing, operations and disposal of satellites.

It became clear that implementing all of the above was not a task to be done overnight, but required significant time and effort. However, - and this can be seen in analogy to the history of environmental protection on earth – it seemed we could be able to prevent at least catastrophic chain-collision events of the kind Donald Kessler described in the Kessler effect (also called "Kessler Syndrome") that was named after him.

2. NEW SPACE – NEW RISK

Around 2020, the picture began to change drastically. In the US, space transportation had become liberalized and commercialized [1] and, though largely funded through and still quite controlled by federal entities, allowed industry to develop a significant industrial and commercial launch capacity (SpaceX and others). In parallel, satellite manufacturing changed. CubeSats, Micro- and Nano-satellites led to a drastic reduction in size and weight, making it possible to launch large numbers of objects with a single launcher. This step was not only important for research purposes, but allowed large satellite manufacturers to revolutionize their production processes. They showed that satellite manufacturing can be industrialized and automated to create satellite factories (e.g., OneWeb).

These so-called "New Space" activities completely changed the picture of population and risk dynamics in outer space. In a way, the almost exponential increase in the number of objects in certain orbits resembles the dynamics of an epidemic, of a pandemic. [2]

Given such dynamics, the big disaster becomes a vision (a nightmare) that we have to face as a future reality. Like with other disaster topics such as power black-outs, forest fires, flooding, accidents in chemical industry (why don't we talk about earthquakes or volcanoes? – because they are not human-made), chain-collision accidents in space or even the complete congestion of an orbit according to the Kessler effect are not just theoretical considerations, but a reality we will have to face sooner or later, and repeatedly.

3. A COMPLEX MATTER

The above findings lead us to the question how we should deal with outer-space disaster as an upcoming reality. Are we sufficiently prepared for this? Beyond pure material loss (per-object), what are the “environmental” impacts we would be facing? What are the derived consequences e.g., related to business continuity of the space ecosystem and its dependent stakeholders on earth? How quickly would we notice the damage? How long would it take to recover from it?

To approach this quite complex topic we propose to use a well-established framework what should help to cover the whole life cycle of the system including its very wide field of impacted stakeholders in a structured way.

4. AN ESTABLISHED FRAMEWORK

The United Nations (UN) define “disaster-risk” as: *“the potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity”* [3].

A sudden or slowly evolving outage of the satellite infrastructure leads to significant changes in the socio-economic living on Earth [4][5], with the biggest impact for technology-dependent societies. We therefore assume the materializing of such risks represents a disaster according the above UN definition.

The Sendai Framework for disaster risk reduction defines the following priorities (see Table 1):

Priority 1	Understanding disaster risk
Priority 2	Strengthening disaster risk governance to manage disaster risk
Priority 3	Investing in disaster risk reduction for resilience
Priority 4	Enhancing disaster preparedness for effective response and to “Build Back Better” in recovery, rehabilitation and reconstruction

Table 1: Sendai Framework Priorities

The Sendai framework is not just a crisis management, but an overall risk management framework. The framework was originally conceived for environmental catastrophes affecting human lives, living conditions and critical infrastructure. Its priorities are not completely independent from each other, they are interfacing each other as can be seen in Figure 1.

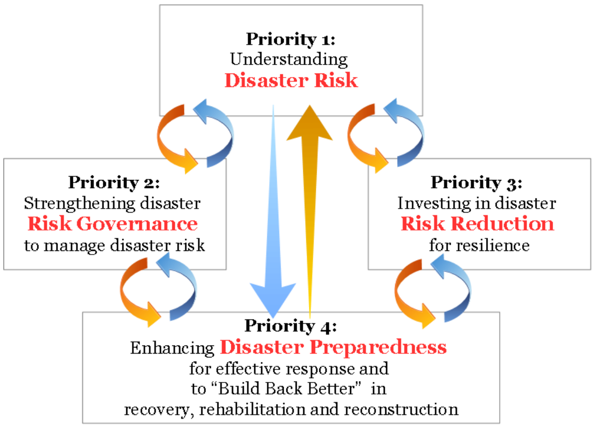

Figure 1: Sendai Framework Priority Interrelations

The subsequent chapters apply the context of impact, consequences to and outage of space services using the proposed framework.

5. PRIORITY 1: UNDERSTANDING DISASTER RISK

The Sendai Framework summarizes this priority as: “*Policies and practices for disaster risk management should be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment. Such knowledge can be leveraged for the purpose of pre-disaster risk assessment, for prevention and mitigation and for the development and implementation of appropriate preparedness and effective response to disasters.”* [3]

To follow the definition of disaster in the context of outer space, a disaster is not a single outage of one spacecraft but a significant degradation of the “system” in service provision or the usability of outer space. To go back in history there are following examples of major events within the last 20 years in the reverse order of produced number of known space debris parts[ref] as shown in Table 2 below.

Envisat	8,200 kg satellite in 790km orbital height, uncontrolled spinning in 3 axes, April 2012
NOAA 16	Polar-Orbiting Environmental Satellite in 846 km orbital height, fragmentation November 2015
Iridium 33 - Cosmos-2251	Crash, 789km orbital height, February 2009
Fengyun-1C	anti-satellite missile test, 865 km orbital height, January 2007

Table 2: Major space debris events of the past

These events do not fall under the classification "disaster" as they can be seen as single "local" events without an immediate influence to the total system.

The big disaster has not yet arrived, but it will. The occurrence of the Kessler Syndrome, an uncontrollable chain collision spreading across a whole orbital shell, would qualify as a disaster. With the launch of the first mega-constellations with their >1000 satellites, the risk of such chain collision gets significantly increased, the disaster becomes more likely.

The triggers for this disaster can be manifold, as the simple increase of the number of objects by one or two orders of magnitude also means a correspondingly higher susceptibility of the overall system against influences such as sun outage, meteor showers, cyber security threats, fragmentations and collisions with other orbital objects.

In the event of a chain collision the following main degradation of services and the use of outer space will happen in the following order of occurrence:

- Terrestrial monitoring/measurement of space objects (debris and active satellites) will be curtailed due to the enormous number of new parts in the scenery resulting in a loss of perceptive faculty of discrimination
- Outage of the services from the infected mega-constellation in the same orbital 'traffic lane'
- Spread of the infection to other orbital planes from cross trafficking orbital objects
- Outage of other services like Earth observation, telecommunication
- Evacuation of ISS due to loss of space debris monitoring capability and possible debris spreading
- Infection of complete LEO orbit section
- Infection of MEO orbit section
- Infection of GEO orbit section

The above series of events clearly shows the characteristics of a disaster according the UN disaster-risk definition.

Other scenarios of a "system degradation" could be a crash of satellites in the save orbit in Geo-synchronous orbit caused by two dead satellites (inclined orbits) or a major collision of two rocket stages in their highly-elliptical orbits. Former would produce a very hard traceable debris cloud moving around the GEO arc (in direction of higher gravity like and Himalaya Massive) and latter would produce a debris cloud crossing through several orbits increasing the risk for very different assets.

5.1. Disaster risk pattern, disaster risk modelling and the use of data

The following chapter uses mega-constellation conjunction data from the past to visualize a walk-through of one risk scenario (as described in [7], we use the publicly available Two-Line Element (TLE) data from CelesTrak [8] to calculate the conjunction data). As mentioned before, disaster can be initiated by various triggers; luckily, none of these triggers were present at the time the empiric data was measured and, therefore, no disaster evolved. In accordance with the Sendai Framework, we use the historical data to strengthen the disaster risk modelling, assessment and mapping, and include scientific research on disaster risk patterns, disaster risk modelling and the use of data.

To describe the situation in a figurative way, we introduce the term "Space Pandemic" to follow the analogy to the actual Covid pandemic and – using this analogy – to understand the "infection paths" with their resulting consequences.

The following picture shows the "diary" of one satellite (let us call it 1126) in the Starlink constellation between 2021-02-12 and 2021-02-17, with all its "meetings" (conjunctions) with other satellites. The graph shows on the x-axes the meeting (conjunction) times and on the y-axes the distance of the conjunctions (red = "internal meetings", yellow = "external meetings").

1126 shows 46 internal meetings (conjunctions) and three external meetings. Seven (7) of these meetings are quite close and held within 1km to other objects.

Now we come to the "infection" (collision) risk: If object 1126 is "infected" in the form of a crash similar to the Iridium 33 – Cosmos-2251 event mentioned before, the potential of a chain collision is significant.

To use the wording of the Covid pandemic: 1126 has the potential to become a super-spreader.

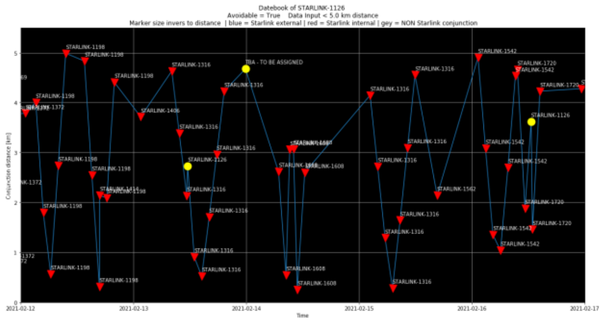

Figure 2: Diary of satellite 1126 in the Starlink constellation between 2021-02-12 and 2021-02-17

If we now assume that 1126 would have a collision with 1198 at the first close meeting (conjunction) on 2021-02-12 at 06:24, what would happen?

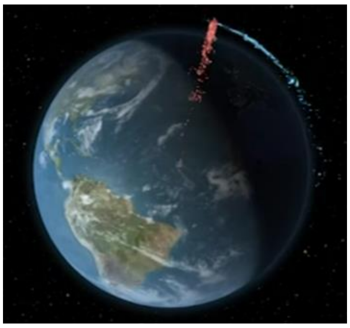

Figure 3: Distribution of "fresh" space debris shortly after the collision of Cosmos-Iridium in 2009 (source: ESA)

At the event itself nobody would notice it [9]. The operator would notice later on that there is an anomaly on two satellites and will investigate. The first space debris radar operator would notice an undefined cloud of new (uncatalogued) parts at the overpass (see Figure 3) and start to investigate. After some time, the operator will judge the loss of two satellites as establishing contact is no more possible.

At 16:48 (approximately 13 orbits later), the fresh debris from 1126 will have a meeting with 1414 and probably damage this satellite to an outage. In the meantime, the operator got in touch with their contracted space debris radar operators and is also in contact with authorities. Around the world, other space debris radar measurement stations notice several additional space debris clouds.

At 19:26, the debris from 1414 has a good chance to destroy 1198, and the mega-constellation operation declares an emergency situation.

At 01:32, 1126 debris destroys 1406 and about 40 minutes later, at 02:19, the 1406 debris collides with 'Object F' (Norad ID 43836) leading to its outage. At 08:09, 1126 debris destroys 1316. 26h after the initial collision, a total 6 operational objects of the mega-constellation and one external Object (Object F) might have been destroyed, brought to outage or left tumbling.

If a satellite gets hit from parts from the debris cone is a hit-or-miss situation as long as no evidence of the new debris is given. Nevertheless, the chance to be hit shortly after the collision is high as the cone is not spread apart. The measurements of the new pieces will take between 24h and 36h until catalogued and published to the operators, which in the given example corresponds with 30 to 45 orbits of the new debris before collision avoidance maneuvers will be effective. In the best case, the collision avoidance action vs. the debris clouds starts on 2021-02-13 at 06:24.

Next possible collisions in the given risk pattern are: 1414 with 1650 (09:03), 1650 with LEMUR 2 WANLI (Norad ID 44402.0) (09:37), 27h after the initial event.

48h after the initial crash the following 46 objects are "infected": 12987, 16881, 16986, 27119, 28592, 32226, 35380, 37582, 39930, 43023, 43663, 43836, 44252, 44351, 44394, 44402, 44407, 44729, 44921, 44951, 45053, 45076, 45200, 45365, 45369, 45381, 45415, 45687, 45690, 45695, 45708, 45732, 45776, 46038, 46039, 46079, 46146, 46170, 46490, 46491, 46533, 46537, 46573, 46706, 46725, 87107. (The numbers are the Norad IDs.)

Note once more that the results are not from a theoretical simulation for a future scenario, they are from the conjunctions which happened in the past, joined with the hypothetical assumption of a disaster trigger occurring at some point in time.

The next two graphs provide two views to the infection scenario. Figure 4 represents the latitude distribution on the time continuum and Figure 5 the height distribution for the first 48h after initial crash. The 'infections' are shown as pink crosses. All other dots show the recorded conjunctions where grey are other conjunctions out form the mega constellation, yellow shows the conjunctions with object from the mega-constellation and the red dots the internal conjunctions.

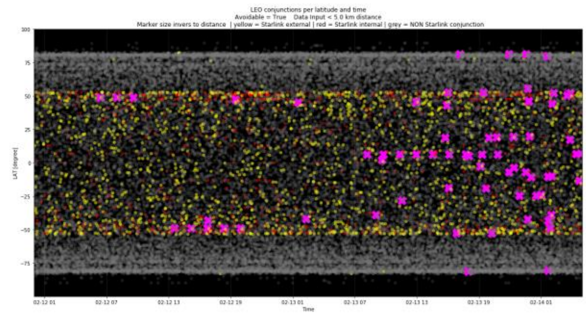

Figure 4: Latitude distribution of conjunctions on the time continuum for the first 48h after initial crash; Infections as pink crosses

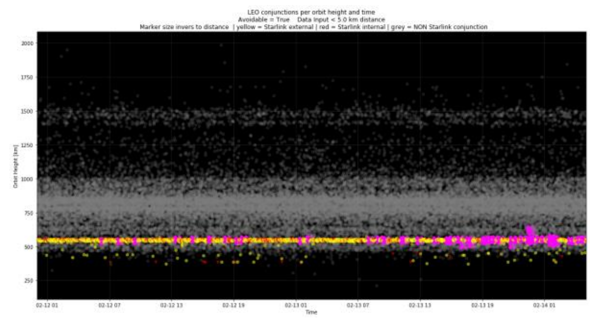

Figure 5: Orbit height distribution of conjunctions on the time continuum for the first 48h after initial crash; Infections as pink crosses

In the given scenario the mega constellation has electric propulsion on board which allows only quite slow orbit changes in comparison to chemical propulsion. Even if there is a 'red button' to escape the question is: where to escape to? And if there is a possibility to escape, how could the rest of the constellation be stabilized after the 'fire escape'. In addition, any orbit change also crosses the original orbit again. This would mean an additional risk to cross the infected orbits (see Figure 5). In fact, it is much easier to escape upwards than downwards.

What might initiate the first crash? In the overall risk scenario analysis, the specific risk of the initial event (trigger) needs to be assessed. The following bullets list several major reasons for an initial trigger event.

<u>Events with significant influence of the operator</u>

- Operational anomaly resulting from a SW problem on board or in the network operation center
- Anomaly in the autonomous control on the spacecraft
- Spacecraft hardware anomalies
- Data errors in distribution to the space craft

<u>Events with limited influence of the operator</u>

- Cyber-attack to the spacecraft or ground operation
- Data errors or missing data of other conjunction objects

<u>Events with no influence of the operator</u>

- A minor debris or near-earth object impact on the spacecraft resulting in an anomaly in the orbit path keeping (tumble or spin) before a planned conjunction
- Crash of two “foreign” satellites or fragmentation of one “foreign” satellite near or in the same orbital shell as the mega-constellation
- Space craft operation or HW/SW error of a “foreign” satellite in the same orbital shell as the mega-constellation
- Solar wind eruption
- Intentional crash with another (controlled) object
- Use of anti-satellite weapons

5.2. The vulnerability in context of the consequences

In their 2019 paper [10], Sokolova & Madi categorized and visualized the vulnerability of terrestrial assets which depend on the outer space system infrastructure. As can be seen in Figure 6, the socio-economic impact to society is drastic and covers a wide range.

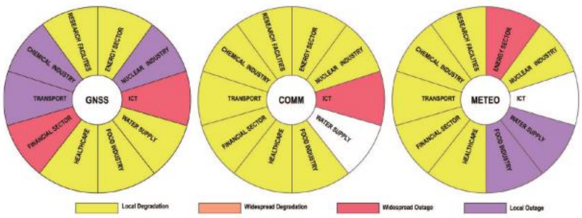

Figure 6: Terrestrial critical disruptions caused by the loss of multiple space assets loss (Source: Sokolova et al. [10])

Abbreviations: GNSS (Global Navigation Satellite System), COMM (Satellite Communication), METEO (Meteorological Satellite Systems), ICT (Information and Communications Technology).

5.3. Conclusion in the context of vulnerability of a mega constellation

The above-mentioned risk pattern scenario shows the vulnerability of a mega-constellation in the context of the consequences to the outer space environment and the significant socio-economic impact. The set of possible events for the initial trigger shows that the initial risk does not depend only on the operator of the mega-constellation.

6. PRIORITY 2: STRENGTHENING DISASTER RISK GOVERNANCE TO MANAGE DISASTER RISK

The Sendai Framework summarizes this as: “*Disaster risk governance at the national, regional and global levels is of great importance for an effective and efficient management of disaster risk. Clear vision, plans, competence, guidance and coordination within and across sectors, as well as participation of relevant stakeholders, are needed. Strengthening disaster risk governance for prevention, mitigation, preparedness, response, recovery and rehabilitation is therefore necessary and fosters collaboration and partnership across mechanisms and institutions for the implementation of instruments relevant to disaster risk reduction and sustainable development.”* [3]

In the context of outer space, the UNOOSA COPOUS Long Term Sustainability Guidelines (LTS) [11] cover the above-mentioned *vision*. A few nations have already implemented national space laws with the vision of the LTS to cover the *plans* and (national) *competence*. The majority of national states does not have a sufficient LTS space law implemented, especially the leading space nations.

The problem lies in the multi-nationality and in the definition of outer space as "common heritage of mankind" [12] to find a way for *clear plans, competence, guidance and coordination* of all countries and cultures. Never the less it is possible to implement laws on national level to create rules for behavior in outer space and/or in connection with space missions, so that operators acting within this specific national state or their partners/suppliers/service providers have to comply to these national LTS space law implementations.

There are several initiatives backed by industrial and space operations stakeholders such as "The Responsible Space Group" (OneWeb), the SSC (Space Safety Coalition, new US-led organization built on the ashes of the GVF working group), the SDA (Space Data Association) and others. However, these activities can't be seen as an efficient risk governance as the initiatives deliberately mix commercial and public interests and escape most cases of practical public responsibility and liability.

A recent paper from ASD EUROSPACE [6] gives an indication of the current US policy in the context of plans, competence, guidance and coordination.

The increased congestion of the Earth orbit is seen as a major driver for visibility and evolution of STM (Space Traffic Management), which in turn has become a significant opportunity for national industry performing key developments for STM.

With the reinstatement of the National Space Council, the creation of the Space Force, and e.g., the executive order referring to exploitation of resources in outer space, the Trump Administration has established further steps to "ensure and maintain the US dominance in space".

The ASD EUROSPACE study authors identify two main guiding principles of the US strategy: growth of the (US) commercial sector and US leadership and superiority in space.

The above-mentioned strategy and rules implementation can also be seen as positive example that it is possible to implement *plans, competence, guidance and coordination* for outer space activities, even this is not done in the context of disaster-risk-reduction.

The following table shows the current disaster risk governance in outer space according to the specific categories:

Prevention	Handled on the technical level (e.g., ISO Standard) and in Working Groups for best practices to share experience and know-how on a voluntary basis. What is missing here are the *plans, competence, guidance and coordination* of systemic risks coming from mega-constellations and other New Space risk drivers, as described in the risk pattern sample above.
Mitigation	Handled with conjunction warnings from government bodies; collision avoidance is done case-by-case on operator level. Mitigation of systemic risks (e.g., chain collisions, orbital pollution) is currently not done except on simple statistics level comparable to recording 100 years' flooding maxima. Mitigation of RF interference is done by, within and in cooperation with ITU.
Preparedness	Barely visible, except for example in one side statement in the US Space Policy Directive 7: "*The United States is also encouraging the development of alternative approaches to PNT (Positioning, Navigation and Timing) services and security that can incorporate new technologies and services as they are developed, such as quantum sensing, relative navigation and private or publicly owned and operated* ***alternative PNT services****."* [14]
Response	Not visible
Recovery	Not visible
Rehabili-tation	Not visible

Table 3: Current Disaster Risk Governance

6.1. Conclusion in the context of disaster risk governance

Some activities in prevention and mitigation are already existing today, but the preparedness, response, recovery and rehabilitation regarding a disaster in outer space is neither publicly discussed nor is any information made available to the public. Public information and public discussion are essential activities in fostering individual contributions to the overall resilience.

7. PRIORITY 3: INVESTING IN DISASTER RISK REDUCTION FOR RESILIENCE

The Sendai Framework describes this as:

"Public and private investment in disaster risk prevention and reduction through structural and non-structural measures are essential to enhance the economic, social, health and cultural resilience of persons, communities, countries and their assets, as well as the environment. These can be drivers of innovation, growth and job creation. Such measures are cost-effective and instrumental to save lives, prevent and

reduce losses and ensure effective recovery and rehabilitation." [3]

Numerous future-oriented activities exist today for prevention and mitigation of risks in outer space, especially for avoiding physical interference and, in addition, also a few activities for avoiding RF interference.
In Europe, we should mention project and program funding from ESA (e.g., Clean Space, CREAM), from EU (e.g., EUSST, but also HORIZON and EDIDP) and from different national projects for space debris tracking, mitigation and removal, as well as all military activities limited to surveillance of the space objects and private investments in space debris and object measurements.

An upcoming global problem is that a large portion of today's major capacities in optical monitoring (telescopes and laser ranging) are used and maintained by scientific organizations, mainly and by definition for their non-commercial scientific purposes, and not permanently usable on a 24/7 basis that will become necessary for future safe space operations.

According to [6], US government spends $15 million to provide basic Space Situational Awareness (SSA) data and basic Space Traffic Management services to the public, based on the publicly releasable portion of the Department of Defense catalogue supported by the US Space Policy Directive-3 dated 18 June 2018 focusing specifically on STM [13].

It should be mentioned that activities like the ESA space weather reporting represent an important additional contribution to the safety of spacecraft operations and to the long-term sustainability guidelines governance.

7.1. Conclusion in the context of disaster risk reduction

The awareness of risk reduction is reflected in different public funding schemata complemented with investments from private bodies. Nevertheless, the measurement of objects in space is significantly under-funded. As long there is no obligation of spacecraft operators/owners to routinely measure and communicate the position of own assets, there is no commercial market for the measurement data with the consequence that there is no profitable business case for private investments.

8. PRIORITY 4: ENHANCING DISASTER PREPAREDNESS FOR EFFECTIVE RESPONSE AND TO "BUILD BACK BETTER" IN RECOVERY, REHABILITATION AND RECONSTRUCTION

The Sendai Framework describes this as:

"The steady growth of disaster risk, including the increase of people and assets exposure, combined with the lessons learned from past disasters, indicates the need to further strengthen disaster preparedness for response, take action in anticipation of events, integrate disaster risk reduction in response preparedness and ensure that capacities are in place for effective response and recovery at all levels." [3]

The framework lists a number of points which we try to allocate to global, national and regional implementation as shown below.

It is important on **National Level**…
(a) To prepare or review and periodically update disaster preparedness and contingency policies, plans and programs.
(b) To invest in, develop, maintain and strengthen people-centered multi-hazard, multisectoral forecasting and early warning systems, disaster risk and emergency communications mechanisms, social technologies and hazard-monitoring telecommunications systems; develop such systems through a participatory process; tailor them to the needs of users, including social and cultural requirements, in particular gender; promote the application of simple and low-cost early warning equipment and facilities; and broaden release channels for disaster early warning information.
(c) To promote the resilience of new and existing critical infrastructure.
(i) To promote the cooperation of diverse institutions, multiple authorities and related stakeholders at all levels, including affected communities and business, in view of the complex and costly nature of post-disaster reconstruction, under the coordination of national authorities.
(k) To develop guidance for preparedness for disaster reconstruction.
(p) To review and strengthen, as appropriate, national laws and procedures on international cooperation.

It is important on **Global Level**… It is important on **Regional Level**…
(a) To develop and strengthen, as appropriate, coordinated regional approaches and operational mechanisms to prepare for and ensure rapid and effective disaster response in situations that exceed national coping capacities.
(b) To promote the further development and dissemination of instruments, such as standards, codes, operational guides and other guidance instruments, to support coordinated action in disaster preparedness and response and facilitate information sharing on lessons learned and best practices for policy practice and post-disaster reconstruction programs.
(c) To promote the further development of and investment in effective, nationally compatible, regional multi-hazard early warning mechanisms, where relevant, in line with the

Global Framework for Climate Services, and facilitate the sharing and exchange of information across all countries.
(d) To enhance international mechanisms, such as the International Recovery Platform, for the sharing of experience and learning among countries and all relevant stakeholders.
(e) To support, as appropriate, the efforts of relevant United Nations entities to strengthen and implement global mechanisms in order to raise awareness and improve understanding of disaster risks and their impact on society, and advance strategies for disaster risk reduction upon the request of States.
(f) To support regional cooperation to deal with disaster preparedness, including through common exercises and drills.
(g) To promote regional protocols to facilitate the sharing of response capacities and resources during and after disasters.
(h) To train the existing workforce and volunteers in disaster response.

8.1. Conclusion in the context of disaster preparedness for effective response and to "Build Back Better"

On national level, the US are probably the most prepared nation to comply with one topic on the **national level** in respect to point (b) subsection of *warning systems, disaster risk and emergency communications mechanisms and hazard-monitoring telecommunications systems* by the DoD infrastructure to monitor the space objects along with the warning of conjunctions. The several different worldwide catalogues of space objects form a base of information covering a small section of this point (b).

On trans-national level the EUSST shows a first step to coordinate European activities with the goal to strengthen the independence from US exposing several drawbacks in the form of conflict of interests, slowing down evolution every once in a while, a project governance leaving many open questions, implementing a secretive participation and data use policy.

To point (c), the efforts to increase the resilience of space objects against small debris impacts should be noted.

On the **global and regional levels,** point (b) is addressed in activities in risk reduction of space conjunctions from the International Astronautical Federation (IAF) STM working group, the efforts to develop ISO and CCSDS standards as well as to evolve ECSS, "The Responsible Space Group" (OneWeb), the SSC (Space Safety Coalition, the new US-led organization built on the ashes of the GVF working group), the SDA (Space Data Association). The ITU and the Satellite Innovation Group (SIG) are active in developing standards for RF interference reduction.

Point (c) is touched by the open distribution of the two-line-elements and similar easy-to-use orbit data, and with the distribution of warnings.

To all other required actions on national and international level, awareness in the public discussions and publications is barely visible so far.

8.2. Conclusion of the mapping of the UN-SPIDER Sendai Framework to the actual implementation of Space Traffic Management

The proposed Sendai Framework can structure all STM activities to the UNOOSA LTS including governance, technical and operational topics.

The current situation in STM implementations shows that risk awareness of a possible disaster with its socio-economic impact to the society has neither yet arrived in the public discourse, nor it is reflected in national and trans-national laws and rules. Only some side aspects of guidance from the Sendai Framework are already existing or implemented. The risk pattern shown in this paper results in a critical situation where the authorities are not prepared to protect the society, and no preparations are known how to limit the impact or to build back better after the catastrophe.

9. CONCLUSIONS AND RECOMMENDATIONS

We understand our proposed methodology as the most efficient holistic approach so far to the Space (Debris) Management problem.

Resulting from this we give the following **fundamental recommendations** which go hand in hand with a change of mindset:

1. **Space Activities shall be conducted in the spirit of the Sendai Framework.**

2. **National responsibles are called upon to check and invigorate the resilience regarding their dependencies on space services and their infrastructure.**

The **first concrete actions** derived from the above should be:

1. **Elaborate the risk scenarios.**

2. **Start with what-if scenarios in the existing environment, its dynamics, and the empirical data describing it.**

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