Review Journal of Social Psychology & Social Works

http://socialworksreview.com

ISSN-E: 3006-4724 Volume: 3
ISSN-P: 3006-4716 Issue: 3 (July - September, 2025)

Artificial Intelligence Driven Early Warning Systems in the Himalayan Region: Strategic Implications for China, Pakistan, and Regional Stability in South Asia

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Abstract
The Himalayan region, also known as the "Third Pole," is a geopolitically and ecologically fragile area under growing threat from climate-related disasters, including glacial lake outburst floods (GLOFs), landslides, and earthquakes. All these risks are compounded by the influence of swift glacier melt, unchecked development, and tectonic activity in the region. Since millions of people rely on Himalayan ecosystems for livelihoods and freshwater, there is a critical need for efficient disaster risk reduction strategies. Artificial Intelligence (AI) powered Early Warning Systems (EWS) have been developed as revolutionary means of real-time monitoring and predictive modeling, providing higher forecasting accuracy and response speed than conventional approaches. This study examines the application of AI-driven EWS in the Himalayan region and its strategic implications for China and Pakistan. Both nations, which share parts of the Himalayan belt and have strategic and military interests in the region, have pursued different trajectories in terms of adopting AI. China has integrated AI into its civilian-military infrastructure in Tibet and Xinjiang, whereas Pakistan has begun AI-driven projects in Gilgit-Baltistan and Azad Jammu & Kashmir through international collaborations. Although these systems hold the potential for enhanced disaster resilience, they also embody challenging geopolitical risks based on their dual-use nature and absence of regional governance frameworks. The effect of AI deployment among indigenous communities is also under researched, particularly about land rights, epistemic marginalization, surveillance, and ecological disturbance. Using thematic analysis, this paper discusses AI's contribution to contemporary EWS, its use in Himalayan geohazards, national responses by China and Pakistan, its socio-cultural effects on local populations, and the wider strategic and security consequences. This paper advocates for inclusive and cooperative AI governance models that prioritize indigenous participation, regional confidence-building measures, and normative frameworks for dual-use technologies. Bridging the divide between environmental technology and security studies, the research calls for a rethinking of AI’s role in conflict-prone ecological zones and highlights the urgency of establishing AI-specific arms control and disaster cooperation mechanisms in South Asia.

Keywords: Glacial lake outburst floods (GLOFs), Landslides, Earthquakes, Artificial Intelligence (AI), Early Warning Systems (EWS), Real-time monitoring, Predictive modeling, Civil-military integration, Indigenous communities, Surveillance, Environmental governance, Transboundary cooperation, AI governance

Introduction
The Himalayan region, often referred to as the "Third Pole" due to its vast glacial reserves, is one of the most ecologically sensitive and geopolitically complex areas in the world. Spanning

across multiple countries, including China, India, Pakistan, Nepal, and Bhutan, the region is increasingly vulnerable to climate-induced hazards such as glacial lake outburst floods (GLOFs), landslides, earthquakes, and severe weather events. The frequency and severity of these disasters have grown due to rapid glacier melting, unregulated development, and seismic instability. With millions of people depending on its ecosystems and water resources, the region's vulnerability underscores the urgent need for robust disaster risk reduction strategies. In recent years, Artificial Intelligence (AI) has emerged as a transformative force in disaster management, particularly in Early Warning Systems (EWS). AI technologies, including machine learning, remote sensing, and data fusion, offer real-time risk assessments, anomaly detection, and forecasting capabilities far superior to traditional methods (Fan et al., 2024). These systems utilize vast amounts of multi-source data, ranging from satellite imagery to sensor feeds and social media, to issue timely warnings and enable pre-emptive responses. In mountainous terrains like the Himalayas, AI-driven EWS can overcome the limitations of manual monitoring and slow information dissemination, thus saving lives and reducing economic losses (Sun et al., 2023). China and Pakistan, two key stakeholders in the Himalayan belt, have both shown increasing interest in integrating AI into their national disaster risk management frameworks. China, with its expansive Belt and Road Initiative (BRI) infrastructure projects and military modernization in Tibet and Xinjiang, is deploying AI for geospatial analysis, early warnings, and strategic surveillance (Yang & Liu, 2021). Pakistan, though comparatively at an early stage, has initiated AI-based projects in Gilgit-Baltistan and Azad Jammu & Kashmir to improve flood forecasting and seismic risk management, often in partnership with international organizations (Naseer et al., 2023). These national approaches reflect broader security, economic, and environmental priorities and have implications for regional stability.

However, the deployment of AI in such a geopolitically tense and environmentally fragile zone raises complex strategic concerns. AI systems, particularly those with dual-use capabilities, can be leveraged for both humanitarian and military purposes. When deployed near borders, AI technologies for surveillance and infrastructure protection can escalate suspicion and fuel arms races between neighboring states. Moreover, the lack of international regulatory frameworks governing the use of AI in conflict-prone regions adds to the strategic ambiguity. In South Asia, where historical rivalries and territorial disputes persist, the militarization of AI under the pretext of disaster management may deepen mistrust and hinder transboundary cooperation (Zhou et al., 2022). This research paper explores the integration of AI-driven early warning systems in the Himalayan region, its impact on indigenous communities and evaluates their strategic implications for China and Pakistan. It investigates how these technologies impact regional stability in South Asia, not only from a disaster resilience perspective but also through the lens of geopolitics and security. The study aims to bridge the gap between environmental technology and strategic studies by analyzing both the opportunities and risks associated with AI-enabled disaster preparedness. In doing so, it contributes to a more nuanced understanding of the dual nature of AI in one of the world's most sensitive regions.

AI in Modern Early Warning Systems

The rapid evolution of Artificial Intelligence (AI) has ushered in a new era in disaster risk management, particularly through the development of AI-driven Early Warning Systems (EWS). These systems are now central to predictive disaster analytics, integrating data from remote sensing, geospatial platforms, environmental sensors, and social networks to provide real-time hazard alerts and risk assessments. In regions like the Himalayas, where terrain, climate, and geopolitical sensitivities converge, AI-based EWS offer transformative potential for mitigating the impacts of glacial lake outburst floods (GLOFs), landslides, and seismic events. Over the past five years, a growing body of literature has explored the multifaceted applications of AI in EWS across technical, environmental, and strategic dimensions. This review synthesizes recent research under four primary themes: the role of AI in modern EWS, AI applications in Himalayan geohazard contexts, national approaches in China and Pakistan, and the strategic and security implications of AI deployment in this geopolitically sensitive region. Artificial Intelligence (AI) has revolutionized early warning systems (EWS) by enhancing predictive modeling, image recognition, and real-time risk assessment through machine learning (ML) and deep learning algorithms. These models process multi-modal data from satellites, sensors, and social media to detect emerging threats (Fan et al., 2024). AI-EWS are being deployed globally to manage natural disasters, including floods, earthquakes, and wildfires, offering significantly reduced lead times and improved accuracy (Sun et al., 2023). Recent advancements include AI-based weather forecasting systems like Aardvark Weather, which can generate accurate local forecasts using minimal computing resources, making them accessible to developing countries (Weatherwatch, 2025). In urban settings, AI enhances disaster response by improving forecasting accuracy and real-time monitoring, as seen in initiatives like the UN's Global Initiative on Resilience to Natural Hazards through AI Solutions (Time, 2024). In Australia, AI applications such as the Early Warning Network (EWN) and Flood Mapp utilize AI to analyze data from radars and sensors, providing timely alerts for extreme weather events (The Guardian, 2024).

Despite these advancements, challenges remain. For instance, while AI-enhanced forecasting systems successfully predicted intense rainfall in Europe, they did not prevent extensive damage, highlighting the need for effective communication and infrastructure investment (Reuters, 2024). AI models like those developed by Nvidia and Google's DeepMind have shown promise in predicting hurricane paths, offering faster and sometimes more accurate forecasts than traditional models (Wired, 2023). Furthermore, projects like Bellwether by Alphabet's X leverage AI to predict and analyze natural disasters by processing vast geospatial datasets, significantly reducing assessment times (Time, 2024). AI-based visual early warning systems have also been developed to detect disasters through image analysis, enhancing the speed and accuracy of warnings (Al-Tekreeti et al., 2024). In the realm of flash flood prediction, emerging technologies like AI, ML, IoT, and cloud computing are being critically reviewed for their effectiveness in early warning systems (Al-Rawas et al., 2024). Additionally, AI-driven early warning systems are being explored for their potential in natural disaster prediction, integrating satellite imagery and geospatial information to provide timely alerts (Deekshith, 2024). A comprehensive review of machine learning applications in wildfire science and management highlights the use of various ML methods, including random forests and neural networks, in predicting and managing wildfires (Jain et al., 2020). Moreover, the analysis of natural disaster-related multimedia content from social media and satellite imagery is gaining attention for disaster detection and analysis (Said et al., 2019). Data mining techniques are also being applied to combat natural disasters, focusing on prediction, detection, and the development of appropriate disaster management strategies based on collected data (Goswami et al., 2016). Furthermore, the application of machine learning in early warning systems for geotechnical disasters is being systematically reviewed to enhance prediction accuracy (Demir & Sahin, 2022). These advancements underscore the transformative role of AI in modern early warning systems, offering improved accuracy, timeliness, and effectiveness in disaster risk reduction.

Himalayan Geohazards and AI Interventions:

The Himalayan region is highly susceptible to glacial lake outburst floods (GLOFs), landslides, and seismic events. AI tools using remote sensing and sensor data analytics have been successfully implemented to detect slope instability and monitor glacial lake expansion in real time (Gupta et al., 2024). Studies indicate that combining AI models with indigenous knowledge systems improves the contextual relevance and response efficacy of early warning frameworks in remote mountainous terrains (Kumar & Sharma, 2021). Recent advancements in AI have further enhanced the monitoring and prediction of geohazards in the Himalayas. For instance, Ullah et al. (2024) developed a machine learning-driven landslide susceptibility mapping model in the China–Pakistan Economic Corridor region, demonstrating the effectiveness of AI in identifying high-risk zones. Similarly, Meena et al. (2022) utilized machine learning algorithms and U-Net for landslide detection in the Himalayas, achieving high accuracy in identifying vulnerable areas. In the realm of GLOFs, Ahmed et al. (2022) conducted a hazard and risk assessment of Gangabal Lake in the Upper Jhelum Basin using geospatial technology and hydrodynamic modeling, highlighting the potential of AI in early warning systems. Shrestha et al. (2023) compiled a comprehensive database of GLOFs in High Mountain Asia, providing valuable data for AI-based predictive models. Furthermore, Khan and Rahman (2022) integrated explainable AI techniques for feature selection in landslide susceptibility mapping, enhancing the interpretability of AI models. Hussain et al. (2022) validated machine learning algorithms for landslide susceptibility mapping using Persistent Scatterer In-SAR techniques, confirming the reliability of AI in geohazard assessment. In the context of seismic events, Faillettaz et al. (2018) proposed a method for early warning of gravitational slope failure by co-detecting micro seismic activity, offering a cost-effective AI-based solution for disaster risk reduction. These studies collectively underscore the transformative role of AI in monitoring and mitigating geohazards in the Himalayan region, enhancing the accuracy and timeliness of early warning systems.

National Approaches: China and Pakistan

China has aggressively advanced its national AI strategy, integrating AI into military and disaster response systems, particularly in its western regions bordering the Himalayas. These systems support civil-military integration, strategic infrastructure monitoring (e.g., Belt and Road Initiative routes), and territorial surveillance (Yang & Liu, 2021). Pakistan, while still developing its AI ecosystem, has collaborated with global institutions such as the World Bank and UNESCO to deploy AI-powered flood early warning systems and earthquake risk modeling in Gilgit-Baltistan and Azad Jammu & Kashmir (Naseer et al., 2023). These efforts aim to build climate resilience and reduce economic and human losses. Recent studies highlight the application of geospatial techniques for landslide risk assessment in regions like Abbottabad, Khyber Pakhtunkhwa, utilizing remote sensing data and GIS for hazard mapping (Gull et al., 2023). Probabilistic seismic hazard assessments have been conducted in areas such as Attock City to understand earthquake hazards and inform sustainability efforts (Qadri et al., 2023). Integrated seismic risk assessments using satellite data and field information have been implemented in Northern Pakistan, providing valuable insights for disaster risk reduction (Shah et al., 2024). Machine learning models have been employed for landslide susceptibility mapping in the rugged terrains of Northern Pakistan, enhancing the accuracy of hazard predictions (Ali et al., 2022). Furthermore, geohazard susceptibility assessments along the Upper Indus Basin have utilized multiple machine learning and statistical models to develop comprehensive hazard maps (Ahmed et al., 2021). Probabilistic seismic hazard analyses have been conducted in Azad Jammu and Kashmir, contributing to a better understanding of regional seismic risks (Rafi et al., 2012). The integration of AI in disaster risk reduction strategies in Pakistan is gaining attention, with discussions on its potential benefits and challenges (Ahmad, 2025). Studies have also focused on landslide susceptibility mapping along the China-Pakistan Economic Corridor (CPEC) route, employing multi-criteria decision-making methods (Maqsoom et al., 2021). These efforts collectively underscore the growing emphasis on leveraging AI and geospatial technologies for disaster risk management in both China and Pakistan.

Impact on Indigenous Lifestyles in the Himalayan Region:

The integration of Artificial Intelligence-driven Early Warning Systems (AI-EWS) in the Himalayan region, while technologically promising, poses critical social and cultural challenges for indigenous communities. These impacts are rarely considered in strategic or technological planning but are essential for sustainable and ethical development. The installation of AI infrastructure (e.g., sensors, communication towers, drone surveillance nodes) often takes place in high-altitude tribal areas without community consent, undermining indigenous rights over land and resources. Research by Karki & Banskota (2022) highlights how state-led climate adaptation programs in the Himalayas frequently override local authority, contributing to forced relocation and loss of governance autonomy. “Deployment of AI-based climate systems in Nepal’s Mustang region disrupted seasonal herding routes and displaced 200+ yak herders due to restricted access zones created by sensor networks” (Karki & Banskota, 2022).

AI-EWS often functions through algorithmic logics that exclude indigenous indicators such as animal behavior, wind patterns, or oral history. This **techno-centric approach marginalizes local epistemologies**. As Kumar & Sharma (2021) have shown, community-based systems that blend AI with traditional practices are more effective and culturally acceptable than purely digital interventions. “Failure to include indigenous forecasting methods leads to erosion of local agency and undermines decades of experiential risk understanding” (Kumar & Sharma, 2021). Furthermore, AI deployments in border-adjacent Himalayan zones serve the dual purpose such as disaster monitoring and **military surveillance**. As noted by Zhou et al. (2022), these systems often include drones, infrared scanners, and facial recognition technologies that create **digital enclosures**, restricting the movement of indigenous pastoralist communities and raising privacy concerns. “The transformation of highland spaces into smart surveillance zones criminalizes nomadic movements and leads to over-policing of native groups, especially in Tibet and Gilgit-Baltistan” (Zhou et al., 2022). AI systems extract large datasets (glacial dynamics, seismic activity, migration flows) from indigenous territories, often without benefit-sharing agreements. According to Couldry & Mejias (2019), this represents a form of “data colonialism,” where indigenous territories serve as raw input zones for machine learning models owned by foreign firms or central governments. “Predictive tools built on Himalayan geospatial data rarely return value to source communities, disaster knowledge is privatized while the risk remains localized” (Fatima, 2022). Infrastructure for AI systems, roads, towers, and data centers frequently leads to **ecological degradation**.

Construction activities disturb highland ecosystems and disrupt fragile biodiversity corridors. These environmental changes directly affect traditional livelihoods like herding, agriculture, and ethno-ecotourism. “AI-linked construction projects near Pangong Tso in Ladakh led to habitat fragmentation and decline in wild yak populations, disrupting both ecological balance and Buddhist pastoralist economies” (Sharma et al., 2023). AI-EWS, while improving forecasting, can create **technological dependency**, especially when local communities are not trained or included in data interpretation. This not only weakens indigenous self-reliance but also poses risks during system breakdowns or cyber conflicts. “When satellite-based warnings failed during the 2022 Kashmir floods, indigenous dwellers had no alternate mechanisms to fall back on, leading to delayed evacuations and preventable fatalities” (Ahmed et al., 2022).

Strategic and Security Implications:

AI-driven Early Warning Systems (EWS) have the potential to enhance regional stability by fostering cooperation in data sharing and joint hazard management. However, they also raise concerns about dual-use technologies and surveillance capabilities, especially when deployed near sensitive border areas (Zhou et al., 2022). The strategic overlap of AI in disaster management and defence further complicates diplomatic negotiations in South Asia. The militarization of AI in South Asia, particularly by India, has significant implications for regional security dynamics. India's integration of AI into its military strategy, including

autonomous weapon systems and surveillance technologies, has prompted concerns about an arms race and strategic instability in the region (Ahmed et al., 2023; Khurshid & Zaman, 2023). Pakistan, while still developing its AI capabilities, faces challenges in keeping pace with India's advancements. The asymmetry in AI integration between the two countries could potentially destabilize the deterrence equilibrium and increase the risk of miscalculations (Arif, 2019; Rafiq, 2021). Moreover, the dual-use nature of AI technologies complicates governance and arms control efforts. The lack of international agreements specifically addressing AI in military applications leaves a regulatory gap that could exacerbate tensions in already volatile regions like South Asia (Wasil et al., 2024). The strategic implications of AI extend beyond bilateral relations. The involvement of major powers, such as the United States and China, in South Asia's AI landscape influences regional security policies and alliances. The U.S.'s support for India's technological advancements, for instance, affects the strategic calculus of neighboring countries (Iftikhar, 2025).
In this context, the development of AI-specific confidence-building measures and international norms is crucial to mitigate the risks associated with the militarization of AI and to promote stability in South Asia (Altaf & Javed, 2024).

Conclusion:
This research investigated the development and integration of Artificial Intelligence (AI)-powered Early Warning Systems (EWS) in the Himalayas, their strategic implications for China and Pakistan, and their overall influence on regional stability in South Asia. Through the evaluation of technical developments, national strategies, socio-cultural impacts on local communities, and dual-use strategic aspects, the study spotlighted the promise and risks of AI uses in one of the globe's most sensitive ecological and political environments. The statement of the central research issue in this study is: How do AI-based Early Warning Systems in the Himalayas affect disaster cooperation and competition or competition and cooperation between China and Pakistan, and with what regional implications for peace and stability in South Asia? This study concludes that though AI-based EWS holds large promise for building robust disaster preparedness and resilience in climate-prone Himalayan areas, nationalized and centralized perspectives dominate their present perspectives. Instead of promoting strategic cooperation, the establishment and introduction of AI-EWS in China and Pakistan seem to perpetuate competition, militarization, and geopolitical fragmentation.

China has been at the forefront of AI incorporation, integrating these technologies into its Belt and Road Initiative (BRI) infrastructure, military surveillance in Tibet, and civil-military disaster preparedness systems. This is a techno-authoritarian one in which AI is not only a humanitarian response tool but also a tool for strategic positioning and territorial monitoring. Pakistan's integration of AI in disaster risk reduction, by contrast, is externally funded and underdeveloped. However, it is strategically oriented towards Gilgit-Baltistan and Azad Jammu & Kashmir, sensitive regions because of their disputed status and location near the Line of Control (LoC) and Line of Actual Control (LAC). Hence, both nations utilize AI for their national interest, historic insecurities, and wider regional power balance.

The study addressed some of the key gaps in the current literature. Most of the current research on AI-EWS dwells on technical effectiveness, risk forecasting, or ecological science with too little heed to how these systems engage regional geopolitics. This analysis makes a novel contribution by situating AI-EWS in the China-Pakistan-India triangle and uncovering how technological deployments can reform power dynamics, border securitization, and regional confidence. The research puts the marginalized place of indigenous populations at the center, who are disproportionately affected by AI-driven interventions in the Himalayas. From the displacement of herding communities in Nepal's Mustang district to the surveillance of nomadic populations in Gilgit-Baltistan, the data indicates a trend of epistemic and material violence. The concept of "data colonialism" highlights how indigenous knowledge systems are marginalized, and their lands are turned into extractive spaces for world data economies and centralized power. The dual-use character of AI technologies—to serve either humanitarian or military goals has been relatively unregulated in international institutions. This loophole raises severe threats, as AI-EWS along borders of contention may end up as surveillance assets or targets in war. The absence of AI-specific arms control norms, especially in the South Asian nuclearized context, heightens the risk of miscalculation and escalation. Existing AI applications are primarily state-centered, technocratic, and top-down. The failure to engage communities, incorporate local governance, or regional cooperation severs long-term resilience. This study reminds us of the imperative for cooperative and culturally relevant AI governance for disaster-prone areas.

From a bilateral perspective, both Pakistan and China consider AI-EWS to be strategic assets. But the asymmetry of capability and political intent between the two is profound. China is not simply taking up AI for disaster preparedness; China is reconfiguring its frontier governance framework via AI. By planting sensor networks, satellite overwatch, and real-time glacial monitoring systems across Xinjiang and Tibet, China is incorporating AI into a larger state-security infrastructure. These technologies afford detailed command over distant areas and potential rivals, such as India and indigenous Tibetan populations. China's AI-based EWS therefore, operates as both climate infrastructure and strategic blackmail. Pakistan, although more restricted in ability, has sought to demonstrate sovereignty and climate resilience status with AI initiatives in the northern provinces. With support from global allies like UNESCO and the World Bank, Pakistan's application of AI for the prediction of floods and landslides is a significant departure. Yet, indigenous capacity-building deficit, excessive dependence on imported technology, and restricted local trust-building hold back its strategic influence. This disparity of magnitude, intent, and investment renders South Asia an imbalanced AI environment. It also threatens to draw Pakistan deeper into China's AI system, limiting its strategic autonomy and assisting in the formation of a regional techno-bloc. AI-EWS, rather than building resilience through collaboration, is being taken in by competing security systems. The Himalayan region is at the crossroads of several fault lines: ecological, political, ethnic, and technological. Bringing AI into this environment, in the absence of established rules or cooperative norms, adds new instabilities. AI installations within the Himalayas tend to have twofold objectives: predicting disasters and conducting military surveillance. Facial scanning, drone surveillance, and AI-driven infrared sensors deployed in disputed territories are all part of an environment of recrimination. The militarization of AI by India for itself adds to the trend, threatening an AI arms race. The techno "enclosure" of border areas by AI, i.e., off-limits areas around sensors or data collection regions, interferes with customary livelihoods and tests transboundary governance. Such innovation is especially delicate in such regions as Ladakh, Aksai Chin, and Gilgit-Baltistan, where sovereignty claims overlap and continue unabated. AI-EWS refine real-time situational awareness with possible erosion of the strategic ambiguity that has maintained deterrence stability in South Asia for so long. The lopsided AI integration among India, China, and Pakistan can result in misunderstandings about intent, especially in times of crisis related to water shortages, earthquakes, or border floods. Traditional indigenous knowledge systems, which have long informed disaster readiness in the Himalayas, are being bypassed by algorithm-based forecasting mechanisms that favor computational speed over cultural sensitivity. The techno-oriented shift undermines trust, agency, and long-term adaptive ability of the mountain people.

To mitigate the risks enumerated and tap the potential of AI-based EWS, the study suggests the creation of regional AI confidence-building measures, the institutionalization of an AI-arms control framework, indigenous knowledge incorporation in the design of EWS, cross-border environmental cooperation promotion, and policies on ethical data governance. Mechanisms of transparency in AI-EWS deployment, such as joint data protocols, hotline communication, and joint monitoring missions, must be adopted by China, Pakistan, and India. International cooperation will need to start framing discussions on how to control dual-use AI technologies. Early warning systems for disasters need to incorporate local indicators and indigenous forecasting methods, as well as technical innovations, to make them both legitimate and accurate. Regional regulation of common river basins and glacier systems needs to take precedence, and multilateral organizations such as SAARC or subregional climate federations can do so. Lastly, information gathered from indigenous areas must be bound by ethical frameworks that ensure community participation, consent, and benefits.

Recommendations:

The use of AI in disaster management marks a paradigm shift in the way states react to environmental challenges. In the Himalayas, however, this technological revolution is taking place amidst unresolved political tensions, ecological fragility, and profound social inequalities. AI-EWS, unless regulated via inclusive, transparent, and cooperative frameworks, stand to become tools of surveillance, exclusion, and strategic distrust. This research fills the gap between international security studies and environmental technology by showing that the future of AI in high-risk areas such as the Himalayas will be determined not just by innovation but also by diplomacy, ethics, and governance. Regional actors' dilemma is clear: militarize AI for singular gain, or lead it together towards survival. South Asia, at the intersection of climate emergency, technological transition, and great power rivalry, can take a leading role in forging a new pattern of cooperative AI. Whether this possibility becomes a reality is contingent upon the states' willingness to transcend zero-sum competitions and look toward a future that is based on mutual responsibility, resilience, and peace**.**

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