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Risk Trajectory 'theory'– Temporally Conceptualizing Risk to Aid Decision-Making Processes

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This paper introduces the concept of risk trajectories to bridge the gap between the capstone risk concept and practical application. The framework conceptualizes risk trajectory as a sequential, causally linked series of consequences characterized by escalating uncertainty due to compounding effects, external factors, and diminishing control. This approach challenges traditional tools like risk matrices by incorporating uncertainty and temporal aspects of risk, empowering decision-makers to proactively manage risk trajectories. The framework's relevance is tested by NATO personnel. Initial results show that visualizing risk as a trajectory provides a nuanced depiction, capturing interconnected actions, uncertainties, and timing. This dynamic approach facilitates informed planning and decision-making, allowing practitioners to anticipate deviations and adjust proactively. Although promising for enhancing risk management in complex environments, further empirical validation through real-world applications is essential to establish robustness and reliability.

Keywords: Risk-trajectory, Planning, Decision-Making, Military Operations.

1. Introduction

This paper is written as part of the NATO Risk Propensity Project, which is conducted as part of NATO Supreme Allied Commander Transformation's Professional Doctorate Program by one of its doctoral candidates. The intent of this paper is not to present a complete theory, but a prototype methodology for depicting risk over time based on a novel theoretical concept that views risk as a trajectory into the uncertainty of the future. This is done with the desire for the prototype and the risk-trajectory concept to be exposed to substantial scrutiny, and to offer a broader audience the ability to assess its wider applicability. This study conducts an initial test of the following hypothesis: 'Risk can, for management purposes be theoretically conceptualized as a trajectory of sequential and causally linked series of consequences of the events and actions conducted as part of an activity, where the subsequent consequences are characterized by escalating levels of uncertainty as a result of the compounding effects of prior consequences, external factors and diminishing control of future events.' Firstly, the theoretical foundation and the professional environment from which the concept of risk trajectories are derived is presented. Secondly the hypothesis, of 'risk trajectory', is articulated and the prototype methodology is explained. Thirdly, this paper leverages military planning and decision-making in complex environments to test its potential utility before it offers a conclusion and recommendations for future research.

The North Atlantic Treaty Organization (NATO) is a defensive military alliance. In order to be a credible deterrent and a reassurance for the alliance members it needs to be able to plan and conduct large scale military campaigns in a complex and constantly evolving operational environment (NATO 2022a). An environment with compounding uncertainties that can have the most disastrous potential consequences for millions of people. Moreover, an environment which includes a plethora of actors some of which are adversaries. All of this results in NATO having to manage risk as a part of its planning of, and its decision-making while conducting military operations.

2. Theoretical and Professional Foundation

Decision-making is a cognitive process that hinges upon a plethora of factors, some arbitrary, others more substantial (Tversky and Kahneman

1974; Kahneman, Sibony, and Sunstein 2021; Silver 2012; Slovic 1987). The most thorough analysis of risk may be futile if it is not perceived relevant to the decision-makers dilemma. Tools for decision-making such as risk matrices have in NATO proven less than optimal, particularly when used to articulate opportunities that should be exploited (Solli and Borrie 2024).

2.1. *Theory of risk*

There are myriads of working definitions for risk utilized across the world today but as illustrated by Aven (2023) they do, for the most part, all fit within the same conceptual theoretical framework. They address the outcome of future events, while trying to measure or articulate to some degree the associated uncertainties (Aven 2012). This paper takes as its definition of risk the Society of Risk Analysis endorsed definition (Aven et al. 2018, 4), advocated for by Aven and Thekdi (2022, 11) with risk being the '*consequences of the activity and associated uncertainties'* (C, U) as a capstone definition of risk.

For a deeper understanding of this risk concept the mathematical formulation (A, C, U) is used to illustrate the interdependencies between events (A), Consequences (C) and the perpetual state of uncertainty (U). Pragmatically, the equation can be elaborated upon to support practical risk assessment, where the equation is formulated (A'. C', Q, K). Here A' indicates specific event, C' a range of consequences considered plausible, Q the measurement of uncertainty related to C' and K the knowledge from which the analysis is built (Aven & Thekdi, 2022). For illustrative purposes C' is depicted as the standard deviation of the full range of potential consequences, including both positive and negative outcomes, to exemplify variability, as shown in Figure 1.

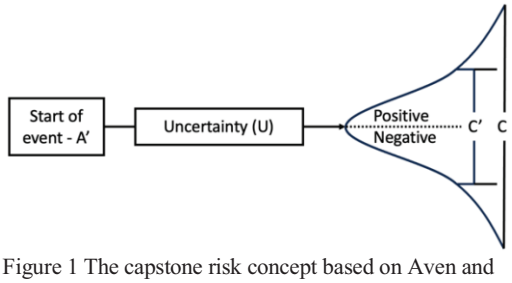

Figure 1 The capstone risk concept based on Aven and Thekdi (2022, 10)

The management of risk is defined as 'Activities to handle risk such as prevention, mitigation, adaptation and sharing' (Aven et al. 2018, 8).

2.2. *NATO's planning and decision-making*

Within the limitations of this paper the NATO planning of, and decision-making during, military operations is presented in a very simplified way. Firstly, military operations are planned using several steps and analytical processes covering a broad range of aspects of military forces. This enables the creation of an operations framework, which is a tool that visually depicts the organization of actions designed to create effects and conditions envisioned necessary to achieve a desired future state. This makes the operations framework a linear anticipatory and conditions based "timeline" aimed towards a desired future state (NATO 2019b; 2022a; 2021). Figure 2 illustrates how an operations framework with two parallel lines of effort may be visualized including key milestones represented by triangles.

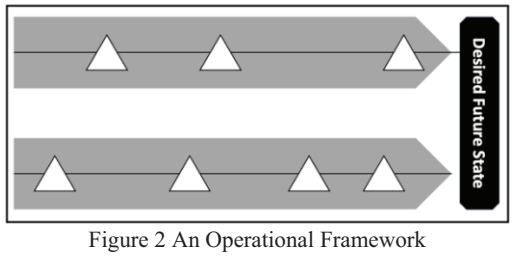

Figure 2 An Operational Framework

During a military operation the predetermined operations framework remains a reference tool for what is referred to as the decision cycle. This is a process normally bespoke to the respective headquarters, conducting the operation, but adhering to four primary parts; Assessment, Planning, Directing and Monitoring (NATO 2019a). The operations are being assessed while they are being conducted to aid the commander's decision-making allowing for corrections to the ongoing operations based on the most updated knowledge on how the situation is developing. Risk assessment is a key element in these operational assessments. (NATO 2022b; 2019a).

An important aspect to planning of military operations is that these operations are not conducted in a permissive environment. There are opposing actors, whose desired future state directly contradicts that of the military planners. Military planners must therefore plan for external

factor such as threat actors, competing actors and hazards to seek influence over their operational environment.

3. Risk Trajectory

Both the risk concept and planning of military operations address the future, but the 'future only exist in the human minds, and can therefore not be comprehended by rational reasoning alone' (Hatlebrekke 2019, 41). The theoretical concept of risk as a trajectory has been developed to aid the ambition of foresight and provide a basis for management of risk over time in concert with other risk management tools. By expressing risk across a figurative trajectory, it incorporates aspects of risk normally missing in tools like risk matrices. At the same time advocating for agency for those facing risk intendent to motivate a proactive strategy of risk management.

3.1. *The risk trajectory hypothesis*

The foundation of the risk concept rests upon the humble acknowledgement of the perpetual presence of uncertainty in relation to any activity. This includes both the irreducible aleatory uncertainty and the reducible epistemic uncertainty. Starting with the current moment, and historical knowledge the confidence in short term forecasting is not as affected by uncertainty as forecasting into the future. The scope of uncertainty increases the further into the future one tries to anticipate. The cone of increasing uncertainty (Figure 3), illustrates how the scope of uncertainty can grow with the length of the forecast period (solid line). Additionally, the volume of erroneous assumptions about the future is initially at its highest, and reduces over time as illustrated by the cone of decreasing uncertainty. (dotted line) Both cones are often referred to in the singular as the cone of uncertainty, while depicting two different but equally relevant aspects of uncertainty in planning and decision making (Berardi 2018; Sellers and Blythe 2024; Aroonvatanaporn, Koolmanojwong, and Boehm 2012). This interaction between the cones creates a perpetual decision-makers dilemma that require a proactive strategy to be effectively navigated and to avoid biased judgement (Lunde 2014).

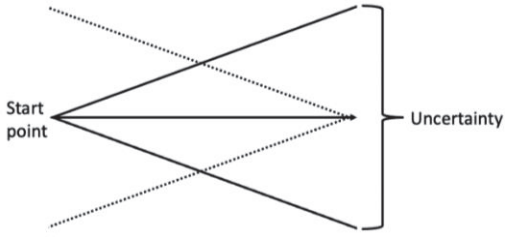

Figure 3 The Cones of Uncertainty

Figure 4, illustrates that over the course of an activity from its starting point to its culmination, opportunities and challenges may arise that those navigating the activity can exploit or mitigate. Opportunities, are defined as 'a time when a particular situation makes it possible to do or achieve something' (Hornby 2020, 1089). Challenges are defined as a form of hazard or threat that can undermine the efforts to achieve the goals of the activity. In this context a hazard is a 'risk source where the consequences relate to harm' (Aven et al. 2018, 6), and threats, is a 'risk source […] with the intention to inflict harm […]' (Aven et al. 2018, 7).

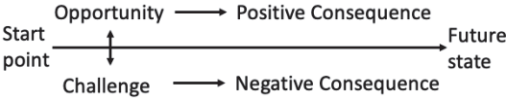

Figure 4 Opportunities and Challenges

While conducting an activity it's navigator will be performing actions in the efforts of steering the trajectory of events throughout the duration of the activity. This may include seizing opportunities that can elevate the risk trajectory from neutral in to the realm of possible positive consequences. Additionally, opportunities can accelerate the progress towards the desired future state. The risk trajectory is simultaneously vulnerable to influences by challenges that will pull it towards negative consequences.

Risk Management through the lens of a risk trajectory is as illustrated by Figure 5, a process of exploiting opportunities and avoiding being adversely affected due to the duration and exposure to potential challenges. Arguably effective executive level decision-makers are focused on exploitation of opportunities (Drucker 2006). This should compel navigators at all levels to explore and seize opportunities in order to steer the risk trajectory towards positive consequences while avoiding or mitigating for challenges. In the

simplest form risk trajectory is for management purposes visualized as is a trail of navigating potential opportunities and potential challenges over time.

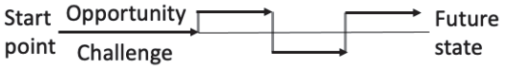

Figure 5 Managing Risk Trajectories

The events (A) within an activity generally contain 'actions' (a) taken during the event in the attempt to reach the desired outcome of the overall activity. These 'actions' (a) and the linearity of thinking is illustrated in Figure 6. During planning of an activity, it is easy to imagine its events starting with action 1 (a1) that leads to a set of possible consequences a1 C', followed by a2 which leads a2 C' and so forth. Given that actions will normally generate more than one consequence the actual action-consequence relationship is far more complex than the simplified version depicted in Figure 6.

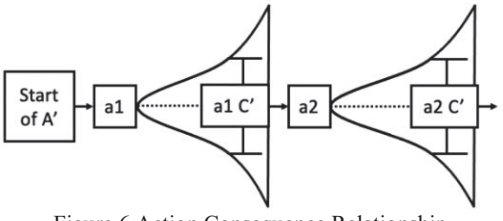

Figure 6 Action Consequence Relationship

When executing the planned activity, it is probable that the events and actions conducted will lead to a version of the anticipated range of consequences, and not necessarily the desired consequences or even a foreseen possible consequence. The initiation of a2 may therefore have to start from a less than optimal situation. This can lead to a sub-optimal performance of the action and yet another deviation from the expected range of consequences, or the need for modifications of a2 in order to compensate for a1 C'. As illustrated in Figure 7, when time passes and more and more actions are taken as part of the events, the compounding effect of uncertainty and variance of sequential consequences a trajectory of risk emerges. Figure 7 only depicts a downward trending trajectory, but it could equally be ascending or moving up and down over the duration of an activity as illustrated in Figure 5.

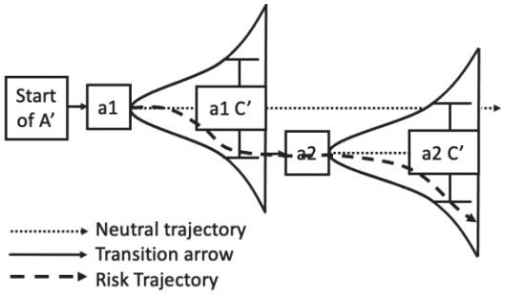

Figure 7 Risk Trajectory Concept

In a dynamic multi actor environment such as war the risk concept can practically be viewed as a trajectory of risk. Subsequently risk trajectories can therefore be defined as *sequential and causally linked series of consequences of the actions conducted as part of an activity, where the subsequent consequences are characterized by escalating levels of uncertainty due to the compounding effects of prior consequences, external factors and diminishing control of future events*.

3.2. *The prototype tool*

To bridge the gap between the Risk and the Risk Trajectory concept on one side and NATO's planning and decision-making on the other the following prototype "Risk Trajectory Alignment Tool" (RTAT) was developed allowing for opportunities and challenges to be depicted along the "timeline" of the operations framework (Figure 8).

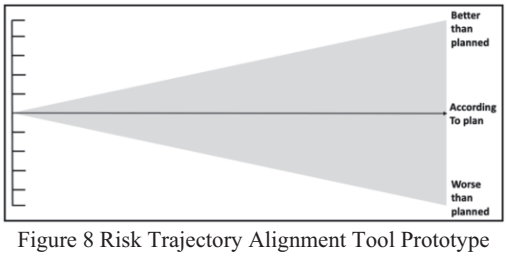

Figure 8 Risk Trajectory Alignment Tool Prototype

Opportunities are depicted above, and challenges below the centered "timeline", similar, to Figure 4. Moreover, a cone of increasing uncertainty from Figure 5 is included in the background to remind the user of the escalating uncertainty. The "scale" at the far left can be used to indicate the anticipated impact of opportunities and challenges, or the level of knowledge from which said risk factors categories have been analyzed.

The RTAT is intended to be used in conjunction with the operations framework. The RTAT indicates estimated correlation in time between the two risk factor categories and the content of the operations framework. It demonstrates which aspects of the plan are potentially affected by the different elements of the identified risk picture, at what time and for what duration. Finally, an anticipated risk trajectory can be illustrated based on the relationship between the content of the operations framework, the identified opportunities and challenges (Figure 9). Practically, illustrating the risk exposure of the planned military operation.

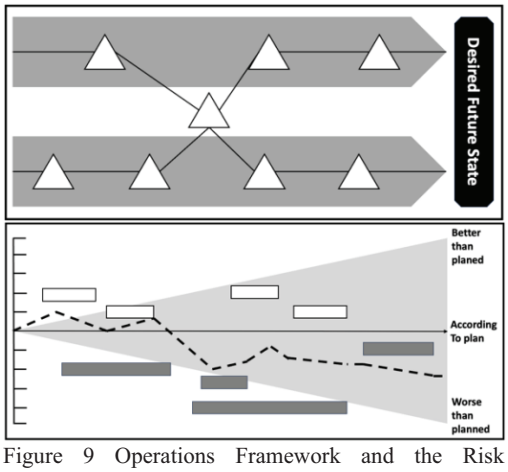

Figure 9 Operations Framework and the Risk Trajectory Alignment Tool Prototype shown in parallel.

4. Method

In order to assess responses to the RTAT NATO personnel from a variety of nations and roles were shown a theoretical RTAT paired with a fictitious operations framework. This allowed for a qualitative assessment of RTAT suitability as a concept framework to aid planning and decision-making with regards to risk management.

This research was conducted by an insider researcher who collected data while serving as an observer and advisor to members of NATO headquarters participating in NATO exercises. The data utilized in this paper was collected in the period from November 2023 – December 2024.

The RTAT data in this paper was drawn from a larger ethnographic study examining risk. The larger study encompassed more than 800 hours of ethnographic observation of seven headquarters managing risk during eight exercise related activities related to four NATO exercises. Specific to this paper eleven officers involved in operational planning were asked to trial a RTAT prototype. Seven senior officers were also interviewed about how the RTAT might support their operational decision-making. Personnel, headquarters and exercises are for ethical considerations referred to by codenames. Interviewed personnel's codenames were derived from randomly selected playing cards and referred to by the abbreviation of that selection.

Table 1 – List of research participants interviewed about the RTAT prototype

Codename	Rank
Ten of Diamonds (10D)	Major
King of Clubs (KC)	Lieutenant Colonel
Five of Clubs (5C)	Colonel
King of Spades (KS)	Colonel
Three of Clubs (3C)	Major General
Nine of Spades (9S)	Major General
Seven of Hearts (7H)	Lieutenant General

Both the interview data and the qualitative responses of the RTAT triallists were coded using a simple deductive coding system in three priori groups.

5. Results & Discussion

It is not possible within the scope of this paper to fully report on the ethnographic study and reporting here will focus on individual responses to using RTAT. However, it should be noted that the primary ethnographic observations showed wide variation in HQ thinking in dealing with the issue of risk. All headquarters observed during the ethnography articulated risk at different stages of operations and used a variety of formats and activities to generate their analysis. Even within a single HQ multiple methods were used to bridge the gap between the operations framework and risk analyses during both planning and conduct of military operations. It was clear from the observations that there is a requirement to refine NATO risk analysis and develop more coherent tools for the assessment and management of risk.

As such the ethnographic work reinforced the need for development of the RTAT.

5.1. Testing the prototype

Due to the context of the 11 officers received minimal instructions and had only 15 minutes to work with the RTAT. In despite of this they successfully populated the RTAT with opportunities and challenges. The overall response from the triallists indicated that a group of military practitioners can align opportunities and challenges with the operations framework with relative ease. However, the practitioners struggled with making professional judgements when creating an anticipatory risk trajectory. During post trial discussion the practitioners were positive to RTAT identifying that it forced them to connect risk with the content of the operations framework. In addition, it helped identify when opportunities can be exploited in relation to foreseen challenges.

During the conversations subsequent to testing the prototype participants demonstrated positive attitudes to having such a tool, praising it for forcing them to connect risk with the content of the operations framework and clearly identify at what time opportunities can be exploited in relation to the foreseen challenges. However, participants raised two important points of criticism. Firstly, the task was deemed to be complicated with a considerable degree of complexity. Secondly, one participant expressed an opinion that the prototype would be better paired with another planning tool than the operations framework.

With regards to room for improvement, participants argued that opportunities and challenges should also be plotted at angles. This was argued due to the fact that an opportunity or challenge can have diminishing or increasing effect with respect to where on the "timeline" it materializes given the content of the operations framework. One of the participants highlighted the importance for the users of the RTAT to understanding the actions consequences relationship within an activity when making judgment of how to develop anticipatory risk trajectories. Another participant emphasized that the cones of uncertainty will follow you as you progress through the activity, acknowledging the perpetual presence of uncertainty. Which post planning and during the conduct of operations align with having the cone of increasing uncertainty moved to once current position on the operational framework, and updating the risk trajectory based on past events.

The reviewed results indicate that for a group of diverse military practitioners aligning opportunities and challenges with the operations framework is an easy task. Making a professional judgement of where an anticipatory risk trajectory should be drawn proved more challenging. However, it is reasonable to assume that given more through instructions and time the task is manageable. It will never the less remain to be a complicated task dealing with complexity. As for all planning tools this will, if fully developed and implemented be used where the planners see most fit. Plotting opportunities with variability of impact in relation to content of the operations framework appears sound, and will probably aid the development of an anticipatory risk trajectory. Updating the risk trajectory during the operations and moving the cone of increasing uncertainty to the current stage in order to remain cognizant of its perpetual presence appear to be a necessary improvement of the RTAT framework.

5.2. Interviewing officers about the prototype

All of the interviewees were positive to the RTAT. The generals in the sample were very positive about the RTAT. Even prior to being shown the RTAT 3C stated a preference for charts in order to track changes. 7H initial response was 'I love it' and followed this by discussing a previous positive experience of an improvised tool with similarities that provided useful but less comprehensive information than the RTAT. Moreover, 7H emphasized the key point by stating 'that kind of temporal depiction allowed our decision-making'. 3C and 9S while also being positive focused on two other aspects. 9S stated 'It will not only help the commander see where he needs the decision points it will help with developing opportunities, and I think that we are not so good at that'. 3C's commented on how the RTAT can help improve the operations framework. 'It helps us prioritize our efforts. […], it challenges your thinking to be multi-dimensional.' 3C also saw the RTAT as helpful in identifying decision points and temporal relations between elements in the operations framework.

The remaining officers were generally positive making statements like: 'I clearly see potential […] during planning and as a tool during assessment of an ongoing operation' (5C), 'Using this tool gives me a view of potential windows of opportunities, […] I like that it looks holistically at both plan and risk, […] I prefer this to the risk matrices that look at risk individually' (KS) and 'It can be used to display relationship between urgency and importance of risk. […] This can give us more nuance to our decision-making' (10D). Despite their positive view of the tools relevance for generating foresight and connecting risk to the timeline of an operations, they also raised important concerns. Firstly, 5C addressed the concern that this prototype and the concept of a risk trajectory suffer from the same flaw as all tools and concepts that try to explain real world phenomena. Such tools try to simplify complexity and should be used cautiously remaining cognizant of that potential pitfall. Additionally, KS stated that despite its qualities the tool will be manipulated by the staff to convince the commander to approve the plan. This point linked to 9S statement that 'the commander will never accept a plan that has a risk trajectory below the level of ambition of the plan'. This highlights that also this tool is vulnerable to cognitive biases in its application. Most critical was KC who doubted that the drawing of the risk trajectory would be possible to do with an acceptable level of methodological rigor. KC's doubt came from an objection to risk being quantifiable and the impression that risk trajectories is an expression of an average between opportunities and challenges. Despite not being equally critical of the risk trajectory line 10D expressed that he was content with the content of RTAT without the risk trajectory explicitly depicted. It should be noted that individual interviewees did at times present contradictory perspectives of RTAT.

Some of the interviewees also addressed room for improvement. KS expressed what the output must be by stating 'For the depiction of risk to be valuable for decision-makers it requires the ability to demonstrate the compounding effects of risk' (KS). This was supported by 10D's suggestion to explicitly depict interconnectivities between challenges, opportunities or both. Furthermore, 10D echoed the suggestion from the officers testing the RTAT in not just depicting opportunities and challenges horizontally as '[Opportunities and challenges] can also increase or decrease over time' (10D).

Higher officers, expressed strong enthusiasm for the RTAT, recognizing its potential to improve planning and decision-making by linking risk trajectories with operational framework. This aligns with the desire to foster foresight and enhancing the clarity of complex plans. The ability to visually map risk to the operations framework was lauded for providing a holistic view, enabling better prioritization, and identifying critical decision points. However, significant challenges were also noted. For example, the difficulty in accurately plotting risk trajectories and the vulnerability of cognitive biases and misuse or over-simplification. Actionable room for improvement was also identified. For example, accounting for the evolving impacts of opportunities and challenges over time and depicting their inter-connectedness. These insights reinforce the need for iterative refinement of the RTAT to balance its theoretical sophistication with its practicality.

6. Conclusion

This study is part of a research program that aspires to enhance risk management in complex, uncertain environments, fostering foresight and informed decision-making. It is attempting to lay the groundwork for a more dynamic and adaptive approach to risk management. In Risk Trajectory Alignment Tool an attempt has been made to link theoretical concepts with practical application by integrating temporal and sequential dimensions into a risk management tool. This research has attempted to lay the groundwork for a more dynamic and adaptive approach to risk management, bridging theoretical concepts with practical application by integrating temporal and sequential dimensions into risk assessment. The framework challenges traditional tools like risk matrices and may offer decision-makers a more nuanced, actionable perspective. The potential of the proposed Risk Trajectory Alignment Tool was evidenced by preliminary feedback from NATO personnel. However, the complexity of applying the tool, coupled with concerns about usability and susceptibility to cognitive biases, underscores the need for further refinement. The aforementioned recommendations for iterative improvement of the framework appear to be highly relevant. Ultimately, the findings affirm

the promise of risk trajectories in advancing the discourse on proactive and adaptive risk management while acknowledging the necessity of ongoing empirical validation.

6.1 *Recommended future research*

The findings of this research are exploratory and limited in scope. To establish the robustness and generalizability of the risk trajectory concept, and RTAT as a tool, further research will be required. The next stage will be to refine the RTAT based on feedback from this study. Finally, the concept and tool will need to be validated and tested in diverse operational contexts.

Acknowledgement

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