Seismic Reevaluation of Nuclear Facilities in Taiwan

Development of the Hazard Input Document for Taiwan
Using SSHAC Level 3 Methodology

WORKSHOP #3 PROCEEDINGS

June 2017

National Center for Research on Earthquake Engineering
National Applied Research Laboratories
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AEC</td>
<td>Atomic Energy Council</td>
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<tr>
<td>AFE</td>
<td>Annual Frequency of Exceedance</td>
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<td>ANS</td>
<td>American Nuclear Society</td>
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<td>ANSI</td>
<td>American National Standards Institute</td>
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<tr>
<td>BBP</td>
<td>Broadband Platform (SCEC)</td>
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<tr>
<td>CA/Mex</td>
<td>California/Mexico</td>
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<tr>
<td>CBR</td>
<td>Center, Body and Range</td>
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<tr>
<td>CEUS</td>
<td>Central and Eastern United States</td>
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<td>CFR</td>
<td>Code of Federal Regulations</td>
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<td>CGS</td>
<td>Central Geological Survey</td>
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<td>CWB</td>
<td>Central Weather Bureau</td>
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<td>DBE</td>
<td>Design Basis Earthquake</td>
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<td>DCPP</td>
<td>Diablo Canyon Power Plant</td>
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<td>DCR</td>
<td>Design Change Request</td>
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<td>DSHA</td>
<td>Deterministic Seismic Hazard Analysis</td>
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<td>EE</td>
<td>Evaluator Expert</td>
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<td>EPRI</td>
<td>Electric Power Research Institute</td>
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<td>ESEL</td>
<td>Expedited Seismic Equipment List</td>
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<td>ESEP</td>
<td>Expedited Seismic Evaluation Process</td>
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<td>FCR</td>
<td>Field Change Request</td>
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<td>FLEX</td>
<td>The Diverse and FLEXible Coping Capability</td>
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<td>FSAR</td>
<td>Final Safety Analysis Report</td>
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<td>GEM</td>
<td>Global Earthquake Model</td>
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<td>GIS</td>
<td>Geographic Information Systems</td>
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<td>GMC</td>
<td>Ground Motion Characterization</td>
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<td>GMM</td>
<td>Ground Motion Models</td>
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<td>GMPE</td>
<td>Ground Motion Prediction Equation</td>
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<td>GMRS</td>
<td>Ground Motion Response Spectrum</td>
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<td>GPS</td>
<td>Global Positioning System</td>
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<td>GS</td>
<td>Geometric Spreading</td>
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<td>HCLPF</td>
<td>High Confidence of Low Probability of Failure</td>
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<td>HID</td>
<td>Hazard Input Document</td>
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<td>IES</td>
<td>Institute of Earth Sciences (Academia Sinica)</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<td>SPID</td>
<td>Screening, Prioritization and Implementation Details</td>
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<td>SPRA/SPSA</td>
<td>Seismic Probability Risk (Safety) Assessment</td>
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<td>SS</td>
<td>Strike-Slip Fault Mechanisms</td>
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<td>SSC</td>
<td>Seismic Source Characterization</td>
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<td>SSCs</td>
<td>Structures, Systems and Components</td>
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<td>SSE</td>
<td>Safe Shutdown Earthquake</td>
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<td>SSHAC</td>
<td>Senior Seismic Hazard Analysis Committee</td>
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<td>SSI</td>
<td>Soil-Structure Interaction</td>
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<td>SWUS</td>
<td>Southwestern United States</td>
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<td>TAO</td>
<td>Terrestrial, Atmospheric and Oceanic Sciences</td>
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<td>TDI</td>
<td>Technical Defensible Interpretation</td>
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<td>TEC</td>
<td>Taiwan Earthquake Research Center</td>
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<td>TI</td>
<td>Technical Integrator</td>
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<td>TNGA</td>
<td>Taiwan Next Generation of Attenuation Relations</td>
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<td>TPC</td>
<td>Taiwan Power Company</td>
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<td>TSMIP</td>
<td>Taiwan Strong Motion Instrumentation Project</td>
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<td>UHRS</td>
<td>Uniform Hazard Response Spectrum</td>
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**Workshop #3 Introduction**

In response to the 50.54(f) letter issued in March 2012, an updated probabilistic seismic hazard analysis (PSHA) based on a Senior Seismic Hazard Analysis Committee (SSHAC) Level 3 process (Budnitz et al., 1997; NRC 2012, NUREG 2117) is required to be conducted for all operating nuclear power plants in the United States. In Taiwan, the Atomic Energy Council (AEC) requested Taiwan Power Company (TPC) to reevaluate seismic hazard and review the seismic design basis of nuclear facilities in Taiwan based on the suggestions in NTTF 2.1: Seismic. As the result, TPC launched the “Seismic Reevaluation of Nuclear Facilities” Project executed by the National Center for Research on Earthquake Engineering (NCREE). A seismic hazard analysis will be performed for four nuclear power plants assigned by the Taiwan Power Company (TPC) by developing the Seismic Source Characterization (SSC) model and the Ground Motion Characterization (GMC) model as basic inputs to a site-specific probabilistic seismic hazard analysis (PSHA). SSC describes the future earthquake potential (e.g., magnitudes, locations and rates), and GMC describes the distribution of the ground motion as a function of magnitude, style of faulting, source-to-site geometry and site condition. For the seismic hazard analysis, both of these models will be developed following the guidelines of the Senior Seismic Hazard Analysis Committee (SSHAC) Level 3 process (Budnitz et al., 1997; NRC, 2012). The SSC model developed in this study is majorly specific to the region of the study sites with a 320-kilometer radius. The GMC model for the rock ground motions applicable to the study sites will be developed in this study in parallel. The GMC logic tree model will incorporate relevant empirical ground motion models as well as results from numerical simulations. The PSHA calculations and the development of surface response spectra considering site-specific site amplification are not part of this project and will be performed subsequent to the SSC and GMC SSHAC Level 3 studies by another project. The hazard results of four study sites evaluated by using the SSC and GMC models developed in this study will meet the requirements of SSHAC Level 3 methodology.

The objective of this study is to develop SSC and GMC models that capture the center, body and range (CBR) of the technically defensible interpretations (TDI) with SSHAC Level 3 methodology as described in NUREG 2117 (NRC, 2012) for use in PSHA for the study sites. TDI are defined as the development, assessment, and weighting of the scientifically justifiable and defensible interpretations of earth science and geotechnical data by appropriate experts in these fields using a structured process of evaluation and integration with full access to all available data. The purpose of this Project Plan is to describe how the SSHAC Level 3 process will be applied to develop the SSC and GMC models for the study sites.

This is the third out of three Workshops that will be conducted in accordance with the applicable SSHAC Level 3 guidelines.

**Objective**

The primary goal of Workshop 3 will be for the TI Teams to integrate information into models that represent the CBR of TDI.

**Preparation**

Following Workshop 2, a series of meetings and internal work will be performed to evaluate the available data and range of alternative proponent models. The SSC and GMC TI Teams will evaluate the data presented at Workshop 2 and integrate the information into logic trees that constitute the SSC and GMC...
model V2. Formal RE and PE presentations based on newly available data will be provided at working meetings, where possible. These presentations at working meetings will be provided as part of the final documentation of the Taiwan SSHAC Level 3 project. The basis for the SSC and GMC model V2 characterizations will be documented and provided to PPRP prior to Workshop 3 so that PPRP will be able to fully evaluate the SSC and GMC model V2 before the workshop.

Process

Workshop 3 will last five days and be attended by PTI, the TI Teams and staff, PPRP, the Hazard Analysts, and the selected REs and PEs that are identified by the TI Teams, as needed. The first part of Workshop 3 will be allocated to select PE presentations based on data or analyses performed following Workshop 2. Following the selection of the PE presentations, the main activities of Workshop 3 will begin. In contrast to Workshops 1 and 2, PPRP will be the active participants in Workshop 3 to fully query the model parameters, level of documentation, uncertainty, and rationale in developing the model.

During Workshop 3, the SSC and GMC model V2 logic trees will be presented to PPRP and the selected REs and PEs, as needed. The workshop provides an opportunity for the REs, PEs, and PPRP to review and challenge the TI teams’ evaluations and the technical justifications used to develop the structure of the SSC and GMC logic trees and weights on branches of the logic trees (e.g., whether any significant interpretations are missing, how the TI Teams have integrated the alternative models and data uncertainties, etc.). The TI Teams will use this feedback in developing the final version of the SSC and GMC logic trees.

At Workshop 3, the Hazard Analysts will present the results of hazard sensitivity analyses to the TI Teams and PPRP to provide the TI Teams with feedback about the implications of the SSC and GMC logic trees on hazard. REs, PEs, and PPRP will also use the hazard sensitivity results to focus the discussion on the technical issues and parameters that have the greatest effect on the hazard at the study sites.

The proceedings of Workshop 3 will be documented in a brief workshop summary report for distribution to the Project Sponsor and members of PPRP, and PPRP will submit a letter to the Project Sponsor, PTI, and TI Team Leads documenting their observations of the workshop. PTI and the TI Team Leads will provide written responses to the PPRP comments. The workshop summary and PPRP letter will be made publicly available and become part of the final documentation of the Taiwan SSHAC Level 3 project.

Topics and Issues

- SSC and GMC model V2 logic tree.
- Preliminary hazard calculations of study sites and sensitivity analysis of SSC and GMC model V2 logic tree to identify hazard-significant issues and parameters.
- Review and challenge of the TI Team logic tree.
- Identification of shortcomings of the logic tree.
- Identification of key models and parameters requiring further evaluation.
- Identification of additional analyses to better constrain logic trees.
Workshop #3 Agenda with RE&PE
Taiwan SSHAC Level 3 Project
Workshop #3 Agenda – Day 1 Morning
June 19, 2017 (Monday), Morning
Tsai Lecture Hall of National Taiwan University, Taipei, Taiwan

<table>
<thead>
<tr>
<th>Session</th>
<th>Time</th>
<th>Topic</th>
<th>Dur. (min.)</th>
<th>Speaker</th>
<th>RE&amp;PE</th>
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<tr>
<td><strong>Project Introduction</strong></td>
<td>09:00</td>
<td>Opening, Project Introduction and Workshop Ground Rules</td>
<td>10</td>
<td>S.J. Hwang (黃世建) C.L. Wu (吳俊霖) N. Abrahamson</td>
<td>Jean-Claude Sibuet Wen-Nan Wu (吳文男) Ya-Ju Hsu (許雅儒) Jing-Yi Lin (林靜怡) J.Bruce H. Shyu (徐瀚德) Song-Chuen Chen (陳松春) Char-Shine Liu (劉家瑜) Kuo-En Ching (景國恩) Ruey-Juin Rau (饒瑞鈞) Yin-Tung Yen (顏銀桐)</td>
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<td>09:10</td>
<td>SSHAC Training</td>
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<td>09:30</td>
<td>SSC Tasks and Issues</td>
<td>30</td>
<td>B.S. Huang (黃柏壽)</td>
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<td>10:00</td>
<td>Sensitivity Analysis</td>
<td>30</td>
<td>C.H. Loh (羅俊雄)</td>
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<td>10:30</td>
<td><strong>PPRP Reviews, Comments and Question</strong></td>
<td>90</td>
<td>K. Clahan</td>
<td>Jean-Claude Sibuet Wen-Nan Wu (吳文男) J.Bruce H. Shyu (徐瀚德) Yin-Tung Yen (顏銀桐)</td>
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<td>11:00</td>
<td><strong>Logic Tree</strong></td>
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<td>Current Logic Tree</td>
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<td>11:00</td>
<td>Principle of Weighting, Scaling Law</td>
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<td>11:00</td>
<td><strong>PPRP Reviews, Comments and Question</strong></td>
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<td>11:00</td>
<td><strong>REs and PEs Comments and Questions</strong></td>
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<td></td>
<td>12:30</td>
<td><strong>Lunch</strong></td>
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Taiwan SSHAC Level 3 Project
Workshop #3 Agenda – Day 1 Afternoon
June 19, 2017 (Monday), Afternoon
Tsai Lecture Hall of National Taiwan University, Taipei, Taiwan

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<th>Time</th>
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<th>Dur. (min.)</th>
<th>Speaker</th>
<th>RE&amp;PE</th>
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<td></td>
<td>13:30 ~ 15:00 Chaired by Kevin</td>
<td>Areal Source Shallow, Deep zone and Zoneless 1. Geological Scheme Zoning 2. Seismic Source Type PPRP Reviews, Comments and Questions REs and PEs Comments and Questions</td>
<td>90</td>
<td>C.T. Cheng (鄭錦桐)</td>
<td>Kuo-En Ching (景國恩) Ruey-Juin Rau (饒瑞鈞)</td>
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<td>15:00 ~ 15:20</td>
<td>Break</td>
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<td>16:50 ~ 17:00</td>
<td>Break</td>
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<td>17:00 ~ 17:40</td>
<td>Summary of Day 1 (N. Abrahamson)</td>
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<td>17:40 ~ 18:00</td>
<td>Comments and Questions from Observers</td>
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<td>18:00</td>
<td>Adjourn</td>
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<td></td>
<td>18:00 ~ 19:00</td>
<td>Closed Meeting: PPRP, Sponsor, PM, PTI and TI Lead</td>
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<td>Session</td>
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<td>Fault Source-I</td>
<td>09:00 ~ 10:30</td>
<td>Introduction of Fault Source Modeling</td>
<td>90</td>
<td>C.H. Yeh (葉錦勳)</td>
<td>Jean-Claude Sibuet, Wen-Nan Wu (吳文男), J.Bruce H. Shyu (徐澔德), Kuo-En Ching (景國恩), Ruey-Juin Rau (饒瑞鈞)</td>
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<td><strong>PPRP Reviews, Comments and Questions</strong></td>
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<td><strong>REs and PEs Comments and Questions</strong></td>
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<td>10:30 ~ 11:00</td>
<td>Break</td>
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<tr>
<td>Fault Source - II</td>
<td>11:00 ~ 12:30</td>
<td>North Primary Fault - Shanchiao, ST-II, Aodi, North Ilan and S Fault</td>
<td>90</td>
<td>B.S. Huang (黃柏壽)</td>
<td>Jean-Claude Sibuet, J.Bruce H. Shyu (徐澔德), Kuo-En Ching (景國恩), Ruey-Juin Rau (饒瑞鈞)</td>
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<td><strong>PPRP Reviews, Comments and Questions</strong></td>
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<td>12:30 ~ 13:30</td>
<td>Lunch</td>
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<td>Session</td>
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<td>Fault Source</td>
<td>13:30</td>
<td>South Primary Fault-Hengchun Fault and West Hengchun Offshore Structure (Geometry of Manila Subduction Zone)</td>
<td>90</td>
<td>A.T. Lin (林殿順)</td>
<td>Jean-Claude Sibuet</td>
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<td>-III</td>
<td>15:00</td>
<td><strong>PPRP Reviews, Comments and Questions</strong></td>
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<td>Ya-Ju Hsu (許雅儒)</td>
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<td>Jing-Yi Lin (林靜怡)</td>
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<td>Song-Chuen Chen (陳松春)</td>
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<td>J.Bruce H. Shyu (徐澔德)</td>
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<td>Kuo-En Ching (景國恩)</td>
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<td>Ruey-Juin Rau (饒瑞鈞)</td>
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<td>15:00</td>
<td><strong>Break</strong></td>
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<td>Fault Source</td>
<td>15:20</td>
<td>Other Faults Onshore and Offshore Faults</td>
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<td>Jing-Yi Lin (林靜怡)</td>
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<td>-IV</td>
<td>16:50</td>
<td><strong>PPRP Reviews, Comments and Questions</strong></td>
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<td>Song-Chuen Chen (陳松春)</td>
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<td><strong>REs and PEs Comments and Questions</strong></td>
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<td>J.Bruce H. Shyu (徐澔德)</td>
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<td>Ruey-Juin Rau (饒瑞鈞)</td>
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<td></td>
<td>17:00</td>
<td>17:00 ~ 17:40 Summary of Day 2 (N. Abrahamson)</td>
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<td>17:40</td>
<td>17:40 ~ 18:00 Comments and Questions from Observers</td>
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<td><strong>Adjourn</strong></td>
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<td>18:00</td>
<td>18:00 ~ 19:00 Closed Meeting: PPRP, Sponsor, PM, PTI and TI Lead</td>
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## Taiwan SSHAC Level 3 Project
### Workshop #3 Agenda – Day 3 Morning

June 21, 2017 (Wednesday), Morning

Tsai Lecture Hall of National Taiwan University, Taipei, Taiwan

<table>
<thead>
<tr>
<th>Session</th>
<th>Time</th>
<th>Topic</th>
<th>Dur. (min.)</th>
<th>Speaker</th>
<th>RE&amp;PE</th>
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<tr>
<td></td>
<td>09:00 ~ 10:40 Chaired by A.T. Lin</td>
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<td></td>
<td>09:00 ~ 10:20</td>
<td>Ryukyu Subduction Zone</td>
<td>80</td>
<td>C.T. Cheng</td>
<td>Jean-Claude Sibuet</td>
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<td>Ya-Ju Hsu (許雅儒)</td>
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<td>Jing-Yi Lin (林靜怡)</td>
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# Taiwan SSHAC Level 3 Project
## Workshop #3 Agenda – Day 3 Afternoon
### June 21, 2017 (Wednesday), Afternoon
Tsai Lecture Hall of National Taiwan University, Taipei, Taiwan

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# Taiwan SSHAC Level 3 Project
## Workshop #3 Agenda – Day 4 Morning
**June 22, 2017 (Thursday), Morning**
Tsai Lecture Hall of National Taiwan University, Taipei, Taiwan

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<td><strong>Adjusted Foreign Model for Crustal Source in Taiwan</strong></td>
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# Taiwan SSHAC Level 3 Project
## Workshop #3 Agenda – Day 4 Afternoon
### June 22, 2017 (Thursday), Afternoon
Tsai Lecture Hall of National Taiwan University, Taipei, Taiwan

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## Taiwan SSHAC Level 3 Project
### Workshop #3 Agenda – Day 5 Morning
#### June 23, 2017 (Friday), Morning
Tsai Lecture Hall of National Taiwan University, Taipei, Taiwan

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<td>GMMs with TDIs for Subduction Source - I</td>
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<td>C.L. Wu (吳俊霖)</td>
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| 12:30 ~ 13:30 | Lunch |
### Taiwan SSHAC Level 3 Project
#### Workshop #3 Agenda – Day 5 Afternoon
**June 23, 2017 (Friday), Afternoon**
**Tsai Lecture Hall of National Taiwan University, Taipei, Taiwan**

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<td>13:30 ~ 15:00</td>
<td>Chaired by H.C. Chiu</td>
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<td>Logic Tree of Median for Subduction Source</td>
<td>13:30 ~ 14:10</td>
<td>Visualization Technique and Weights of Median Models for Subduction Source</td>
<td>40</td>
<td>C.H. Loh (羅俊雄) V.B. Phung</td>
<td>Adrian Rodriguez-Marek, Nicolas Kuehn, Ralph Archuleta, Hungjun Si, Yi-Hau Chen, Yi-Tung Yen</td>
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|         | 14:10 ~ 15:00 | **PPRP Reviews, Comments and Questions**  
**REs and PEs Comments and Questions** |             |                                |                                |
|         | 15:00 ~ 15:20 | Break                                                                 |             |                                 |                                |
| Logic Tree of Sigma for Subduction Source | 15:20 ~ 15:50 | Logic Tree and Weights of Tau Model for Subduction Source | 30          | Y.N. Huang (黃尹男)              | Adrian Rodriguez-Marek, Nicolas Kuehn, Ralph Archuleta, Hungjun Si, Yi-Hau Chen, Yin-Tung Yen |
|         | 15:50 ~ 16:20 | Logic Tree and Weights of PhiSS Models for Subduction Source          | 30          | Y.N. Huang (黃尹男)              |                                |
|         | 16:20 ~ 16:50 | **PPRP Reviews, Comments and Questions**  
**REs and PEs Comments and Questions** |             |                                |                                |
|         | 16:50 ~ 17:00 | Break                                                                 |             |                                 |                                |
|         | 17:00 ~ 17:40 | Summary of Day 5 (N. Abrahamson)                                      |             |                                 |                                |
|         | 17:40 ~ 18:00 | Comments and Questions from Observers                                  |             |                                 |                                |
|         | 18:00     | Adjourn                                                                |             |                                 |                                |
|         | 18:00 ~ 19:00 | Closed Meeting: PPRP, Sponsor, PM, PTI and TI Lead                    |             |                                 |                                |
### Workshop #3 Participants

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