Date of Submission	13 July, 2023

IPL Project Proposal Form 2023

(MAXIMUM: 3 PAGES IN LENGTH)

1. Project Title: (2 lines maximum)

   New project: Understanding the seismic response of large-scale geological hazards for developing early warning methods

2. Main Project Fields

   (1) Technology Development

   Monitoring and Early Warning

   (2) Targeted Landslides: Mechanisms and Impacts

   Catastrophic Landslides, avalanches and debris flows

   (3) Capacity Building

   Collating and Disseminating Information/ Knowledge

   (4) Mitigation, Preparedness and Recovery

   Mitigation

3. Name of Project leader: Yifei Cui

   Affiliation: Associate Professor, Tsinghua University (THU)

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   Core members of the Project: Names/Affiliations: (4 individuals maximum)

   Dr. Yan Yan/Associate Professor, School of Civil Engineering, Southwest Jiaotong University (SWJTU), China

   Dr. Hui Tang/ Senior Scientist, German Research Center for Geosciences (GFZ), Germany

   Dr. Fan Xie/ Senior Research Scientist, Institute of Geophysics, China Earthquake Administration, China

   Dr. Shuofan Wang/ Post-Doctoral Fellow, River Research Institute, Department of Hydraulic Engineering, Tsinghua University, China

   Objectives: (5 lines maximum; what you expect to accomplish?)

   Based on the laboratory experiments, numerical simulation, and field monitoring, this research aims to develop a new physical model for the seismic signal generated by mass movements considering the basal force, together with a seismic inversion model considering path effect by improving empirical green's functions, finally propose a seismic signal based early warning system combining on-site monitoring, fast numerical simulation, and big data analysis.

4. Background Justification: (10 lines maximum)

   Recently, with the development of seismic methods, it is possible to use seismic signals recorded by seismometers to provide a new geological hazard diagnostic. So far, several groups have studied the correlations between seismic signal and debris flow properties such as flow depth, velocity, and sediment concentration. However, those estimates are empirical and specific to monitoring sites. Scientific challenges still lie in constraining the link between seismic signals and the flow properties and dynamics, such as the initiation mechanism and transportation characteristics of large-scale mass flows, and the numerical model to link the seismic signals caused by those geological hazards and their physical properties. The proposed research aims to study the initiation mechanism and transportation of large-scale mass movement evengs, and to develop a numerical model to link the seismic signals caused by landslide and debris flows and their physical properties in a general way.

5. Study Area: (2 lines maximum; where will the project be conducted/applied?)

   The Parlung Tsangpo River Basin, Tibet, China; Wenchuan earthquake area, Sichuan, China

   Illgraben, Switzerland

6. Project Duration: (1 line maximum)

   2024.1-2027.12

7. Resources necessary for the Project and their mobilization

Personnel, Facilities, and Budgets

	Year 2024	Year 2025	Year 2026	Year 2027	Total
Research cost	$17,000	$16,000	$19,000	$20,000	$72,000
Equipment/Instruments	$20,000	$17,000	$16,000	$17,000	$70,000
Seminar/Workshop Costs	$6,000	$6,000	$6,000	$6,000	$24,000
Cooperation and Exchanges	$18,000	$18,000	$18,000	$18,000	$72,000
Graduate Students	$13,000	$13,000	$13,000	$13,000	$52,000
Total	$74,000	$70,000	$72,000	$74,000	$290,000

Total amount applied: $290,000 USD.

Applicant has successfully applied funding from National Natural Science Foundation of China (Project No. 42120104002, funding: 320,000 USD). The fundings will support the ongoing of the International Research Program of IPL.

8. Project Description: (30 lines maximum)

(1) Flow dynamic characteristics and seismic signals. On this basis, a small-scale flume test will be carried out at Tsinghua University to explore the relationship between the flow properties and the fluctuating basal forces distribution. The seismic signals will be recorded by acceleration transducers installed at the side of flume base. Meanwhile, a solid-fluid coupling numerical method using CFD-DEM is adopted to carry out parametric study and subsequent statistical analysis on the impact frequency, segregation, and force variation for all experiments. Finally, the relationship between flow properties, impact force distribution characteristics, and seismic signals will be established.

(2) Inversion model/method for dynamics based on seismic signals. The empirical Green’s function will be improved by both measured (hammer test) and machine learning method considering the heterogeneity of soil structure. Then, the inverse model for seismic signals, basal force distribution characteristics and flow properties is established and is verified with experiment results.

(3) Rapid simulation, quantitative hazard assessment and early warning methods. Through the proposed inverse model, the physical and mechanical parameters can be estimated, and the depth average method will be used for site scale numerical simulation. By simulating different events under various boundary conditions, different scenarios database can be established. According to GIS methods and field surveys, the susceptibility, risk, and vulnerability for different hazards can be quantitatively assessed.

(4) Fast risk assessment and early warning methods. Seismic signals for landslides and debris flows can be identified during signal processing. By combining with the established scenario database, using the long and short-term memory (LSTM) method, the relationship between seismic signals and the risk (risk range, possible loss, risk level) can be trained and the no-linear model between them can be established. Finally, the early warning method was developed, which can achieve fast risk assessment by inputting seismic signals.

9. Work Plan/Expected Results: (30 lines maximum; work phases, milestones, and publication) including the contribution plan of articles on the IPL project (progress/result) to the Open Access Book Series P-LRT in the coming few years.

2024:

(1) Carry out field investigation, collect sediment samples and soil lab tests, and arrange the seismometers for avalanche and landslide-debris flow events monitoring in the study area.

(2) Design and conduct small scale flume tests to explore the seismic signal characteristics.

(3) Develop a physical model to link physical properties, basal impact force and seismic signals.

(4) Organize a session on environmental seismology in EGU (European Geosciences Union) 2024 for presentation the research outcomes and discussion.

2025:

(1) Design and carry out in-situ large-scale flume experiments to reveal the dynamic characteristics at geological hazard based on recorded seismic signals.

(2) Build the quantitative relationship for fluid properties (velocity, flow depth, rheology)-particle characteristics (particle gradation, concentration)-basal impact force (impact force distribution, frequency).

(3) Submission of research outcomes to World Landslide Forum 2025 in Japan for presentation and discussion.

(4) Publication 2~3 articles of the physical model of fluid properties, basal impact force and seismic signals.

2026:

(1) Feature recognition of disaster seismic signals based on the machine learning.

(2) Establish hazard fast assessment early warning method of the whole disaster from seismic signals acquisition and analysis-movement process simulation.

(3) Organize a session on environmental seismology in EGU (European Geosciences Union) 2026 for presentation the research outcomes and discussion.

(4) Publication 2~3 articles of the seismic observations and early warning systems of the geohazards.

2027:

(1) Preparation for the conclusion of the project.

(2) Expected to publish 4 to 6 articles, including 2 to 3 papers published in Nature Index journals.

10. Deliverables/Time Frame: (10 lines maximum; what and when will you produce?)

January-September 2024: Literature review on the seismic response of landslide, avalanches, and debris flows and related research.

October 2024-June 2025: Implementation of monitoring systems (e.g., seismic instrumentation, remote sensing techniques, meteorological observation) to collect data on avalanche, landslide-debris flow events.

July 2025- May 2026: Analysis of large-scale flume experiments data to identify factors contributing to seismic response. Build the quantitative relationship of fluid properties, particle characteristics, and bottom impact force.

June 2026- July 2027: Development of a comprehensive database on the avalanche, landslide-debris flow events, and the geohazard disaster risk early warning system based on deep learning method.

August-December 2027: Final research report compilation and documentation.

11. Project Beneficiaries: (5 lines maximum; who directly benefits from the work?)

The above project related researches not only improve our understanding of the seismic response of large-scale landslides, avalanches and debris flows but also help to develop the early warning system with site application. Moreover, the proposed physics based early warning method via seismic waveforms could be implemented by technical/scientific agencies for the prevention in the mountainous area, such as, and thus provide a guarantee for the sustainable development of society and economy of the regions threatened by the large-scale landslides, avalanches and debris flows.

12. References (Optional): (6 lines maximum; i.e. relevant publications)

Yan, Y., **Cui, Y**., Guo, J., Hu, S., Wang, Z., Yin, S., 2020. Landslide reconstruction using seismic signal characteristics and numerical simulations: Case study of the 2017 “6.24” Xinmo landslide. Engineering Geology. 270, 105582.

Yan, Y., **Cui Y.**, Tian, X., Hu, S., Guo, J., Wang, Z., Yin, S., Liao, L. 2020. Seismic signal recognition and interpretation of the 2019 “7.23” Shuicheng landslide by seismogram stations. Landslides. 17, 1191-1206.

Yan, Y., **Cui, Y**., Liu, D., Tang, H., Li, Y., Tian, X., Zhang, L., Hu, S. 2021. Seismic signal characteristics and interpretation of the 2020 “6.17” Danba landslide dam failure hazard chain process. Landslides. 18, 2175-2192.

Yan, Y., **Cui, Y**., Huang, X., Zhou, J., Zhang, W., Yin, S., Guo, J., Hu, S. 2022. Combining seismic signal dynamic inversion and numerical modeling improves landslide process reconstruction. Earth Surface Dynamics. 10, 1233-1252.

Yan, Y., Tang, H., Hu, K., Turowski, J. M., Wei, F. 2023. Deriving Debris-Flow Dynamics From Real-Time Impact-Force Measurements. JGR Earth Surface. 128, e2022JF006715.

Note: Please fill and submit this form by 15 July 2023 to:

ICL Network <icl-network@iclhq.org> and KLC secretariat <klc2020@iclhq.org>