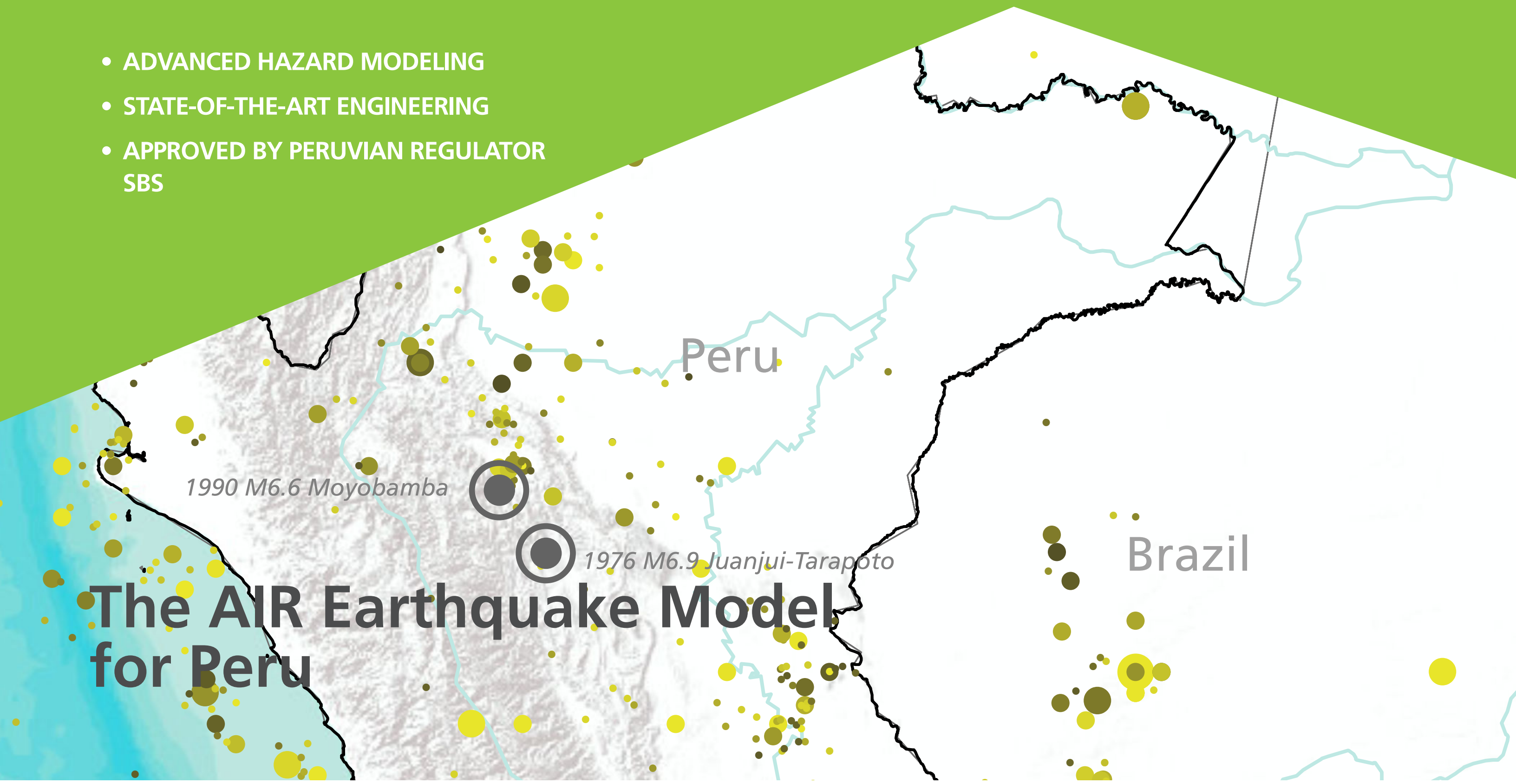
- **ADVANCED HAZARD MODELING**
- **STATE-OF-THE-ART ENGINEERING**
- **APPROVED BY PERUVIAN REGULATOR SBS**



The AIR Earthquake Model for Peru

ADVANCED HAZARD MODELING	THE ISSUE.	THE SOLUTION.
Comprehensive Data Set to Improve Assessment of Seismic Potential	While Peru has experienced earthquakes for many millions of years, the recorded history is relatively short. Therefore, additional information is needed to improve assessment of seismic hazard.	AIR compiled detailed active fault data, which was used in conjunction with local and regional GPS data and paleoseismic data, to determine the crustal deformation rate in all of Peru's seismic source zones. This information was used to create a stochastic catalog reflecting the full range of future seismic activity.
Next Generation Ground Motion Amplification Factors Capture Unique Characteristics of Earthquakes in Peru	The soil types and earthquake types that are typical of the Lima region of Peru—the country's area of highest seismic risk—have resulted in higher levels of observed shaking than ground motion prediction equations (GMPEs) alone might indicate.	The AIR model incorporates next generation attenuation (NGA) amplification factors to modify ground motion estimates from GMPEs to accurately reflect ground motion throughout Peru, including the Lima region.
High Resolution Geological Maps Capture Potential for Soil Amplification and Liquefaction	Soil properties play a critical role in amplifying or de-amplifying seismic waves. For example, the softer soils in some coastal districts of Lima city tend to amplify seismic waves, while the stiffer soils in the mountainous regions east of the city have little impact on seismic waves. Furthermore, soil properties also play a role in liquefaction risk.	The liquefaction module explicitly captures liquefaction risk in the entire country. For better risk differentiation, the AIR model features multiple layers of detailed soil maps of varied resolution, including resolutions as fine as 50 meters for the entire central western region of the country, which includes the cities of Lima, Arequipa, Trujillo, Chiclayo, Iquitos, and Piura. The rest of the country is covered by 100-meter resolution soil maps. The model also incorporates a microzonation study for the capital city Lima.
Stochastic Catalog Reflects Time-Independent and Time-Dependent Earthquake Rupture Probabilities to Provide the Most Robust View of Risk	According to time-dependent views of earthquake risk, the annual probability of an earthquake occurring on a given fault is dependent on when the last earthquake occurred on that fault and how much that fault is accumulating elastic strain (or slip deficit).	The AIR model incorporates both time-dependent and time-independent earthquake rupture probabilities—the former, for seismic source zones in Peru with well-known rupture histories, and the latter for source zones where rupture histories are not well documented. The use of time-dependent rupture probabilities allows the AIR model to accurately reflect Peru's seismic risk, which is elevated compared to the surrounding region due to the fact that a major earthquake has not occurred in the vicinity of Lima since 1746.

AIR WORLDWIDE®

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MODEL AT A GLANCE

MODELED PERILS Ground shaking, tsunami, and liquefaction

CATALOG The model incorporates a 10,000-year catalog of 324,316 simulated earthquakes, 82,131 of which cause loss to the industry exposure (2014) of Peru. Stochastic events included in the model are of magnitude 5.0 and greater.

HAZARD MODULE Integrates all global, regional, and local catalogs, including: ISC-GEM Global Instrumental Earthquake Catalog, GEM Global Historical Earthquake Catalog, ISC EHB Bulletin, USGS ANSS Comprehensive Catalog, Catálogo de sismicidad from the Red Sismológica Nacional de Colombia (RSNC), the South America CERESIS catalog, the Utsu Catalog of Damaging Earthquakes in the World, and the Global Centroid Moment Tensor Catalog.

VULNERABILITY MODULE Supports 115 occupancy classes and 106 construction classes; accounts for the impact of the evolution of Peru's building codes and other local factors affecting the seismic performance of buildings in Peru. In addition, Touchstone® supports occupancy classes for industrial facilities, including chemical processing, oil refineries, and mining. Occupancy classes for infrastructure such as bridges, pipelines, and tunnels are also supported. Further, AIR's detailed modeling solution supports builder's risk.

HISTORICAL EVENT SET The AIR software systems include a historical event set consisting of 99 historical earthquakes, 35 of which cause loss to the industry exposure (2014) in Peru. The five earthquakes of the historical event set that cause the highest insurable losses in Peru are, in descending order: 1746 Lima, Peru, M8.8; 1687 Lima-Callao, Peru, M8.6; 1940 Lima-Callao, Peru, M8.1; 1868 Arica, Chile, M8.68, and 1784 Arequipa, Peru, M8.4.

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Probabilistic Tsunami Modeling Capability	Capturing the detailed mechanics of a tsunami from initial formation to dissipation is critical to understanding potential damage and loss.	A numerical model was developed to simulate thousands of stochastic tsunami events, from rupture through the entire inundation period. The model takes into account the effects of friction with the ocean floor on a tsunami's height and forward speed—two major determinants of its damage potential.
STATE-OF-THE-ART ENGINEERING		
Damage Estimation Based on Rigorous Engineering Analysis	How buildings respond to earthquakes depends on both the ground motion and the building type. Traditional approaches to damage estimation don't capture these complex interactions.	Complementing local expertise, damage estimation in the AIR model uses state-of-the-art engineering analysis, including results from nonlinear dynamic analysis (NDA) computer models of buildings subjected to actual ground motion records from historical earthquakes.
Comprehensive Set of Damage Functions	Peru's building stock is diverse, and vulnerability varies by construction and occupancy.	The AIR model offers a robust set of damage functions for 115 occupancy classes and 106 construction classes. The supported lines of business are: residential building, residential contents, residential combined, commercial, industrial, commercial/industrial combined, and automobile.
Considers Impact of Local Construction Practices on Building Vulnerability	The seismic performance of buildings in Peru is greatly influenced by local construction practices, with damageability often affected by variations in workmanship, materials, and building code enforcement across the country and over time.	AIR engineers collaborated with local experts to better understand regional vulnerability of Peru's various building types, enabling AIR to develop a model that takes into account these local factors and the evolution of Peru's building codes.

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Peru's insurance market is among the fastest growing in Latin America, and regulators have a strong supervisory role over the transparency and solvency of companies operating in this market. AIR's earthquake model for Peru has been officially approved by the Superintendencia de Banca y Seguros (SBS) to offer catastrophe modeling services to local insurance companies in the country.

UNPARALLELED INDUSTRY EXPOSURE DATABASE

The industry exposure database (IED) for Peru is constructed at a high resolution (1 km grid), and contains the most recent risk counts and their respective replacement values, along with information about the occupancy and physical characteristics of structures such as construction type and height classification. In addition to the residential, industrial/commercial, and automobile lines of business, the IED features industrial facilities.