**Amphitec Pty Ltd Pty Ltd**

**DRAFT**

**FY21 R&D Tax Incentive Plan**

**(Activity Description Report)**

**- CONFIDENTIAL -**

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# Company and Contact Details

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| **Company Details** | | | |
| Company Name | Amphitec Pty Ltd | | |
| Australian Business Number | 46 102 717 297 | | |
| Company Registration Date | 04/11/2002 | | |
| Income Period | 1/07/2020 | | 30/06/2021 |
| Companies ANZSIC Division & Class | C – Manufacturing  2462 – Mining and construction machinery manufacturing | | |
| Website | <https://www.phibion.com/> | | |
| **Employees** | | | |
| How many employees did the company have across all companies at the end of 30 Jun 2021? | | 58 | |
| How many employees across all companies were engaged in the R&D activities included in this application? | | 3 | |
| **Finance** | | | |
| For your selected income period, what was the company's taxable income or loss across all companies | | $TBD | |
| For your selected income period, what was the company's aggregated turnover? | | TBD | |
| For your selected income period, how much revenue did the company earn across all companies from export sales? | | TBD | |
| **Primary Contact Details** | | | |
| Title | Mr | | |
| First Name | David | | |
| Last Name | Frazer | | |
| Position or Role | Information Technology and Robotics | | |
| Phone Number | 0427982653 | | |
| Email | [david.frazer@phibion.com](mailto:david.frazer@phibion.com) | | |
| Main Business Address | 158 Benjamin Place, Lytton 4178 | | |

# Project 1

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| **Project Details** | | |
| Project Name | Development of an electric power autonomous MudMaster ® | |
| Project Reference | #1 | |
| Project Location (Postcode) | 4178 | |
| Project Start Date | 1/07/2019 | |
| Project End Date | 30/06/2023 | |
| ANZSRC Division | B – Mining | |
| ANZSRC Group | 1090 – Other mining support services | |
| **Project Expenditure** | | |
| How much is expected to be spent over the life of the Project? | | $4,389,950 |
| Expenditure on Feedstock inputs (FY21) | | $TBD following exp analysis |
| **Objectives of the Project** | | |
| *1000 Character Limit* | | |
| Amphitec Pty Ltd (“Amphitec”) develops tailings management technology to dewater mineral tailings across various mine sites in Australia, and the world. Their design is based on the twin Archimedes screw which is capable of usage in harsh and high-risk environments and remote locations.  The overall objective of this project is to develop a sensing technology based on the measurement of the dielectric permittivity for selected frequency windows to quantify the density of tailings as the main targeted information (Core Activity 1); and further parameters that allow a more comprehensive characterization of the tailings allowing the automation of the MudMaster® and an overall optimization of tailings management (Core Activity 2). | | |

# Core Activity 1

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| Activity Title | To develop a robust MudMaster tailings sensor that can remotely determine tailings characteristics in a range of mineral commodities. |
| Which Project is this Core Activity related to? | #1 |
| Estimated Current Year Expenditure | $TBC following exp analysis |
| Activity Start Date | 1/07/2019 |
| Activity End Date | 30/06/2021 |

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| What was the hypothesis? |
| ***4000 Character Limit*** |
| At the outset of these activities, Amphitec identified a need for accurate and reliable data collection in relation to tailings in a mining environment, particularly relating to water management. Following prior year activities, technical personnel have established that it is possible to provide accurate and usable data for land reconstitution and restoration and water management through accurately measuring the amount of water that is removed from tailings and mapping the mud field for high levels of water. In addition, technical personnel hope to develop new knowledge that will enable them to provide the properties of the tailings (i.e., toxicity, composition, density etc.).  The technical objective of this core activity is to develop a sensing technology based on the measurement of the dielectric permittivity for selected frequency windows to quantify the density of tailings and further parameters that allow a more comprehensive characterization for overall optimization of tailings management.  To achieve the technical objective, the following specific objectives have to be targeted:   1. Development of a non-invasive sensing system to be mounted on the MudMaster for selected frequency windows that cover a wide frequency range including calibration procedures. 2. Development of a probe that allows the direct measurement of the dielectric permittivity over a wide frequency range that can be used for calibrating the non-invasive sensing system. 3. Development of mixing equations for quantifying targeted soil parameters and state variables and to provide a comprehensive database that can be used to optimize and predict the success of mud farming.   Entering FY21, Amphitec continued investigative and experimental to evaluate the initial hypothesis that by developing a robust real time tailings sensor that can be attached to the MudMaster, it will be possible to remotely determine tailings characteristics in a range of mineral commodities and provide real time material updates on the properties of the slurry as the equipment moves through the tailings.  Whilst Amphitec’s hypothesis is based on sound scientific principles and a comprehensive understanding of tailing management technology (both hardware and software), the dearth of comparable technology currently available, and the complexity introduced from the interoperability of the overall system and variables introduced at every level of the operations (i.e., the type of material mined, the processes that the mine uses, the type of soil, the type of the mining operation, the extent of planning for tailings processing etc.), meant that there is no ability to establish whether the proposed technology can achieve the various technical objectives concurrently. Accordingly, technical personnel (in concert with the University of Queensland (UQ)) established that it will need to undertake a series of experimental activities focused on developing new knowledge in the form of technical advancements, which will assist in the development of a robust tailings sensor that can remotely determine tailings characteristics in a range mineral commodities. |

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| New knowledge | | |
| *Were these R&D activities undertaken for the substantial purpose of generating new knowledge?* | | Yes |
|  | ***1000 Character Limit*** | |
| The primary objective and purpose of these activities is to develop new knowledge regarding the relationships between numerous variables, impacting the ability to develop a method for quantifying in real time the density of soil waste and soft soil based on electromagnetic measurements results to improve TSF management and safety. The new knowledge that will be generated includes:   * Ability to develop robust and precise remote sensor for real-time analysis of tailings properties to allow machine operation to be better aligned to the constantly changing tailings properties. * Ability to integrate this data stream into specific algorithms required to operate a MudMaster® autonomously. * Ability to fabricate a fully electric autonomous MudMaster® that will allow Amphitec to produce at scale an electric vehicle manufacturing process in Australia. | | |

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| Outcome cannot be known or determined |
| ***Please select all that apply:*** |

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|  | There was no applicable information in scientific, technical, or professional literature or patents | |
|  | Experts in the field provided advice that there was not a solution that could be applied | |
|  | There was not a way to adapt solutions from other companies in, and out of, Australia | |
|  | Other | |
|  | The company did not look into existing knowledge | |
| *Please explain what sources were investigated, what information was found, and why a competent professional could not have known or determined the outcome in advance.* | | |
|  | | ***1000 Character Limit*** |
| To establish the outcome these activities could not have been known or determined in advance Amphitec undertook significant industry reviews and extensive literary investigations in concert with UQ into the applicable sciences of sensor engineering and AI development both within Australia and overseas to address the requirements of the system.  Based on these research activities Amphitec (and UQ) determined that there are no currently available, off the shelf solutions utilizing dielectric sensors or AI that could be integrated into the MudMaster system. Additionally, Amphitec emphasize that the unpredictable influence of the variables associated with the environmental and MudMaster (density/composition of the slurry and variance in speed/height of the sensor) mean that there are no available means to fill the gaps in knowledge for the Amphitec system without a systematic progression of experimental activities. | | |

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| Systematic progression of work |
| **What was the experiment and how did it test the hypothesis?** |
| ***4000 Character Limit*** |
| In pursuit of their technical objectives and the generation of new knowledge needed to overcome the identified knowledge gaps, Amphitec undertook an iterative process of experimentations and development to test the hardware (non-invasive dielectric sensors and integration/mounting to the MudMaster) and software systems (algorithm development and smart AI programs).  Experimentation has been divided into 3 phases, each of which will require successful completion prior to undertaking the next phase, emphasizing the systematic and progressive nature of this activity.  [@David]: Could you please confirm any delays due to Covid on the experimentation conducted throughout FY21 – it would be could to provide contact as to why experimentation has been delayed?   * Schedule delays were experienced due to multiple isolation periods which delayed several site visits * Hardware delivery had impacted delivery dates were impacted * In-house tasks were prolonged due to the availability of resources both with ASI and Phibion   *Phase 1: Experimentation to develop project startup and definition of system capabilities (FY21)*   * Site visits were conducted to clarify the features of the environment, tailings characteristics and to understand the required specifications that the technology platform is to function in. * Experimentation to develop an understanding of the dielectric properties of diverse soil types and the relation with its density (including water saturation properties). * Experimentation to establish a three-dimensional (3D) numerical analysis program (based on electromagnetics propagation model) to determine the optimum range of working frequency and required Radio Frequency (RF) power level. * Experimentation to analyze the antenna aperture size of the dielectric sensor and its distance to inspected soil surface and the effect this has on metrics obtained.   *Phase 2: Experimentation to design and develop contactless dielectric sensors in full-wave simulation environment (FY22)*   * Experimental activities to develop an Integrated optimized antenna design in terms of its working frequency and near-field characteristics. * Experimentation to design an RF circuit sensor to connect to the designed antenna structure. * Experimentation to Optimize sensor geometry via a computational electromagnetic (EM) simulator to achieve an acceptable impedance balance, near-field pattern, efficiency, and frequency-domain response. * Experimentation to evaluate the sensitivity and reliability of the dielectric sensor in terms of different soil properties.   *Phase 3: Development of a proof-of-concept minimum viable product (MVP) prototype (FY22)*   * Experimentation to build up an antenna design from investigational studies and measure its near- and far-field radiation performance. * Experimentation to integrate the RF feeding networks designed from investigational studies with the antenna body. * Experimentation to connect the developed sensor to the vector network analyser and capture the data over the specified frequency in both free space and a homogeneous medium for calibration purposes. * Experimentation to integrate the Minimum Viable Product (MVP onto the MudMaster platform and capture raw RF signals from live application scenarios. * Experimentation to collect data and interpret the collected RF signal and mapped data with soil properties. * Experimentation to conduct testing of the sensor in various slurries to identify the feedback. The field trials will be conducted with the meter attached to a MudMaster. This information will be input into algorithms in an attempt to develop full automation of the technology platform.   In collaboration with the University of QLD, Amphitec we will be testing the sensor in various slurries to identify the feedback. From there field trials will be conducted with the meter attached to a MudMaster®. This information will be made available to Amphitec partners in the US who will develop the algorithms to move to full automation of the MudMaster®. After the desktop evaluations and development of the algorithms it will be installed on the MudMaster® in Australia and tested at the Port of Brisbane. |
| **How did you evaluate or plan to evaluate results from your experiment?** |
| ***4000 Character Limit*** |
| In undertaking experimental activities as part of this core activity, Amphitec will collect extensive data on the signals received by the tailings sensor in 3 separate trials, laboratory, larger scale laboratory (workshop) and on a MudMaster ® in the field. The analysis of this data is integral to machine learning and will attribute to the advanced detection of water in a variety of soil/material types.  Amphitec (in collaboration with University of Queensland) made the following evaluation in FY21:  *Phase 1: Experimentation to develop project startup and definition of system capabilities*   * Metrics of the soils, including the mineral retention and the water retention and the impact these metrics have on density of the soil * Specify the working frequency, RF power level and antenna type to be applied on the dielectric properties * The effect of the antenna aperture size, its distance to the soil on the ability to record accurate data. * Quantitative metrics of the electromagnetics propagation characteristics in the soil as well its response to the dielectric properties * Acquiring the dielectric properties (permittivity and conductivity) of the inspected soil form database and imported those data into the numerical analysis model * Understand the working environment of the Mud-Master platform and determine the possible positions to be installed with dielectric sensors   Amphitec (in collaboration with University of Queensland) plan to make the following evaluations in FY22/FY23:  *Phase 2: Experimentation to design and develop contactless dielectric sensors in full-wave simulation environment*   * Evaluations on the preliminary designs and configurations of the sensor geometry and dimensions that are required for accurate, reliable results as well as allowing for a robust and functional device * Evaluations to specify the 3D topology and design parameters of the sensor, along with its feeding circuit * Evaluate sensor performance in realistic full-wave simulation environments and the dynamic range of dielectric measurements.   *Phase 3: Development of a proof-of-concept minimum viable product (MVP) prototype*   * Verification of the 3D simulation model to present the realistic laminates with high reliability. * Quantitative understanding of the system reliability and sensitivity of measuring the soil properties * Evaluation of the commercial viability based on the prototype and MVP. |
| **If you reached conclusions from your experiments in the selected income period, describe those conclusions.** |
| ***4000 Character Limit*** |
| At the conclusion of FY21 Amphitec had generated significant new knowledge; however, had only completed on phase 1 of experimentation, meaning there is still further planned experimentation that is required before Amphitec is able to validate (or invalidate) the overarching hypothesis.  Based on the results of experimentation conducted in FY21, Amphitec (in collaboration with University of Queensland) reached the following conclusions:   * The antenna should operate from about 0.6GHz to over 2GHz, however, during experimentation the range was between 0.5GHz and 1GHz, as soil is approximately constant in this range. * Amphitec concluded that 4 antennas were required to provide accurate depiction capable of 3D development. While 2 antennas were able to generate accurate data, 4 was held as substantially more accurate, while more than 4 did not substantially increase the benefit. * Technical personnel tested these on a range of soils simulated with random permittivity (between 3 and 78 where 3 is 0% water and 78 is 100%). * It was held as not a viable aim to hold the antenna constant distance due to the constant undulations in the slurry and movement of the vehicle. * Regarding the software, about 1500 samples were collected with random soil shape and permittivity before the program and machine learning were able to develop the network capable of utilizing this data. * Technical personnel identified a number of variables that influenced results, and should be isolated and experimented on in future experiments (i.e., is there any metal in the soil, homogeneousness of the soil, magnetic material, is there a floor/waterbed for the soil?)   Following the completion of Phase 1 in FY21, Amphitec will now proceed to Phase 2 and 3 of experimentation in FY22, therefore following a systematic progression of experimentation in order or validate or invalidate the initial hypothesis.  *.* |

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| Supporting documentation the company kept about this core activity | | |
| *Evidence needs to show how you conduct or plan to conduct core R&D activities:*   * *That are based on principles of established science* * *For the purpose to generate new knowledge* * *Whose outcome cannot be known or determined in advance on the basis of current knowledge, information or experience worldwide* * *Whose outcome can only be determined by applying a systematic progression of work – hypothesis, experiment, observation and evaluation, leading to logical conclusions* * *That are not excluded from being core R&D activities* | | |
|  | Evidence of searches or enquires you made to find current knowledge | |
|  | Evidence to show that you could only determine the outcome of the core activity by conducting experiments as part of a systematic progression of work | |
|  | Evidence of your hypothesis and design of your experiments | |
|  | Documented results and evaluation of your experiments | |
|  | Other | |
|  | The company did not keep records | |
| ***Please describe the other evidence:*** | | ***100 Character Limit*** |
| Emails, contracts, meeting notes, raw data etc. | | |

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| Did another entity assist you in undertaking the R&D activities? | | |
| **Was some or all of this core activity conducted by a Research Service Provider or Cooperative Research Centre?** | | |
|  | Yes, | *a non-levy collecting Research Service Provider* |
|  | Yes, | *a levy collecting Research Service Provider* |
|  | Yes, | *a Cooperative Research Centre* |
|  | No |  |
| **If yes, please include the name of RSP or CRC** | | |
| University of Queensland | | |
| **Brief description of the activity, services provided by the Research Service Provider and what new knowledge the activity was intended to create.** | | |
| ***1000 Character Limit*** | | |
| Amphitec in collaboration with the University of Queensland, will develop a method for quantifying in real time the density of soil waste and soft soil based on electromagnetic measurement results to improve TSF management and safety. In the first stage, a specific designed RF architecture (including the contactless dielectric probe) in the theoretical level will be developed in the EM simulation and laboratory environment; in the second stage, a proof-of-concept prototype as a minimum viable product (MVP) will be built and tested in real environment for collecting the measurement data and reshape the data into the form representing the dielectric properties of the soil wastes.  The development of such a method is possible by a multi-disciplinary collaboration involving electrical engineering, geophysics, geotechnics, and mechanical engineering, | | |

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| Have any of the R&D Activities been undertaken overseas? | |
| Do you have an Overseas Finding for these R&D Activities? | No |
| If so, what are the certificate reference numbers for the findings? | #N/a |
| Have these amounts been removed from the claim? | Yes |

# Core Activity 2

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| Activity Title | Develop autonomous capability for the MudMaster® that will eliminate the need for a human operator and have enhanced operability due to the data stream from the on-board tailings’ sensor*.* |
| Which Project is this Core Activity related to? | #1 |
| Estimated Current Year Expenditure | $194,000 USD + |
| Activity Start Date | 1/07/2020 |
| Activity End Date | 30/06/2023 |

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| What was the hypothesis? |
| ***4000 Character Limit*** |
| Amphitec are at the forefront of tailings processes and management. Over the near 2 decades of operation technical personnel have identified significant risks to both drivers and mines. These risks include extended exposure to toxic material in tailings from mining processes, extended and monotonous work that requires concentration for the duration of the shift, and general human errors leading to decreased results. Based on these factors Amphitec have identified the opportunity to develop an autonomous fleet of MudMasters, capable of performing the required tasks, with accuracy, and removing human exposure to toxic materials.  At the outset of this activity, Amphitec commenced a series of investigative and experimental activities develop technology to covert the existing and successful MudMaster design to a remote/autonomous capability with a lower environmental impact. To achieve this, technical personnel set out to develop new knowledge in the form of technological advancements capable of eliminating the need for a human operator and have enhance operability due to the data stream from the on-board tailing’s sensor. On the basis of this work, during the prior financial year, Amphitec has conducted a range of experimentation to test its hypothesis that by developing remote sensing instrumentation that provides real-time material properties of the tailings during MudMaster® operation it will be possible to feed this information into specific algorithms via autonomous hardware and allow the MudMaster® to safely navigate a hazardous  tailings environment without the need for an operator. This capability and associated mass reduction will also permit to conversion of the MudMaster® drivetrain to a battery/electric system reducing environmental risk and lowering carbon emissions from operations.  Entering FY21, Amphitec resolved to undertake further investigations and experimentation in an attempt to validate the initial hypothesis by undertaking phase 1 of experimentation in concert with Autonomous Solutions, INC (AIS).  Phase 1 Objectives:   * Drive a MudMaster ® vehicle in both forward and reverse directions. * The vehicle shall target a straight line at speeds no greater than four kph. * This stage characterizes the ability to maintain a straight path and demonstrates ASI’s ability to interface with the MudMaster vehicle. * This stage does not include control or monitoring of the MudMaster engine or scroll encoders.   The technical objective of phase 1 includes the ability to deliver a fully autonomous MudMaster that will be able to accurately (accuracy in this instance is the ability to travel in a straight path, with as little deviation as possible, regardless of mud composition, and ability to remain in the geofenced area) and reliably (reliability is the ability to complete multiple forward and reverse paths in the mud-field without a drop in accuracy for the full duration of the shift, or until another parameter is met such as refueling or maintenance) complete work without human interaction for extended periods of time. The technical objectives will require solving various technical unknowns, including:   1. The impact of pitch and roll movement in operation on changing height of sensors above the ground and whether this will lead to inaccuracies on the ground position compared to detected position. 2. The impact of mud density on scroll (method of movement uses large scroll/screw like tubes) feedback 3. The impact of limited or no GPS corrections due to areas of operation 4. The impact of hard material on engine load and how this impacts engine feedback 5. The effect of different ground conditions and how this impacts the turn radius. |

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| New knowledge | | |
| *Were these R&D activities undertaken for the substantial purpose of generating new knowledge?* | | Yes |
|  | ***1000 Character Limit*** | |
| The primary objective and purpose of these activities is to develop the necessary new knowledge with respect to developing AI algorithms capable of fully autonomous driving in a tailing’s environment, with the requisite inference of traction, loss of traction, speed, angles, and direction required as part of the tailings process. If successful in the development of this new knowledge Amphitec intend to apply this knowledge across their fleet of MudMasters, increasing their performance while decreasing human risk.  There is a distinct lack of applicable public knowledge available on smart AI algorithms or datasets that would be suitable for Amphitec’s situation, largely due to the nature of the environment (decreased tractions and standard driving practices differ substantially). Hence there are significant ambiguities associated with this experiment, requiring development of new knowledge regarding smart AI and their ability to control the MudMaster. | | |

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| Outcome cannot be known or determined |
| ***Please select all that apply:*** |

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|  | There was no applicable information in scientific, technical, or professional literature or patents | |
|  | Experts in the field provided advice that there was not a solution that could be applied | |
|  | There was not a way to adapt solutions from other companies in, and out of, Australia | |
|  | Other | |
|  | The company did not look into existing knowledge | |
| *Please explain what sources were investigated, what information was found, and why a competent professional could not have known or determined the outcome in advance.* | | |
|  | | ***1000 Character Limit*** |
| Amphitec (who are competent professionals in tailing management) in concert with UQ undertook significant industry reviews both in Australia and overseas to address if their product and the proposed integration with autonomous AI could be resolved. No publicly available datasets for autonomous vehicle operation in tailing environments were identified in the industry and were unable to address the level of functionality and capability. Amphitec acknowledge the existence of current solutions regarding AI based autonomous movement; however, information regarding these systems is not publicly available, nor directly applicable.    Hence there was a need to develop custom applicable algorithms, datasets, and processes for integration. This led to Amphitec to engage ASI (who are overseas experts in autonomous engineering solutions) to provide requisite knowledge capable of adaptation for Amphitec (an advanced overseas finding has been granted prior to engagement). | | |

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| Systematic progression of work |
| **What was the experiment and how did it test the hypothesis?** |
| ***4000 Character Limit*** |
| In pursuit of their technical objectives and the generation of new knowledge needed to overcome the identified knowledge gaps, Amphitec undertook an iterative process of experimentations and development to test the software systems (algorithm development and smart AI programs).  Experimentation has been divided into 3 phases, each of which will require successful completion prior to undertaking the next phase, emphasizing the systematic and progressive nature of this activity.  [@David]: Could you again please confirm if experimentation was delayed due to Covid?   * Schedule delays were experienced due to multiple isolation periods which delayed several opportunities for site visits * Hardware delivery had impacted delivery dates were impacted * In-house tasks were prolonged due to the availability of resources both with ASI and Phibion   *Phase 1: Experimentation to verify proof-of-concept*   * Experimentation to verify use cases, design, and scope * Experimentation to establish basic controls of the MudMaster * Experimentation to verify the effect of MudMaster movement in tailings environment. * Experimentation to characterize the scroll drive interface and data gathering from the MudMaster for control analysis. * Experimentation to develop an ASI demo kit and Vehicle Control Unit (VCU) preparations for driving the MudMaster scrolls * Experimentation to test the control of the MudMaster in a straight line in tailings environments.   *Phase 2: Experimentation to develop software (Mobius) componentry, Teleportation, and Waypoint*   * Experimentation to design and develop an integrated Vehicle Automation Kit (VAK). * Experimentation to develop Mobius (software platform) command and control with teleoperation functions and basic waypoint capability. * Experimentation to establish integrated safety analysis (HARA) and network infrastructure analysis. * Experimentation to integrate the above 3 systems capable of autonomous control, and monitoring of the MudMaster. * Experimental activities to develop pathfinding/following in a tailing’s environments   *Phase 3: Experimentation to develop a program to control the pathing, monitor the metrics of the MudMaster in real-time*   * Experimentation to modify the Mobius’ Area Coverage planner and function and the VCU code to allow for forward and reverse control within the planner and develop an area coverage pattern according to established best practices. * Experimental activities to establish if the above can be automated (automate the pathfinding process) * Experimentation in a real-world environment with full autonomous completion of task for full shifts over consecutive days. |
| **How did you evaluate or plan to evaluate results from your experiment?** |
| ***4000 Character Limit*** |
| In FY21, Amphitec in concert with ASI evaluated the results of phase 1 experiments. This included the following evaluations:  *Phase 1: Experimentation to verify proof-of-concept*   * Technical personnel installed the VAK on a skid steer vehicle for testing of the hardware and software. Metrics were recorded to establish the basic qualities that would be recorded (forward reverse straight line etc.). Technical personnel also monitored the ability to refrain from increase speed beyond four km/h * Vehicle performance was observed and measured using diagnostics within the VCU and visual affirmations from recorded cameras included in the VAK. * Notes were collected on considerations for additional features and performance improvements of future phases.   Amphitec plan on making the following evaluations in future years once phase 2 and phase 3 experimentation has been carried out:  [David] – can you please confirm how you plan on evaluating the results from phase 2 (s*oftware (Mobius) componentry, Teleportation, and Waypoint)* and phase 3 (Area Coverage and Planner updates, Forward/Reverse path controls)?  (*If you cannot provide this information, we will state that future evaluations will be made.*) |
| **If you reached conclusions from your experiments in the selected income period, describe those conclusions.** |
| ***4000 Character Limit*** |
| At the conclusion of FY21 Amphitec was able to generate substantial new knowledge regarding the autonomous control of the MudMaster. Only phase 1 experimental activities were able to be undertaken, requiring further experiments to be undertaken in subsequent years.  Based on experimental activities undertaken thus far, Amphitec have made the following conclusions:   * Technical personnel demonstrated the ability to perform autonomous straight-line travel on the skid steer vehicle. Based on this experimentation was advanced * The autonomous hardware and software were held as capable of integration with the MudMaster design and framework. * The vehicle was able to follow a straight line while traveling forward very easily. The maximum off path error while moving forward while following a straight line was about 0.25m. When the vehicle attempted to follow the ‘s’ curve at the end of the forward path, it could not track back to the path. Eventually it got an “off path” error indicating that the vehicle was more than the configured maximum off path error from the path. It was noted that an ideal value for the maximum off path error for future phases would be less than 2m. The control of the vehicle during this reversal was not stable. The vehicle would overshoot to either side of the path by up to 2m at times. It is unlikely that this was solely because of material. It indicates that there is likely a software issue that technical personnel still need to address or that the dynamics of the system are such that forward operations are more stable than reverse. * Technical personnel also identified that there were serious defects relating to the autonomous joystick operation and the velocity of the MudMaster, with frequent errors between the joystick attempted velocity and the actual vehicle velocity. It was concluded that better mapping of joystick percentages to curvatures and scroll velocities were required. * It was also concluded that crabbing (unintentional sideways movement caused by slippage) has the potential to cause localization issues.   At the conclusion of FY21, technical personnel identified that there were improvements that were required to be made on phase 1 experiments prior to progression to phase 2 activities. There is still substantial experimentation that is required to be undertaken before logical conclusions can be made to validate or invalidate the initial hypothesis. Accordingly, further investigations and experimentation will continue in FY22. |

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| Supporting documentation the company kept about this core activity | | |
| *Evidence needs to show how you conduct or plan to conduct core R&D activities:*   * *That are based on principles of established science* * *For the purpose to generate new knowledge* * *Whose outcome cannot be known or determined in advance on the basis of current knowledge, information or experience worldwide* * *Whose outcome can only be determined by applying a systematic progression of work – hypothesis, experiment, observation and evaluation, leading to logical conclusions* * *That are not excluded from being core R&D activities* | | |
|  | Evidence of searches or enquires you made to find current knowledge | |
|  | Evidence to show that you could only determine the outcome of the core activity by conducting experiments as part of a systematic progression of work | |
|  | Evidence of your hypothesis and design of your experiments | |
|  | Documented results and evaluation of your experiments | |
|  | Other | |
|  | The company did not keep records | |
| ***Please describe the other evidence:*** | | ***100 Character Limit*** |
| Emails, milestone reports, overseas finding, meeting notes, experiment data | | |

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| --- | --- | --- |
| Did another entity assist you in undertaking the R&D activities? | | |
| Was some or all of this core activity conducted by a Research Service Provider or Cooperative Research Centre? | | |
|  | Yes, | *a non-levy collecting Research Service Provider* |
|  | Yes, | *a levy collecting Research Service Provider* |
|  | Yes, | *a Cooperative Research Centre* |
|  | No |  |
| If yes, please include the name of RSP or CRC | | |

# Supporting R&D Activity 1

|  |  |
| --- | --- |
|  | |
| Supporting Activity Title | Investigations including process analysis, expert consultation and industry research |
| Which Core Activities are supported by this activity? | #1, 2 |
| Estimated Current Year Expenditure | $194,000 USD + $50KAUD |
| Activity Start Date | 1/07/2020 |
| Activity End Date | 30/06/2021 |

|  |
| --- |
| **Supporting Activity Details** |
| **How did this activity directly support the core activities?** |
| ***1000 Character Limit*** |
| This supporting activity directly supported the development and refinement of the proposed hypotheses by providing the R&D team with the necessary supporting research, knowledge, and experience with respect to the relevant subject matter. Further through conducting these investigations, expert consultation, and industry research Amphitec’s R&D team were able to define the knowledge gap and effectively design, conduct, and observe the series of experiments described in the core R&D activities. |
| **Briefly describe the supporting activity** |
| ***1000 Character Limit*** |
| Prior to and throughout undertaking the associated core R&D activities, technical personnel undertook investigations for various reasons into available information regarding both the sensor technology and software and the autonomous driving MudMaster activities.  These investigations included: reviewing relevant industry literature, attendance and participation in industry working groups and discussions, benchmarking and sampling activities, discussions with contractors and technology suppliers, observation and analysis or processes, employment of expert consultants. |