



## TotalEnergies EP Malaysia

PROJECT NAME : Subsurface CO<sub>2</sub> storage and fluid production Intelligent Monitoring System Utilizing Optical Fibre Technology


DOCUMENT TITLE : Technical Research Proposal

PREPARED AND SUBMITTED BY : Universiti Teknologi PETRONAS

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## 1.0 INTRODUCTION

Optical fibre sensors are seen as the technology-based solutions to improve subsurface understanding for Carbon Capture and Storage (CCS) through geologic storage or sequestration as well as for O&G production optimization. These solutions can assess carbon storage capacity; monitor the position of CO<sub>2</sub> plume or seismicity for regulatory compliance; and evaluate CO<sub>2</sub> injection profiling, well injection containment, and well integrity. They can also replace conventional 4D seismic survey to optimize O&G field production. Traditional measurements typically rely on discrete sensors that measure at certain points, whereas distributed sensing technology uses fibre-optic (FO) strands as the sensor. This enables continuous, real-time measurements to be captured along the entire length of an FO strand, namely Distributed Acoustic Sensor (DAS). This research program is initiated to develop the necessary technology know-how and advances the scientific breakthrough of subsurface fluid storage (CO<sub>2</sub>) and production (O&G) monitoring system utilising optical fibre technology aided with cloud-based computing. The program shall comprise of three inter-related research projects of multi-disciplines as well as academic activities.

### 1.1 General Agreement

Client: TotalEnergies EP Malaysia  
 Recipient: Universiti Teknologi PETRONAS  
 Type of Fund: Research and Technology Development Fund  
 Amount: US\$ 5 Million  
 Duration: 5 Years (Dec. 2022 – Nov. 2027)


## 2.0 PROGRAMME AIMS

The establishment of this research program enhances collaboration between Universiti Teknologi PETRONAS (UTP) and TotalEnergies E&P Malaysia for research activities pertaining to subsurface fluid monitoring stored underground using state-of-the-art optical fibre sensing technologies, data acquisition, subsurface visualisation and interpretation.

## 3.0 RESEARCH PROGRAM and PROJECTS

Under the proposed research and technology development agreement (“PROGRAM”), three projects are to be developed within specific roles and sets of expertise. Each project is headed by the corresponding research institute as shown below:

Project	Research Theme	UTP Centre of Excellence & Research Institute
P1	Development and Characterization of SubSurface reservoir/sealsthrough Distributed Acoustic Sensing (DAS) Imaging	Centre of Subsurface Imaging (CSI) – Institute of Hydrocarbon Recovery (IHR)
P2	Development of Fibre-Optic Seismic Technologies	Smart Infrastructure Monitoring & Modelling (SIMM) – Institute of Transportation Infrastructure (ITI)

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P3	Data Analytics and Visualisation	Centre for Research in Data Science (CeRDaS) – Institute of Autonomous Systems
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#### 4.0 P1: DEVELOPMENT AND CHARACTERIZATION OF SUBSURFACE FLUIDS (CARBON STORAGE & O&G FIELD) SYSTEMS THROUGH DAS IMAGING

Distributed acoustic sensing (DAS) has rapidly gained recognition for its potential for seismic imaging. For surface reflection seismology, the wide spatial aperture afforded by DAS is a primary motivation for its application, however the lower Signal-to-Noise Ratio (SNR) of DAS has proven to be a significant impediment to acquiring data that may replace conventional receiver arrays (Fig. 1) in the future. A further limitation of DAS cables is that the strain-dependent response is insensitive to acoustic energy which arrives orthogonal to the cable axis, reducing its effectiveness at seeing energy reflected from the deep subsurface. To enhance the sensitivity of DAS cables for reflection seismology, several signal enhancement techniques shall be adopted. In addition, past survey results utilising DAS technology shall be further analysed.

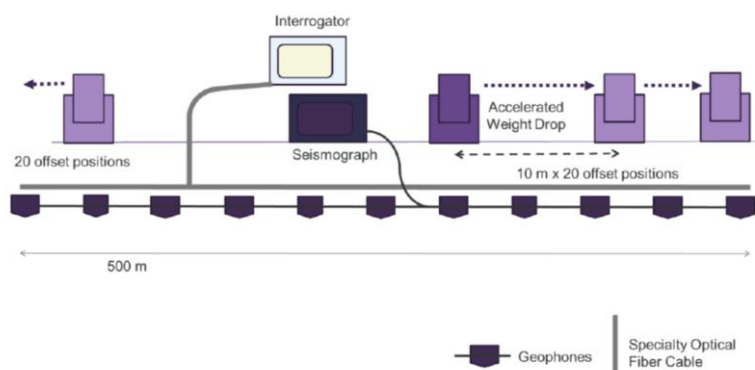



Figure 1: Experimental setup for conventional and DAS system for seismic acquisition

#### Challenges & Issues:

- Optical fibre is not optimized for sensing, in particular Rayleigh scattering based distributed acoustic sensing (DAS).
- DAS fundamental challenge in directivity, i.e., less responsive to transversal strain compared to longitudinal strain.
- The non-existence of high-resolution processing and imaging workflow for continuous reservoir monitoring via DAS in subsurface fluid management systems.

#### 4.1 Research Objectives

Project 1 aims to achieve the following objectives:

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- To investigate the various optical fiber configuration for optimum surface seismic DAS capability.
- To develop enhance signal processing strategy with improve directivity performance.
- To characterize carbonate reservoir for a suitable CO<sub>2</sub> storage or O&G production optimization via a high-resolution acoustic imaging DAS system.

#### 4.2 Project 1 Sub-Programs

Project 1 shall be divided into three sub-projects (SP) and activities as below:

##### P1-1: DAS Data Acquisition

- Surface DAS (active & passive)
- Vertical Seismic Profiling (VSP) DAS
- Geophones (for controlled measure)

##### P1-2: DAS processing and imaging

- SNR Enhancement techniques
- Propose processing and imaging workflow for land and marine application

##### P1-3: Integration and reservoir characterization

- New FO technology
- AI / ML tools for passive seismic interpretation in a reservoir monitoring objective
- Comparison of conventional seismic data vs DAS recorded seismic data

#### 4.3 Targeted Results and Deliverables

It is expected from Project 1 on delivering the following research output:


- Enhance signal processing approach that enables 6C directivity performance.
- Controlled field test to measure and compare the performance of both geophones and surface-deployed DAS system.
- Validation of the proposed method to monitor subsurface fluids (CO<sub>2</sub> & O&G) with improve imaging of acoustic / seismic signal (higher resolution, accurate amplitude and phase).

In addition, the team targets on utilising UTP Halliburton well site in campus for VSP-DAS imaging. In the case of surface-DAS imaging, existing data shall be further processed and analysed from the following projects:

- Containment and monitoring institute (CaMI) field research station, Brooks, Alberta, Canada
- Bokor Field, Offshore Sarawak or any other suitable site in Malaysia

**Commented [HBMAID(1):** (Patrick's Question: TotalEnergies is member of the CaMI consortium è is it the case for UTP or Petronas too ?)

(Halim's Answer: Petronas was part of the consortium before and no longer subscribe since year 2020. Nevertheless, we hope to utilise the data, as we do not yet have the FO DAS implementation for Malaysian field.)

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#### 4.4 Project 1 Gantt Chart

Programme 1		2023				2024				2025				2026				2027			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
P1-1	Surface & VSP Data Collection & Pre-processing																				
P1-2	Optimum DAS Data Acquisition																				
P1-3	DAS Signal Enhancement through Advancement Processing & Imaging																				
P1-4	Integration of Fibre Optic-based Signal and reservoir characterization																				

**PLEASE PROVIDE GANTT CHART WITH MILESTONES**


MILESTONES	DELIVERABLES	DATE	PERSON-IN-CHARGE
M1	e.g. P1 Interim Report	30 Jun 2023	
M2			
M3			
M4			
M5			
M6			
M7			
M8			
M9			
M10			

#### 5.0 P2: DEVELOPMENT OF FO SEISMIC TECHNOLOGY

Project 2 comprised of Fibre-Optic (FO) seismic solution to improve subsurface understanding for a CCS or O&G field project. FO solutions cover distributed acoustic sensing (DAS), distributed temperature sensing (DTS), distributed temperature gradient sensing (DTGS), and distributed strain and temperature sensing (DSTS) systems. The discrete FO sensing based on an optical fibre Bragg grating (FBGs) interferometric technology can be designed for various type transducers. In relation to the CCS project, the technology development can be divided into two applications, namely Distributed FO Borehole sensing and Fibre Optic FBG sensing.

##### Challenges & Issues:

- Collect vertical seismic profile (VSP) data in a completed well and compare acquisition using single- and multimode optical fibres permanently cemented behind casing
- Performance verification of different types of commercial-of-the-shelf FO interrogators and sensing cables
- Deployment (installation) strategy for FO sensors to understand subsurface geological structure for fluid management
- Lack of Broad-Side Sensitivity of the Cable: The straight fibre optic cable is not sensitive to broad-side seismic waves or strain. When DAS functions, it senses the strain along the fibre axis, while the strain perpendicular to its axis can barely be recorded.

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## 5.1 Research Objectives

Project 2 aims to achieve the following objectives:

- To compare the performance of DAS and conventional seismic tools for data verification and validation (under controlled environment).
- To develop FBG based 3C geophones and hydrophones
- To conduct field monitoring of FO-DAS system with different interrogators and optical cables
- To develop data acquisition and sensor integration for web-based solutions

## 5.2 Project 2 Sub-Programs


Project 2 shall be divided into four sub-projects (SP) and activities as below:

**P2-1: DAS Benchmarking Performance** – The objective of this subproject is to compare the performances of commercial-of-the-shelves optical interrogators (DAS, DTS, DSTS), types of FO telecommunication cables that are suitable for fluid subsurface monitoring. Conventional seismic imaging tools and electrical based sensors shall be corroborated as part of FO data validation. A number of interrogators from different vendors shall be tested on their key measurement parameters and to benchmark the interrogators performances.

**P2-2: Development of FBG geophone and hydrophone** – A fibre optic multi-component ground surface or ocean bottom seismic system, for permanent installations, is to be developed and to pilot test data. The cable system contains high reliability fibre optic three-axis (3C) accelerometers and geophones or hydrophones, fibre Bragg grating (FBG) based sensor network and an electro-optic interrogation and read-out system for the sensors. The sensors, fibre network, underwater components and the topside instrumentation system to be subjected to significant qualification programs. The results of analysis of the data from the pilot tests shall confirm the systems high degree of vector fidelity, high signal-to-noise ratio, good ground-station coupling, reliability and excellent response in general to wave modes in connection with ocean-bottom seismic.

**P2-3: Field deployment and monitoring** – Two research areas comprising of downhole distributed FO sensor installation (namely for VSP records) and ground surface or seabed monitoring method using FO multi-component sensor network shall be performed. In VSPs, the deployment FO seismic solution acquires zero-offset, walkaway, 3D seismic, 4D reservoir monitoring within specific measurement spatial resolution. In the later case, the permanent multi-component installation system consists of an array of receivers (4C stations), a lead-in cable and top-side instrumentation. The system utilizes fibre optic interferometric sensing technology based on an optical fibre Bragg grating (FBGs) interferometric design. Comparison between ground surface vs. trench installation method shall be investigated.

For marine application, depending on the facility access granted by the asset owner, the submarine optical cables shall be used (either existing cables or laying new ones) to conduct seismic imaging based on DAS for fluid production or storage monitoring.

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**P2-4: Acquisition & integration web-based system** – This subproject shall involve integration of downhole hardware and surface hardware. Design for efficiency and extend system lifetime with fit-for-purpose connectors and cables that reduce costs and risks, power transmission, data acquisition shall be performed.

### 5.3 Targeted Results and Deliverables

P2-1: DAS Benchmarking Performance (1 PhD topic)

- Benchmark study of DAS interrogators performance (comparison of two or three different DAS units / different vendors) through environmental setup, *e.g.* gauge length, SNR
- Explore customised/ specialised optical cables for DAS against standard telecommunication cables (*e.g.* helical, jacketed: tight-buffered or loose tubes), singlemode/ multimode fibres)

P2-2: Development of FBG geophone and hydrophone (1 PhD topic)

- Develop high performance fibre optic seismic sensor system (FBG 3C geophone or hydrophones)
- 1 patent


P2-3: Field deployment and monitoring (1 PhD topic)

- Ground surface installation (*e.g.* on-site trial, trenched/ surface laid/ cemented?)
- Conventional vs. DAS surface seismic study (passive and active)
- Fibre Cable Coupling
- Losses (attenuation), noise factors
- Integration with other Optical Distributed Sensing family technologies (DTS, DSTS, DAS) for multicomponent parameters (strain, temperature, pressure, vibration)
- Optional future deployment and field monitoring in both onshore and offshore environments

P2-4: Acquisition & integration web-based system

- Integration with Project 3
- Obtain good-quality sitewide with simultaneous acquisition from downhole well or ground surface by using the DAS solution interrogator connected to the daisy-chained single-mode fibres.
- Acquire good FO Seismic solution data on existing multimode fibre and single-mode fibre to map the reservoir structure or utilize for time-lapse analysis of the subsurface fluid




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#### 5.4 Project 2 Gantt Chart

		2023				2024				2025				2026				2027			
Programme 2 Subprojects		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
P2-1	DAS Benchmarking Performance																				
	- procurement & hiring		M1																		
	- optical cable performance																				
	- interrogators performance					M3															
P2-2	Development of FBG geophone and hydrophone																				
	- lab centre renovation			M2																	
	- background/ theoretical study																				
	- experimental setup																				
	- results & analysis							M4													
	- design & fabrication																				
	- field application									M5											
P2-3	Field monitoring deployment																				
	-site identification & installation																				
	- Conventional vs DAS											M6									
	- Multicomponent Parameters													M7							
P2-4	- field monitoring														M8						
	Acquisition & integration web-based system																				
	- DAQ hardware setup																		M9		
	- interface programming																			M10	

MILESTONES	DELIVERABLES	DATE	PERSON-IN-CHARGE
M1	P2 Interim Report	30 Jun 2023	Dr Hisham
M2	SIMM laboratory establishment	31 Dec 2023	Dr Vorathin
M3	Technology Benchmark Report	30 Jul 2024	Dr Hisham
M4	FBG sensing proof-of-concept	31 Dec 2024	Dr Vorathin
M5	FBG field deployment	1 Jul 2025	Dr Vorathin
M6	Completion of seismic profiling (conventional vs DAS)	31 Dec 2025	Dr Hisham
M7	DSTS, DAS, FBG multicomponent sensing	30 Jul 2026	Dr Hisham
M8	Field Monitoring Report	31 Dec 2026	Dr Hisham
M9	DAQ network setup	30 Jul 2027	Dr Azman
M10	Completion of web-based interface	31 Dec 2027	Dr Mokhtar

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## 6.0 P3: DEVELOPMENT OF PREDICTIVE ANALYTICS AND DATA VISUALISATION USING MACHINE LEARNING

Commented [CA(2)]: This project for UR Dr Jepp for TOTAL

Artificial Intelligent (AI) and Big Data Analytics (BDA) is one of the critical fields in the digitalization of the oil and gas (O&G) industry. Its focus is managing and processing an extreme volume of data to improve operational efficiency, enhance decision making and mitigate risks in the workplace. By refocusing this technology strategies and taking a holistic approach to build the right data foundation, upstream oil and gas companies can use new tools to optimize production, increase safety, and improve bottom-line results.

### 6.1 Objectives and Scopes

The aims are to develop Prediction Model and Data Visualization model based on AI and Big Data Analytics. The objectives of this project are:

- to develop prediction model using machine learning (Deep Learning) and survival models;
- to develop visualization model for a data visualization.

The research scopes are:

#### a. Data Analytics

- The data are prepared for supporting predictive analytics and visualization.
- A Machine Learning (Deep Learning) model shall be created for enabling prediction
- A Data Visualization Model shall be created for visualization of data and in dashboard.


#### b. System Prototype

- The system shall be able to store data that has been processed.
- The system shall be able to visualize information related to the data.
- The system shall be able to predict based on existing data using AI and Big Data Analytics approach.

### 6.2 System Architecture

Figure 2 show system architecture for predictive and visualization system. The system will have four main component which are Data Source, Web-Enable application, App/Core (Analytics Engine) and Database.



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- P3-2 Algorithm formulation and development.
- P3-3 Machine Learning Model development and Integration
- P3-4 System development and Testing

These subprojects shall be performed in three phases:

#### Phase 1: Proof of Concept

*Data Collection* - Data been collected from various sources such as exiting report, database, and sensor. All data will be store in database server or cloud database.

*Analyse and Validate Data* - This will involves data understanding, Data Quality Assessment and Exploratory Data Analysis. Also including data acquisition, data merging, data processing and data quality check. The codes for ETL process will be created as well.

#### Phase 2: Development

Predictive Analytics Model Development involve three main task as below:

- **Model Creation** - This phase starts with data visualization to capture patterns and insights from the data. This will be followed by the development and evaluation of several statistical and machine learning models for prediction. Survival analysis techniques will be used to estimate the survival functions based on the different attributes (parameters) for prediction. Then, the information will be used to obtain the optimal time points for preventive maintenance.
- **Parameter Optimization** - hyperparameter optimization or tuning is the problem of choosing a set of optimal hyperparameters for a learning algorithm. A hyperparameter is a parameter whose value is used to control the learning process. By contrast, the values of other parameters (typically node weights) are learned
- **Model Validation** - the process where a trained model is evaluated with a testing data set. The testing data set is a separate portion of the same data set from which the training set is derived.


#### Phase 3: Deployment

In this phase, the dashboard and data visualization will be developed. It follows typical prototype development methodology. It begins with the requirement gathering which determines the scope and boundaries of the dashboard. Then, the process of designing and implementing the prototype as required. This including System Integration with databased, server, sensor etc. It ends with the testing phase.

### **6.4 Targeted Results and Deliverables**

Deliverable as listed below, which can be used in many applications in oil and gas.

- Data Quality Assessment Report
- AI Algorithm and Prediction Model
- Data Visualization Model
- System Requirement, System Design and Architecture
- Databased Design

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- Prediction and Data Visualization Dashboard


## 6.5 Project 3 Gantt Chart

	2023				2024				2025				2026				2027			
Programme 3 Subproject	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
<b>P3-1 Data collection &amp; pre-processing</b>																				
Data Quality Assessment				M1																
Requirement Specification Analysis				M2																
<b>P3-2 ML Algorithm development</b>																				
ML Algorithm Modelling								M3												
ML Data Modelling									M4											
<b>P3-3 Machine learning model development</b>																				
Platform and Database Design									M5											
ML Model Training & Optimization										M6										
<b>P3-4 System Prototype development and testing</b>																				
Prototype Development & Integration																				
Testing and Deployment																		M7		
Documentation																			M8	

MILESTONES	DELIVERABLES	DATE	PERSON-IN-CHARGE
M1	Data Quality Assessment Report	31 Dec 2023	Dr M Hilmi
M2	Requirement Specification Document	31 Mar 2024	Dr M Hilmi
M3	Machine Learning Algorithm	30 Sept 2024	AP Dr Jafreezal
M4	Data Model	31 June 2025	AP Dr Jafreezal
M5	Platform and Database Design	30 June 2025	AP Dr Izzatdin
M6	ML Model Optimization Report	31 June 2026	AP Dr Jafreezal
M7	UAT Report & Prototype Deployment	31 Mar 2027	AP Dr Izzatdin
M8	Final Report and Documentation	31 Dec 2027	AP Dr Jafreezal

## 7.0 LINKAGE BETWEEN PROJECTS within PROGRAM

General description between the three projects is depicted in Figure 3. The research activities shall be focused on the upstream technology development. The program shall not be limited to other new developments and data acquisition of CO<sub>2</sub> subsurface and fluid monitoring.

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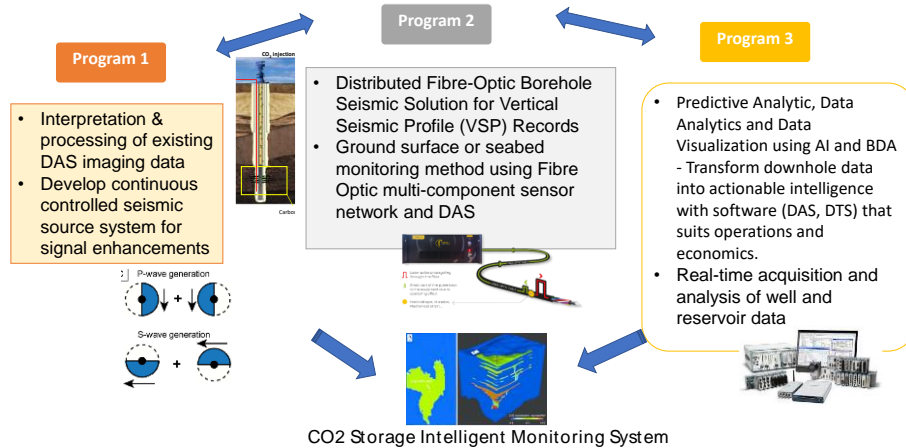



Figure 3 Interlink between three projects

## 7.1 Summary of Program Gantt Chart

Programme 1		2023				2024				2025				2026				2027			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
P1-1	Surface & VSP Data Collection & Pre-processing																				
P1-2	Optimum DAS Data Acquisition																				
P1-3	DAS Signal Enhancement through Advancement Processing & Imaging																				
P1-4	Integration of Fibre Optic-based Signal and reservoir characterization																				
Programme 2		2023				2024				2025				2026				2027			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
P2-1	DAS Benchmarking Performance																				
P2-2	Development of FBG geophone and hydrophone																				
P2-3	Field monitoring deployment (onshore/offshore in red)																				
P2-4	Acquisition & integration web-based system																				
Programme 3		2023				2024				2025				2026				2027			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
P3-1	Data collection & pre-processing																				
P3-2	Algorithm formulation and development																				
P3-3	Machine learning model development & integration																				
P3-4	System development and testing																				

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## 8.0 UTP WORKING TEAM

Figure 4 shows the team layout and technical working committee that are responsible in implementing the research activities.

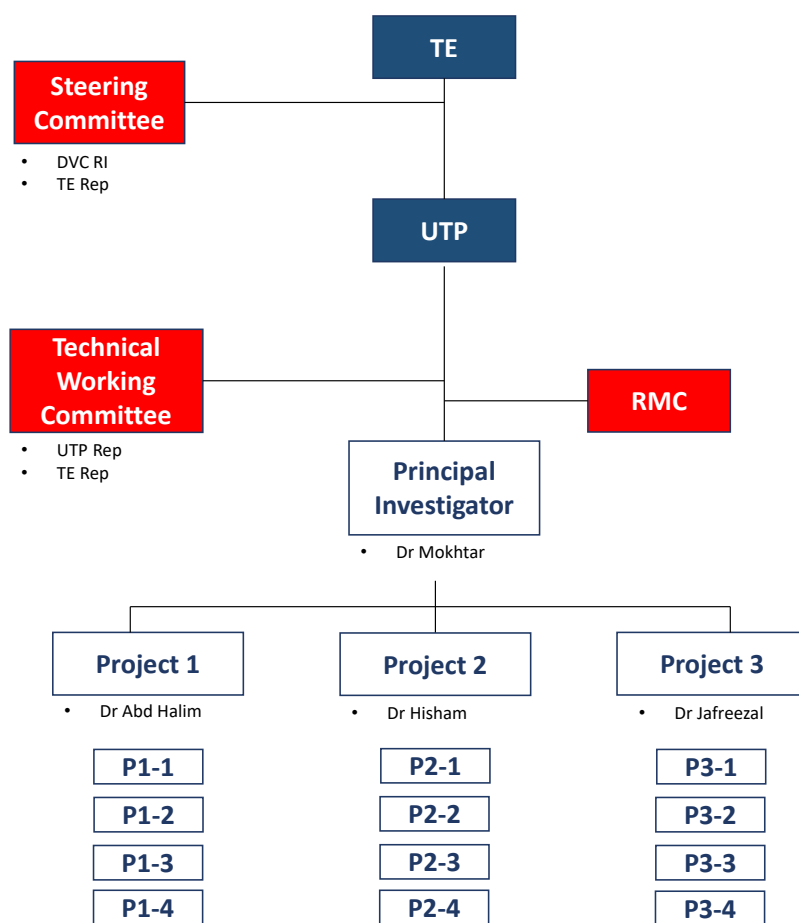



Figure 4 General layout of project members with verification of project progress by two levels of committees. \*TE = TotalEnergies, RMC = Research Management Centre

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## 9.0 COST BREAKDOWN

The following is the proposed grant utilisation for each project (in MYR) within the five years programme. Depending on the current USD to MYR exchange rate during the one-off payment transaction, the calculated amount from USD 5 million is RM 23.73 million. The budgeted amount presented herein is only served as an initial figure or indicative amount and may be subjected to changes based on actual project needs. All amounts are inclusive of Sales & Service Tax (SST).

Vot	ITEMS	P1	P2	P3	Subtotal (MYR)
11000	<b>Manpower</b> ( <i>Post-Doc., Research Scientists, Research Officers, Consultancy man hours</i> )		3,093,960	3,000,600	
21000	<b>Travel &amp; Transportation</b> ( <i>meetings, logistics, conferences, workshops</i> )		545,000	545,000	
24000	<b>Rental</b>		450,000	250,000	
27000	<b>Research Materials &amp; Supplies</b> (Consumables)		1,040,000	20,000	
28000	<b>Maintenance &amp; Minor Repair Services</b>		150,000	50,000	
29000	<b>Professional Services</b> ( <i>external consultation</i> ) & <b>Academic Contribution</b> (student outbound programme)		1,246,000	640,000	
35000	<b>Accessories &amp; Equipment</b> (Assets)		2,294,000	2,150,000	
	<b>University F&amp;A</b> (10%)		881,896	665,560	
	<b>Total</b>	<b>7,xxx,xxx</b>	<b>9,700,856</b>	<b>7,321,160</b>	<b>23,730,000</b>

Details of expenditure of each program is included Appendix A.



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APPENDIX A:

Project 2

Project 2		YEAR 1			YEAR 2			YEAR 3			YEAR 4			YEAR 5		
VOT	DETAILS	AMOUNT (RM)	QUANTITY	TOTAL	AMOUNT (RM)	QUANTITY	TOTAL	AMOUNT (RM)	QUANTITY	TOTAL	AMOUNT (RM)	QUANTITY	TOTAL	AMOUNT (RM)	QUANTITY	TOTAL
11000 (Salary & Wages)	Project Leader (HM)	38640	3	RM 115,920.00	38640	3	RM 115,920.00	38640	3	RM 115,920.00	38640	3	RM 115,920.00	38640	3	RM 115,920.00
	Sub-Project Leader (VE)	14760	2	RM 29,520.00	14760	2	RM 29,520.00	14760	3	RM 44,280.00	14760	3	RM 44,280.00	14760	2	RM 29,520.00
	Sub-Project Leader (MA)	38640	1	RM 38,640.00	38640	1	RM 38,640.00	38640	1	RM 38,640.00	38640	1	RM 38,640.00	38640	2	RM 77,280.00
	Sub-Project Leader (AZ)													20400	3	RM 61,200.00
	GRA PhD #1	3000	12	RM 36,000.00	3000	12	RM 36,000.00	3000	12	RM 36,000.00	3000	6	RM 18,000.00			
	GRA PhD #2	3000	6	RM 18,000.00	3000	12	RM 36,000.00	3000	12	RM 36,000.00	3000	12	RM 36,000.00	3000	6	RM 18,000.00
	GRA PhD #3	-			3000	6	RM 18,000.00	3000	12	RM 36,000.00	3000	12	RM 36,000.00	3000	12	RM 36,000.00
	GRA MSc #1	1800	12	RM 21,600.00	1800	12	RM 21,600.00									
	GRA MSc #2	-			1800	12	RM 21,600.00	1800	12	RM 21,600.00						
	GRA MSc #3	-						1800	12	RM 21,600.00	1800	12	RM 21,600.00			
	Post Doc #1	5800	6	RM 34,800.00	5800	12	RM 69,600.00	5800	12	RM 69,600.00	5800	12	RM 69,600.00	5800	6	RM 34,800.00
	Post Doc #2	-			6400	6	RM 38,400.00	6400	12	RM 76,800.00	6400	12	RM 76,800.00	6400	12	RM 76,800.00
	Research Scientist #1	5300	12	RM 63,600.00	5300	12	RM 63,600.00	5300	12	RM 63,600.00	5300	12	RM 63,600.00	5300	12	RM 63,600.00
	Research Scientist #2	5300	6	RM 31,800.00	5300	12	RM 63,600.00	5300	12	RM 63,600.00	5300	12	RM 63,600.00	5300	12	RM 63,600.00
	Research Officer #1	3600	12	RM 43,200.00	3600	12	RM 43,200.00	3600	12	RM 43,200.00	3600	12	RM 43,200.00	3600	6	RM 21,600.00
	Research Officer #2	3600	6	RM 21,600.00	3600	12	RM 43,200.00	3600	12	RM 43,200.00	3600	12	RM 43,200.00	3600	6	RM 21,600.00
	TOTAL			RM 454,680.00			RM 638,880.00			RM 710,040.00			RM 670,440.00			RM 619,920.00
21000 (Travel & Transportation)	Conference (international)			RM -	20000	2	RM 40,000.00	20000	2	RM 40,000.00	20000	2	RM 40,000.00	20000	2	RM 40,000.00
	Conference (Local)	5000	1	RM 5,000.00	5000	3	RM 15,000.00	5000	3	RM 15,000.00	5000	3	RM 15,000.00	5000	3	RM 15,000.00
	Meeting with Petronas/local Collabor	1250	4	RM 5,000.00	1250	4	RM 5,000.00	1250	4	RM 5,000.00	1250	4	RM 5,000.00	1250	4	RM 5,000.00
	Meeting with international Collaborat	22000	2	RM 44,000.00	22000	2	RM 44,000.00	22000	2	RM 44,000.00	22000	2	RM 44,000.00	22000	2	RM 44,000.00
	Field work	15000	1	RM 15,000.00	15000	1	RM 15,000.00	15000	1	RM 15,000.00	15000	1	RM 15,000.00	15000	1	RM 15,000.00
	TOTAL			RM 69,000.00			RM 119,000.00			RM 119,000.00			RM 119,000.00			RM 119,000.00
24000 (Rental)	additional field equipment rental	20000	1	RM 20,000.00	20000	1	RM 20,000.00	20000	1	RM 20,000.00	20000	1	RM 20,000.00	20000	1	RM 20,000.00
	Laptop leasing	10000	4	RM 40,000.00	10000	4	RM 40,000.00	10000	4	RM 40,000.00	10000	2	RM 20,000.00	10000	1	RM 10,000.00
	server, software, webpage	40000	1	RM 40,000.00	40000	1	RM 40,000.00	40000	1	RM 40,000.00	40000	1	RM 40,000.00	40000	1	RM 40,000.00
	TOTAL			RM 100,000.00			RM 100,000.00			RM 100,000.00			RM 80,000.00			RM 70,000.00
27000 (Research Materials & Supplies)	Multicore cables (singlemode, multimode)	500	30	RM 15,000.00	500	30	RM 15,000.00	500	30	RM 15,000.00	500	30	RM 15,000.00	500	30	RM 15,000.00
	FBG sensors (accelerometers, strain, temperature, 1550nm)	5000	20	RM 100,000.00	5000	20	RM 100,000.00	5000	20	RM 100,000.00	5000	20	RM 100,000.00	5000	10	RM 50,000.00
	FO Consumables (pigtail, connectors, adaptors, couplers, splitters, patchcords, Optical circulator, chemicals)	3000	100	RM 300,000.00	3000	100		3000	100		3000	100		3000	100	
	Office appliance, PPE	5000	1	RM 5,000.00	5000	1		5000	1		5000	1		5000	1	
	Modem/ wireless hardware, antenna			RM -	10000	1	RM 10,000.00	10000	1	RM 10,000.00	10000	1	RM 10,000.00	10000	1	RM 10,000.00
	MEMs sensors, transducers	3000	10	RM 30,000.00	3000	10	RM 30,000.00	3000	10	RM 30,000.00	3000	5	RM 15,000.00	3000	5	RM 15,000.00
	Gateway hardware, DAQ modules	2000	5	RM 10,000.00	2000	5	RM 10,000.00	2000	5	RM 10,000.00	2000	5	RM 10,000.00	2000	5	RM 10,000.00
	TOTAL			RM 460,000.00			RM 165,000.00			RM 165,000.00			RM 150,000.00			RM 100,000.00
	Equipment maintenance (optics)	50000	1	RM 50,000.00	50000	1	RM 50,000.00			RM -	50000	1	RM 50,000.00			RM -
	TOTAL			RM 50,000.00			RM 50,000.00			RM -			RM 50,000.00			RM -
28000 (Maintenance and Minor Repair Services)	Trainings	10000	1	RM 10,000.00	10000	1	RM 10,000.00	10000	1	RM 10,000.00	10000	1	RM 10,000.00	10000	1	RM 10,000.00
	Geotechnical subsurface exploration (borehole, trenching)			RM -	50000	1	RM 50,000.00	50000	1	RM 50,000.00	50000	1	RM 50,000.00	50000	1	RM 50,000.00
	Sensor fabrication & calibration	20000	1	RM 20,000.00	20000	1	RM 20,000.00	20000	1	RM 20,000.00	20000	1	RM 20,000.00	20000	1	RM 20,000.00
	Engineering design & computer modelling, external consultants	30000	1	RM 30,000.00	30000	1	RM 30,000.00	30000	1	RM 30,000.00	30000	1	RM 30,000.00	30000	1	RM 30,000.00
	Transportation & Logistic	2500	2	RM 5,000.00	2500	2	RM 5,000.00	2500	2	RM 5,000.00	2500	2	RM 5,000.00	2500	2	RM 5,000.00
	J. Publication Fee + proofread	5000	1	RM 5,000.00	5000	1	RM 5,000.00	5000	1	RM 5,000.00	5000	1	RM 5,000.00	5000	1	RM 5,000.00
	Insurance (personnel, equipment, travel, safety)	17000	1	RM 17,000.00	17000	1	RM 17,000.00	17000	1	RM 17,000.00	17000	1	RM 17,000.00	17000	1	RM 17,000.00
	SIMM laboratory setup & renovation	311000	1	RM 311,000.00			RM -			RM -			RM -			RM -
	Contribution to Academic Activities (Student exchange, internship, etc)	12000	5	RM 60,000.00	12000	5	RM 60,000.00	12000	5	RM 60,000.00	12000	5	RM 60,000.00	12000	5	RM 60,000.00
	TOTAL			RM 458,000.00			RM 197,000.00			RM 197,000.00			RM 197,000.00			RM 197,000.00
35000 (Accessories and Equipment)	Commercial software license			RM -	10000	5	RM 50,000.00	10000	5	RM 50,000.00	10000	1	RM 10,000.00	10000	1	RM 10,000.00
	DAS interrogator	600000	2	RM 1,200,000.00	650000	1	RM 650,000.00			RM -			RM -			RM -
	Micron Optics Hyperion 1525-1570 nm; 35kHz; I-MON 256 HS	140000	1	RM 140,000.00			RM -			RM -			RM -			RM -
	optical spectrum analyzer (OSA)	55000	1	RM 55,000.00			RM -			RM -			RM -			RM -
	Fusion Splier	11000	1	RM 11,000.00												
	OF inspection scope	18000	1	RM 18,000.00												
	FO toolbox Termination Kits	15000	1	RM 15,000.00												
	SLED light source	25000	1	RM 25,000.00												
	InGaAs Amplified Photodetectors	30000	1	RM 30,000.00												
	NI DAQ 9234	20000	1	RM 20,000.00												
	Optical switch	10000	1	RM 10,000.00												
	TOTAL			RM 1,524,000.00			RM 700,000.00			RM 50,000.00			RM 10,000.00			RM 10,000.00
TOTAL				RM 3,115,680.00			RM 1,969,880.00			RM 1,341,040.00			RM 1,276,440.00			RM 1,115,920.00
F&A (10%)				RM 311,568.00			RM 196,988.00			RM 134,104.00			RM 127,644.00			RM 111,592.00
TOTAL				RM 3,427,248.00			RM 2,166,868.00			RM 1,475,144.00			RM 1,404,084.00			RM 1,227,512.00
														GRAND TOTAL		RM 9,700,856.00

