Minutes and Agenda:

Siew – shl4917, Taha – ata1917, Jeremy – jwt1117, Hussain – mas3717, CS - cst3317

Date & Time:	Monday 14th Oct 2019, 1300
Agenda:	Initial meeting to introduce ourselves and decide our first steps.
Members present:	CS, Siew, Jeremy, Taha, Hussain.
Minutes:	• Each member gave details about their chosen modules this year. Siew and CS have taken ECM in the autumn term so will be largely unavailable as the end of term approaches. • Wednesday chosen as the preferred day for an appointment with the supervisor. • Questions to ask Dr. Salles (supervisor) decided: What is the purpose of the project? Which facilities can be used? Which software is needed? Can aspects of the project be outsourced? Are there previous projects we can use as a basis? Is the group eligible for extra funding? How often should meetings take place? Who should group contact more? (Dr. Salles or Dr. Schwingshakl) • Administrative roles allocated to each member of the group: CS – Supervisor liaison Siew – Document control Jeremy – Deadlines Taha – Budget Hussain – Minutes and bookings • Target: Book appointment with Dr. Salles on the morning of Wednesday 16th. CS is in charge of this.
Filled in by:	Hussain

Date & Time:	Wednesday 16th Oct 2019, 0900
Agenda:	Introduce group to Dr. Salles and get a general direction for the project.
Members present:	Dr. Salles, CS, Siew, Jeremy, Taha, Hussain.
Minutes:	• Dr. Salles introduced himself as a Research Fellow in the department and has very little teaching experience. His research involves heavy use of software. • Ideally, meetings would take place on Mondays before 11am or Friday mornings. • We will see Dr. Salles most often and maybe see Dr. Schwingshakl once a week. • Project is to scan an engine so that CAD models can be made. • Scanner should be able to scan an object with dimensions up to 50cm x 30cm while also being able to measure from the top. • Scanner should be relatively portable with 2 people being able to carry it. • Weight of the scanner and time taken per scan need to be decided by the group. • Language should be Python, C or FabScan. • Fine to not finish software requirements this year. • We are allowed to use the workshops and labs. • There is no extra funding. • Any wiring or electronics must be covered. • Advice from Dr. Salles: Don't set a very difficult quality plan as group has to stick to it for the rest of the year or any changes need to be justified. Next steps are to research the project and see available options. • After discussion, meeting with supervisor set as 0900 – 1000 on Fridays.

	• Group meetings are 1300 – 1400 on Mondays, after DMT lectures, with possible impromptu meetings on Fridays also. • Target: By Monday 21st, bring forward some ideas and be familiar with the PQP.
Filled in by:	Hussain

Date & Time:	Monday 21st Oct 2019, 1300
Agenda:	Discuss PQP, Project Registration Form, teams/document control and laser types (for purchasing).
Members present:	CS, Jeremy, Siew, Hussain, Taha.
Minutes:	**1. PQP:** • Each item on PDS was analysed. • Resolution still remains ambiguous. • Scan time was initially estimated at 30 minutes but then changed to less than one hour. • Mass of the scanned object was limited to 20 kg. • Mass of the scanner itself was limited to less than 30 kg since two people need to be able to carry it. • Laser should be able to be swapped (modular). • Service life could not be decided so group agreed to do market research to find estimate otherwise supervisor will be asked. • Lens needed to be accessible for cleaning and electronics/wiring to be covered. • Costs were added under production. • Aesthetics and operating conditions were also added. • Scannable objects limited to opaque, stationary objects. • We decided that the source of the Gantt chart needed to be added. • Siew removed Latex from the list of required proficiencies. • Taha agreed to add a risk assessment since he had just covered that topic in his ECE lecture in the morning. • As a group, we need to add how we will all acquire the proficiencies in our lacking areas. • Design Testing and Testing Plans were merged into one section: Design Testing and Evaluation. **2. Project Registation Form** • Objectives were decided amongst the group. • "Design, make and test a 3D platform to scan a stationary object of mass up to 20kg, no larger than 50 x 50 x 30 cm (base x width x height)." • "Needs to be portable enough so that two people could carry the scanner." • "Implement a modular scanner to produce a 3D model." **3. Laser Types** • Taha spoke about using point lasers which rotated around the object to be scanned as the basis for our scanner. • Siew pointed out that the scanner would have to move slowly, thereby required some form of transmission plus the manufactured components would need to be at a high tolerance. • Instead, Siew proposed the idea of using a projector with a filter placed in front of the projected light to cast multiple shadows in the shape of lines over the object. A camera would be able to capture an image of the object with said shadows and software would be used to produce a model by analysing the depths of the shadows. --- • Meeting decided for Thursday 24th 1600 – 1700. • Targets for Thursday 24th: Jeremy to fill in Project Registration Form (due Friday 25th), Hussain + Jeremy to fill in Testing section of PQP, Taha to produce a risk assessment, Hussain to ask for a projector, everyone to research scanners for a decision on Friday and try to finish PQP for Friday.
Filled in by:	Hussain

Date & Time:	Thursday 24st Oct 2019, 1600
Agenda:	Project Registration Form, Clarifying unfilled PQP sections, Assign engineering roles, Determine agenda for supervisor's meeting, Progress update on individual components.
Members present:	CS, Taha, Siew, Jeremy, Hussain
Minutes:	• Siew mentioned that he had changed Taha's budget section so that it was in 3rd person and also suggested changing the table to a pie chart. • He had also added a contents page and filled in the PDS along with Jeremy. **Engineering roles** were decided: Project Manager = Jeremy CAD Manager = CS Report Manager = Siew Procurement Officer = Taha Manufacturing Lead = Taha Analysis Lead = Hussain **PQP:** • Information should be added in the introduction about why this group is the best choice for the client. • Reference needs to be added for Gantt chart. • Point cloud resolution changed to 3D scanning resolution. • Siew removed SWOT and instead, the job of adding potential threats to progress of the project was assigned to CS and Jeremy. • Decided to use British English instead of American English. • Design and Testing section still needs completing. • Siew in charge of the prototyping section and Taha to do the final evaluation of the product. • Hussain to add information about competitors. • All tables need to be labelled. **Agenda for supervisor meeting:** • Feedback on objectives for Registration Form. • Confirm service life of product. • Safety standards in labs. • Different scanning types.
Filled in by:	Hussain

Date & Time:	Friday 25th Oct 2019, 0900
Agenda:	Feedback on objectives, Ask about scanner types, Clarify aspects of Project Quality Plan (PQP).
Members present:	CS, Taha, Siew, Jeremy, Hussain, Dr. Salles
Minutes:	• Dr. Salles said that he spoke with Dr. Schwingshakl and decided together that an additional surplus of £1000 can be used to purchase a suitable scanner if necessary. • Dr. Salles checked the project objectives and said they were fine. • Service life for the project, i.e. the length of time the project can be used as a DMT for, was set at a maximum of 5 years. • To be able to use lasers, an induction is required which must be arranged by the group themselves. • Confirmation was given that scanner options other than lasers are allowed. • Resolution was set to be 100 microns ideally but realistic considerations can be made. • An example was given of the distance between the casing and turbine blade was 0.5mm. • Siew asked if there were any cameras or projectors to borrow from labs but Dr. Salles was uncertain.

	• The software used in the Dynamics labs is LabVIEW and the lasers are by a company called Polytec (Vibrometry). • Dr. Salles requested a PDF of the current version of the PQP. • An induction in the Dynamics lab will be arranged by the Department. • Jeremy asked if a laser system could be purchased that would handle most of the software/electronics so that the project would be focused on the mechanical aspect and Dr. Salles said that this was allowed. • Hussain then asked if the opposite was allowed so the project would focus on the software side while keeping the mechanical aspect simple. Dr. Salles said that he would be okay with that but is unsure of the criteria set by the Department ('Mechanical engineering'). • Group told that Gantt chart cannot be changed after the deadline (01/11/19). • Siew asked if components can be prepared prior to scanning, e.g. chalk etc., to remove reflective surfaces and Dr. Salles said that this was possible. • Dr. Salles requested a copy of the minutes to send to Dr. Schwingshackl. • Dr. Salles signed every group member's logbook. • Targets: for Monday 28th, Hussain, Siew and CS to research making our own scanner or scanning mechanism while Taha and Jeremy research commercial options. Also, fill in as much of the PQP as possible.
Filled in by:	Hussain

Date & Time:	Monday 28th Oct 2019, 1300
Agenda:	Review of updates needed for PQP, Decide criteria for market research of scanning devices, Updates on research, Gantt chart review.
Members present:	CS, Siew, Jeremy, Taha, Hussain.
Minutes:	**Updates on research:** • Hussain said that the method of filtering polarised light looks promising but there was a lack of information about errors and resolution in the paper so not sure if it is still worth pursuing. • CS said that scanners typically only provide point clouds (co-ordinates) so an external software must be used manually to produce a mesh and remove noise. **Gantt chart:** • Jeremy had updated the Gantt chart by taking Dr. Salles' advice and started at the end product, working backwards to the start. • Siew suggested splitting the testing and prototyping block and also suggested changing the block colour from black to a different colour. • Decided that final CAD model should be finished before the design review so that only small modifications are needed following the review (ideally). • Jeremy also said that he will add another block to represent the holidays and tidy the headings. • Taha also suggested 3D printing a prototype for the Design Review to show some functionality. **PQP:** • Siew said that he will update the prototyping section and also try to cut down others to reduce the number of pages. • Hussain to add references for competitors and information about lab safety standards. • Discussed resolution as required resolution is 0.1 mm, which seems unattainable. • Decided to leave resolution part of PDS as 'Less than X' until better estimates found from research. • Siew highlighted aspects of the PDS that required justification: Scan Space, 3D Model Resolution, Scan Time, Scanning Device Housing, Scanner Output, Calibration, Transportability, Environment, Ambient Conditions and Assembly. **Criteria for market research of scanning devices:** • Siew suggested making a list of the pros and cons of each option (commercial or DIY).

	• Commercial scanners: Pros: Possibly an extra £1000 Software provided so requires less modification Faster processing Can measure materials not normally scannable Streamlines development as work related to developing scanner is complete. Cons: Expensive (large percentage of budget) Possibly limiting project scope because of the fixed scanner design May simplify the project too much • DIY scanner: difficult to narrow down pros and cons as features of scanner depends on type of scanner used and difficulty of implementation which would drastically affect the quality of the scans. • Photogrammetry was decided not to be used as the resolution is generally too low. • Group unsure about allocation of the extra £1000 as Dr. Salles said that this was for a suitable scanner. • Siew said that he would make a document so the group can write about any research they have done. • Group decided that the main characteristics to research for are resolution, ease of implementation (affects accuracy) and ease of editing software so that autonomy can be integrated into the project design. --- Targets for Thursday 28th: • Jeremy to do the prototyping and design section of PQP, add blocks for holidays in Gantt chart, change block colour for prototyping and to add reference for Gantt chart. • CS to write the justifications for the PDS and email Dr. Salles about clarifying the requirements for receiving extra £1000. • Siew to make a document about research, add pie chart to PQP and reduce no. of pages. • Hussain to arrange a laser cutter induction and to write about lab safety in the PQP as well as add references for the competitors. • Siew, Hussain and CS to look at DIY scanners. • Jeremy and Taha to research compatibility of commercial scanners and maximum resolution within budget of £1000.
Filled in by:	Hussain

Date & Time:	Thursday 31st Oct, 1600
Agenda:	Finalise PQP, Decide scanner type.
Members present:	Taha, CS, Jeremy, Hussain, Siew.
Minutes:	**Scanners:** • Jeremy made a chart detailing the different scanner types against budget. • EinScan-SE has a resolution of 0.17 – 0.2 mm, costs $1200, stand-off distance of 29-50 cm, comes with meshing software, calibration required if object rotates, 8 scans required (4 sec. per scan) at different angles for a full scan. • 3D Scanner 2.0 costs approx. $300, resolution between 0.2 – 1.5 mm. • Taha suggested using the RP LIDAR A2M8 which costs approx. $300, min. distance of object from scanner is 15 cm, min. angular resolution is 0.45 *, dynamic scanning possible, distance resolution less than 0.5mm. • Also mentioned a retro-reflective laser scanner. • Taha read a paper on using a laser around an object for scanning. Resolution was 4.2 microns. • Jeremy did a table of the key characteristics for the Scoobe 3D, 3D Scanner 2.0, EinScan-SE, DIY Structured Light, DIY Polarising Light. • Using this table to rank the features from 1 (poor) to 10 (excellent) combined with a weighting for each feature, a score was found for each product.

	Targets for Friday 1st Nov: Reformatting of PQP to appear more pleasing, CS to type justifications for PDS.
Filled in by:	Hussain

Date & Time:	Friday 1st Nov, 0900
Agenda:	Review PQP, Discuss scanning device, Confirm scan tolerance in PDS, Plans moving forward.
Members present:	Dr. Schwingshackl, Dr. Salles, Hussain, Siew, Taha, CS, Jeremy.
Minutes:	**Supervisor Meeting:** • Dr. Salles looked at the PQP and said that the length of 50 cm should be a diameter. • Dr. Schwingshackl said that the project name should be interesting and to not start with a number. He also said that the Gantt chart should be bigger. The PQP seems a bit long but overall it does seem good. If there is anything uncertain (e.g. resolution) in our PQP, needs to be clear in our PQP as group will not be held to account for everything in PQP. • Dr. Salles said that conflict needs to be resolved amongst the group as he will not get involved. • Dr. Schwingshackl said that the group should keep an action tracker to see which tasks need to be finished. He also said to be aware of the risks like dropping the rig on toes, entrapment in rotating mechanisms, prevent pro-longed exposure to lasers, possibly wearing goggles or having a casing around the lasers so maybe a switch will be required. Write something about safety in the PDS too. • When asked about the resolution, Dr. Schwingshackl said that the resolution could be set as less than 0.5 mm for now but ideally 10 microns is wanted. The bottom of the object cannot be scanned in a single process so may need to be flipped over and the two models need to be integrated into one. He said not to focus on the scanner too much but to instead focus on the mechanism of the rotating object or rotating scanner. Even if the specs in the PDS cannot be reached, the process of developing the final product and justifications are still very important. • Dr. Schwingshackl said that even if the scanner resolution is said to be 0.1 mm, the mechanical design could reduce that. The 'working prototype' in Gantt chart before Design Review was questioned and group told to make sure that prototypes display functionality (rapid prototyping) rather than an almost finished product. • For the Design Review, group told to choose a strict assessor as criticism ensures that mistakes are caught early. • Dr. Schwingshackl said that at least one week before Easter, manufacture should be complete so that the project can be built and tested. The initial design therefore should be completed before mid. Feb. • Dr. Salles said that the software used must be open-source so that it can be modified and integrated into the project infrastructure. The HP DavidScanner seems to do the entire job for us so is not recommended. • Dr. Schwingshackl said that even if group buys a scanner, there is still a lot to do mechanically e.g. stress analysis, deflections, vibrations. Plus, there are different ideas such as a rotating turntable with a vertically moving scanner or a rotating scanner with a stationary object. • Dr. Salles said that the EinScan-SE cannot be used since the software is not open-source. • Dr. Schwingshackl said that at the point, options should not be limited so other things like laser displacement probes should be considered. • Taha mentioned that he found a 2D LIDAR scanner which could be used with a rotating turntable to develop a model. **Group Meeting:** • Jeremy re-formatted the Gantt chart to look more simplified. • Siew added info about safety in the PDS, changed some final details (resolution etc) and reformatted the PQP.

	• Hussain changed the 50 cm length to a diameter and continued to proof-read. • PQP was submitted. • Scanning devices were discussed: laser scanners were brought up by Taha and group considered the accuracy and feasibility of using lasers. • Considered possibility of laser moving vertically while object rotates. • Since calibration issues with optical scanners and accuracy losses with the laser scanners would be encountered, group decided to have object rotate with the scanner stationary rather than the opposite. • Siew suggested having a 'design week' next week to try and finish most of the modelling and drawings in the next week or so, allowing a prototype to be built soon. **Targets for Monday 4th Nov:** Research laser types and other forms of scanning.
Filled in by:	Hussain

Date & Time:	Monday 4th Nov, 1100
Agenda:	Decide on scanner type, start design process.
Members present:	CS, Siew, Hussain, Taha, Jeremy.
Minutes:	• Siew said that there were three viable options: 1) Structured light 2) Laser-optical triangulation 3) Laser distance sensor (time-of-flight, triangulation – no camera). • The time-of-flight method can have repeatability errors of up to 15 mm. • Taha looked at lasers that scan an object while moving vertically then the object rotates slightly so the process can be repeated. However, the rotation increments are too large. • Siew and Jeremy looked at the common elements of the three methods and between the laser-optical triangulation and structured light method, the common features were the turntable and the camera. • A ranking system was produced for the key features of the four scanning types: Price, size, resolution, future-proof, software and ease of implementation. • The task of brainstorming was given to each group member so that ideas could be presented on Tuesday 5th Nov. **Target for Tuesday 5th Nov:** Brainstorm and prepare to present ideas.
Filled in by:	Hussain

Date & Time:	Tuesday 5th Nov, [1]: 1100, [2]: 1300
Agenda:	Present ideas and make basic design decisions.
Members present:	[1]: CS, Hussain, Taha, Jeremy. [2]: Taha, Siew, Hussain, Jeremy.
Minutes:	**Meeting [1]:** • Jeremy presented his ideas: - Box-like rig. - Transmission options e.g. bevel or spur gears, pulleys or belts (good as less constraint on motor position), chains. - Turntable support (pillars) with bearings to smooth movement. - Metal frame with cut-outs for plastic (or another material) panels to be inserted. • Hussain presented his ideas: - Using a bright light to remove the effects of ambient lighting but unsure if bright lights will interfere with the scanner. - A liftable cover (like a car boot) or cover that opens like a microwave but this means two people would have difficulty placing the object inside the scanner. - A cylindrical scanner with a removable 'lid' but this 'lid' would need to be placed somewhere while the object is being set-up inside the scanner.

	- A liftable cover with cut-outs to ease the placing of an object inside the scanner by two people. - For portability, handles could be placed onto the side of the rig and/or wheels could be attached to the bottom. - To stabilise the turntable, arms could be attached to the turntable shaft which rotate with the shaft, reducing the friction due to rotation of the turntable relative to the arms. • CS said: - Using a box rig with a lid that is supported using an arch. - Different transmission options with the idea of using a belt and pulley to conceal the motor in a back compartment. • Taha spoke about the camera mount and said that it should be mounted at an angle to capture the top surface. • Jeremy and Hussain discussed the distance between the camera and projector needed so it was decided that that was something worth looking into. • Group also considered using bearings perpendicular to the axis of the turntable pillars but CS suggested using wheels instead. • Group made a morph chart with up to five options for eight different features: transmission, scanner mount and position, scanner-object relationship, material, scanner type, portability, ambient light control, turntable support. **Meeting [2]:** • Siew suggested: - Using planetary gears to step down the motor transmission. - Thrust bearings on pillars to support the turntable. - Optical encoder to measure and control the speed of main shaft (feedback to motor). • Jeremy asked Siew about the distance between the projector and scanner and Siew replied that the distance should not be too large/too small as it affects the quality of the 3D model. • Siew suggested making a camera mount that is adjustable in terms of angle and position. • Siew also mentioned that a clamp could be used on an object that is unbalanced but the group decided that while possible, it is probably not a problem for the Dynamics Lab. If necessary, a clamp can be added or the surface of the turntable can be made to have a high friction (rubber etc). **Target for Wednesday 6th Nov:** Decide transmission, need reference (or drawing) to show technicians at STW, check high torque motors from RS (£50 - £100).
Filled in by:	Hussain

Date & Time:	Wednesday 6th Nov, 1200
Agenda:	Decide transmission type and basic design.
Members present:	Siew, Hussain, Jeremy, Taha.
Minutes:	• Siew said that he had found some Lazy Susan (turntable) bearings but ran into some difficulty in finding some specs. • Siew also drew up an electronics version of the morph chart made yesterday. • Decided to speak to a design tutor (Marc Masen, Richard Van Arkel, Graham Gosling) to find answers to our questions: - How to manufacture the turntable (most likely laser cut). - How to support the turntable. - How to constrain the thrust bearings. - Where to find thrust bearings. - How to manufacture arms for planetary gears.

	• Taha had researched different motor types and this was said: - Servo motors have limited range of motion (e.g. -90 to 90). - Stepper motors are good but produce a jerking motion. - Higher torque-lower speed motors are more expensive. • There was trouble on deciding on a motor based on torque required as the speed/acceleration needed to rotate the object was difficult to calculate. • The rotation period was set as 15 seconds (4 RPM) but the friction and rotational inertia could not be quantified at this stage. • The max. price of the motor in the budget was estimated as £50 so motors were looked for up to this price which produced an output torque on the turntable of order of magnitude of 10 Nm at a speed of 4 RPM. • An excel sheet was made to see all the different motor options and two possibilities were identified: **Target for Thursday 7th Nov:** - Check feasibility of double spur gears (Jeremy). - Think of design of regular spur gears (Taha). - Siew to prepare for meeting with Graham (On Friday 8th Nov, 1600): 1. Turntable support. 2. Thrust bearings/Lazy Susan bearings. 3. How to attach main shaft to turntable. 4. Optical encoders. - Hussain to think of bearing housing options and securing intermediate shafts.
Filled in by:	Hussain

Date & Time:	Thursday 7th Nov, 1245
Agenda:	Design transmission and basic rig.
Members present:	CS, Hussain, Jeremy, Taha, Siew.
Minutes:	• Jeremy had suggested using four columns to support an intermediate plate and then cutting slots into the columns so that panels could be inserted to enclose the transmission. Siew instead suggested 3D printing a cover. • CS suggested manufacturing a C-bracket to support the intermediate plate as bolts could be placed through the flanges. Siew replied that it would be a lot of effort to manufacture so maybe an alternative solution could be purchased. • CS and Hussain said that columns instead could be bolted to the intermediate and base plate (countersunk for the base plate). • Hussain suggested using cylindrical rods instead of rectangular columns as there are no corners for injury and less material wastage (minimal). • Taha and Siew looked into supporting the shafts with bearings and came up with some designs. • Siew said that it might be better to have the motor orientated horizontally rather than vertically because the motor is very large so the space required would be reduced. This would mean that a motor mount would need to be designed and bevel gears used. • Jeremy had already finished gear calculations for the spur gears so he also calculated the stresses and ratios for bevel gears (1:1 ratio). **Targets for Friday 8th Nov:** Taha to design motor mount, CS to design intermediate plate and struts, Jeremy to design gears, Hussain to design bearing housing and Siew to design shafts.
Filled in by:	Hussain

Date & Time:	Friday 8th Nov, [1] : 0900, [2] : 1400, [3] : 1600
Agenda:	Run through morph chart, stress/vibration calculations.
Members present:	[1]: CS, Siew, Hussain, Jeremy, Taha, Dr. Christoph Schwingshackl, [2]: CS, Siew, Hussain, Jeremy, Taha, Dr. Richard Van Arkel, [3] : CS, Siew, Hussain, Jeremy, Taha, Mr. Graham Gosling
Minutes:	**Meeting [1]:**

- Dr. Schwingshackl asked how the PQP submission went and said that feedback should be thoroughly reviewed to prevent same mistakes in subsequent submissions.

Morph chart:

- Siew explained that laser distance sensors and laser triangulation were not chosen as a laser with the resolution needed was too expensive.
- The optical-laser scanner has resolution issues with different sized objects so structured light scanning (SLS) was chosen.
- Dr. Schwingshackl showed a small turbine blade as an example of the smallest object used for scanning (black, approx. 4 cm long). He also mentioned that preparing the specimen before scanning can be done if necessary but ideally would be avoided to reduce extra work.
- Siew explained how SLS worked and Dr. Schwingshackl told group about a Master's student last year who worked on triangulation for scanning (Tong Wei – used software called DICE) and emailed him.
- Dr. Schwingshackl said that a high-end webcam or GoPro could be bought for a prototype.
- If the college-approved suppliers are more expensive than a different supplier (e.g. Amazon), group could discuss in report that costs could be reduced by using cheaper suppliers. Alternatively, can speak to Peter Higgs about costs (in College on Tuesday and Friday).
- Continuing with the morph chart, Christoph said keeping the scanner stationary is good as it avoids calibration issues; not to use a cardboard casing as it is unprofessional; portability is not as important as other factors like rigidity or resolution.
- Siew and Dr. Schwingshackl clarified that the torque of the motor was more important than the angular speed.
- Dr. Schwingshackl said that the group appears too focused on the software elements (using meshing to overlap scans) and suggested using a Micro-Epsilon laser sensor (lower resolution but cheaper than scanner) but explain that resolution could be improved in the future by buying a better scanner. Also presented the idea of using a point laser and moving it in one-dimension or moving the turntable.

Calculations:

- Jeremy stated that all group members had completed the RAFT course.
- Taha had calculated the torque required to move the turntable as 9.5 Nm which Dr. Schwingshackl had said was too high. The motor used in the Dynamics Lab spins an engine at 3000 RPM from zero in 6 seconds using an 11 Nm motor (direct drive).
- Dr. Schwingshackl suggested using a direct drive with a torsional actuator to implement the stop/start of the turntable.
- He also said that if a laser system is used, the turntable needs to move at constant speed to reduce inertia effects but the angular position needs to be measured accurately.
- Siew spoke about using an optical encoder but Dr. Schwingshackl said not to rely on control from motor and instead, an external controller/measurement device should be fitted.
- Siew mentioned using pulses to sense the turntable position or speed but Dr. Schwingshackl said that the measurement sampling rate must be synchronised with the pulse frequency.
- Jeremy asked about calculations that the group may have missed. Dr. Schwingshackl said to think about vibrations, terminal analysis (resolution variations in different conditions e.g. winter/summer) and said to use basic models for analysis.
- To experimentally validate our calculations related to vibration, the final product can undergo a hammer test and vibrational analysis can be performed to make sure that there are no vibrations close to the resonance frequency.

By next meeting (Friday 15th Nov), group should have considered laser options and should present final scanning method with good justification.

Meeting [2]:

	• Siew told Dr. Van Arkel that the turntable shaft would have a flange and the turntable would have an extrusion so that the two could be attached using bolts. • Dr. Van Arkel said that there was no need for an extrusion on the turntable as the shaft could be bolted directly but Siew said he was concerned about the bolts sticking out of the top of the turntable. • Dr. Van Arkel said that an M8/M6 bolt with only three turns of thread should be sufficient so the bolt sticking out should not be an issue. • He also suggested using some pins on the turntable too as the pins would withstand the shear forces while the bolts would be in tension as the shaft and turntable are attached together. • A H7 and h6/g6 tolerance would give a tighter fit while an m6 would give a loose fit. • Dr. Van Arkel also suggested a belt drive around the turntable like a record player, removing the need for extensive support of the turntable and minimising space usage. • Siew asked about the turntable support (Lazy Susan bearings) and Dr. Van Arkel replied that bearings could be orientated vertically if necessary but if something could be bought, that is probably best. • He also showed a table that contained the compressive force of a bolt holding 2 plates together based on the tightening torque of the bolt. • Siew also asked about constraining the thrust bearings but Richard said that the rules taught in ME1 and ME2 were just guidelines to help students so that accuracy errors during manufacturing did not ruin the design. **Meeting [3]:** • Graham did not like the drawings that he was sent. • Siew asked about the turntable bearings but Graham said that he had never used them before. He said that the group should just purchase them and see if they work. • Siew showed Graham the specs of the turntable bearings but Graham said that he could not give much advice as the information provided in the specs was very limited. • Siew then asked about how to constrain the thrust bearings but Graham refused to give much information and instead said that the group had neglected using radial bearings on the shafts. • Graham then asked why the worm gears were not used as that would have provided a sufficient step down ratio while conserving space. Siew replied that he heard worm drives could not handle high torques but after hearing the torque value from Taha, Graham said that the worm drive should be sufficient. **Targets for next week:** - Make a list of all electronic components needed. - Consider using a worm drive. - Consider using a laser scanning system. - Make a CAD model of the current transmission. - Meetings with Mike Ristic, Tong Wei and Dr. Schwingshackl.
Filled in by:	Hussain

Date & Time:	Friday 22nd Nov, 0900
Agenda:	Preliminary stress calculations, motor selection, CAD model feedback, order list, PQP feedback.
Members present:	Dr. Schwingshackl, Dr. Salles, Hussain, Siew, Taha, Jeremy, CS.
Minutes:	**Turntable:** • Siew explained how he assumed a cantilever system from the edge of the turntable bearings and modelled the 20 kg object as a point mass at the edge of the turntable. • Dr. Schwingshackl and Dr. Salles both said that a distributed load should have been used but Siew said that this was because he was considering the worst case scenario. Dr. Salles replied that this would over design the system. • Siew also said that the final stress calculated was less than the yield stress of aluminium so the structure should be stable. **Motor:**

- Hussain explained how the torque was calculated from the final speed, acceleration time and total mass moment of inertia in three different scenarios. Overall, a stepper motor was chosen since fitting a DC motor caused issues with encoding and control but since a higher rotor inertia was desirable, the motor chosen ended up being a little expensive.
- Dr. Schwingshackl said that the gear backlash was given as one of the reasons why the DC motor was discarded but the stepper motor still uses gears. Hussain replied that the control for a stepper motor is less affected by the backlash from the gears than for a DC motor. He also mentioned that since the gear ratio is 1:1, the backlash should be reduced.
- Dr. Schwingshackl was concerned that the backlash is important regardless of the gear ratio however, Dr. Salles agreed with Hussain and said that a smaller gear ratio produces less effect. He also said that a stepper motor should be easier to control.

Bevel gears:

- Jeremy spoke about the load applied to the bevel gears and said that it came up to 400 N.
- Siew said that the group was worried about the thrust bearing not being able to withstand the radial load applied to the shaft. He looked at angular thrust bearings which turned out to be too expensive and not in the correct sizes; he suggested a new design utilising both a thrust and ball bearing.
- Dr. Schwingshackl and Dr. Salles advised to remove the thrust bearing and use a ball bearing as this should be able to take the radial and axial load. They also recommend using a second ball bearing further up the shaft to stop the turntable from toppling over.
- Jeremy and Siew went on to say that the turntable bearings are also supporting the turntable but Dr. Schwingshackl replied that the turntable bearings could be removed and replaced by a ball bearing. Siew expressed his concern with manufacturing and fixing the upper bearing housing but Dr. Schwingshackl did not share the same concern.
- After hearing the motor dimensions from CS, Dr. Schwingshackl and Dr. Salles recommend connecting the motor directly to the turntable to reduce the turntable height further and simplify the design. However, Siew responded by saying that the axial loading would fall onto the motor which could damage it. Dr. Schwingshackl then suggested using a belt drive and standing the motor vertically adjacent to the turntable shaft to conserve space and to produce smooth motion.

Electronics:

- Siew spoke about the electronics and the use of an Arduino Uno, driver and the initial circuitry.
- Dr. Schwingshackl said that this was beyond his area of expertise and recommended visiting Vim from the Mechatronics Lab to check over the designs.
- When buying electronics, if the suppliers are not college-approved, group should contact Peter Higgs to help but not to send too many messages as he is very busy.

Order list:

- Siew mentioned that it would be ideal to build a prototype as soon as possible (start next week) so confirmation on the order list is important.
- Dr. Schwingshackl said the designs should be revised and group can either present next meeting or email Dr. Salles along with the order request.
- Dr. Schwingshackl asked Siew whether the prototype is actually a prototype or the final design because he was concerned about the group having to repeat work in the workshop. He reiterated that a prototype should just be to test functionality but if the group says that the designs have been completed early, then building early could be a method of testing that the design actually works.
- Dr. Salles suggested using wood for the prototype but Siew said that this would not represent the loading accurately. Dr. Schwingshackl responded by saying that as long as the inertia is accurate, the prototype should run as intended.

	• Dr. Schwingshackl asked if the group would take advantage of Black Friday in buying a camera or projector but Hussain replied that these selections have not been finalised. Taha added that for prototyping, a projector and camera has already been acquired. Dr. Salles said that even a webcam would be sufficient for a prototype. **PQP Feedback:** • Dr. Salles said that he generally marks harshly early on in the project. He said that the PQP was good but there was a lack of information on the implementation of software. • Dr. Schwingshackl said that the feedback should be acted on for the next report otherwise he will not be happy.
Filled in by:	Hussain

Date & Time:	Wednesday 27th Nov, 0900
Agenda:	Present new transmission system, approve order list, updated Gantt Chart.
Members present:	Dr. Salles, CS, Siew, Hussain, Jeremy, Taha.
Minutes:	**CAD Model:** • Siew described the updates made to the CAD model such as: Siew described the updates made to the CAD model such as: - Motor positioned upside down to reduce height of turntable. - Pulley attached to motor shaft with a grub screw. - Two radial bearings to replace the turntable bearing and thrust bearing. - Tensioner for timing belt that can be re-positioned due to a slot cut into the intermediate plate and tightened with a nut. - Clearance of 4 mm between pulley and motor to prevent rubbing. • Siew showed his new stress calculations using the worst case scenario of a point load acting at the edge of the turntable and the final stress was found to be 22 MPa at the edge of the shaft flange. He also showed the graphs of the variation of stress with the radius of the turntable. • Dr. Salles asked about how the belt will be tensioned and said that the group may need to consider being able to re-position the motor. However, Siew replied that the tensioner would be used for that purpose. Jeremy added that the belt needs to be displaced by 6 mm from his calculations. • Dr. Salles was also concerned about the angular alignment of the turntable shaft and mentioned that two ball bearings may be unnecessary so one could be replaced with a roller bearing or even completely removed since the application is low speed. • Taha asked whether the grub screw would be sufficient for supporting the weight of the pulley and Dr. Salles replied that the load is small so the grub screw should be fine. If the group is still concerned, a non-metal pulley could be used instead. • Jeremy asked if the fact that the motor shaft does not go through the pulley fully is a problem but Dr. Salles replied that the loading is small so it should not be an issue. **Gantt Chart:** • Jeremy showed the new Gantt chart and said that the group is currently in the embodiment design/transmission prototype stage. • The scanning prototype has been moved to the first week of the second term. **Order list:** • Jeremy said that the new design costs £20 less than the previous version. • Taha gave Dr. Salles the order form for the ME stores.
Filled in by:	Hussain

Date & Time:	Monday 2nd Dec, 1300
Agenda:	Review manufacturing plan, review engineering drawings, schedule workshop sessions, split into hardware/software teams.
Members present:	CS, Hussain, Siew, Jeremy, Taha.

Minutes:	
Filled in by:	Hussain

Date & Time:	Friday 6th Dec, 0900
Agenda:	Update on manufacturing.
Members present:	Dr. Schwingshackl, Siew, Hussain, Taha, Jeremy, CS.
Minutes:	• Jeremy started by telling Dr. Schwingshackl that Dr. Salles approved the design presented last week so manufacturing has already begun but so far, only for one session on Tuesday evening. The rest of the manufacturing should be completed next week. • Jeremy showed the CAD model and Dr. Schwingshackl said that he liked that the motor had been moved away from underneath the turntable to reduce the height. • Hussain said that the turntable bearings and the thrust bearings had been replaced by two ball bearings. Dr. Schwingshackl asked how the upper bearing was constrained and Jeremy showed that the inner face was constrained with a spacer and shoulder while the outer face was floating. • Siew showed his stress calculations and said that the maximum stress was below the yield stress of aluminium. However, Dr. Schwingshackl replied that yielding may not be of concern but deflection of the turntable needs to be considered. • Hussain said that testing of the entire transmission system was planned for the following week but the pulleys will not arrive until the end of next week so cannot be bored out. He asked whether the Student Teaching Workshop (STW) was open during the winter break but Dr. Schwingshackl replied that the technicians need to be asked directly. He added that a rubber band or a make-shift pulley could be used to test the transmission instead. • Dr. Schwingshackl said not to use brown for the components in the CAD model as it appears like the component is made from wood. • Dr. Schwingshackl asked about the belt used for the pulleys and Siew said that a timing belt is used. Dr. Schwingshackl then asked about the tensioning of the pulley and Jeremy replied that the belt must be displaced by 6 mm according to the HPC schematic, assuming maximum loading. Dr. Schwingshackl was concerned about the belt being too tight so that attaching to the pulleys becomes very difficult, prompting the suggestion of using slots in the design to adjust the motor position during assembly. • Dr. Schwingshackl told the group to consider the Design Review and who the External Assessor will be. Ideally, a brief outline of the project and design will be provided to each member present during the review prior to the meeting.
Filled in by:	Hussain

Date & Time:	Friday 13th Dec, 0900
Agenda:	Update supervisors on manufacturing progress, discuss selection of external advisors for Design Review and set targets for following semester.
Members present:	Dr. Schwingshackl, Dr. Salles, CS, Hussain, Taha, Jeremy, Siew.
Minutes:	**Progress:** • Taha brought the prototype to the meeting. • Siew said that most of the manufacturing has been completed but the holes for the turntable still need to be done and the pulley also needs a dowel pin hole. • A mistake was made to the M5 hole in the main shaft so
Filled in by:	Hussain

Date & Time:	Friday 10th Jan, 1100
Agenda:	Update all members on current progress, allocate tasks in preparation for the Design Review.

Members present:	Hussain, Siew, Taha, Jeremy.
Minutes:	• Jeremy started off by saying tasks need to be allocated to each group member. There are three main components that need to be decided at the moment: clamp, frame and mounting for camera and projector. **Projector and camera mount:** • Siew and Jeremy worked on a design consisting of an acrylic platform resting on three metal rods. Slot mechanisms were incorporated to allow change in lateral and angular position. • Hussain asked how the supporting rods are attached with the slot and Jeremy replied that a screw is used to tighten the supporting rods to intermediate rod. Hussain suggested making an internally threaded hole into the side of the supporting rods and inserting a long screw part of the way with a nut on the screw for tightening purposes but this was decided to be a tacky solution. • Siew suggested using a lathe to cut the rectangular rod into a cylindrical shape and threading externally so that a nut can be attached but Jeremy said that turning a rectangular object on a lathe is too difficult. Siew's next suggestion was to use CNC instead but the waiting time could be an issue. **Frame:** • Jeremy worked on the design for the frame based off his previous design that included slots for insertable sheets to block out light. • Jeremy said that some light must be allowed since Siew had discovered that an absence of light interferes with the calibration process of the scanner since the checked boxes cannot be seen in complete darkness. As a result, Jeremy thought of using a transparent acrylic lid to provide some lighting. • Siew mentioned that the supervisors at the Design Review may have an issue with the slot in the upper rods not extending along the entire length of the rod, causing small leakage of light into the box from the horizontal direction. This prompted him to suggest cutting the rods in half so that there will be no gaps when the sheets are inserted. • Jeremy wanted to weld the rods
Filled in by:	Hussain

Date & Time:	Tuesday 14th Jan, 0900
Agenda:	Update supervisor on CAD progress, scanning, testing, automation and clarify things for Design Review.
Members present:	Dr. Schwingshackl, Hussain, CS, Taha, Siew, Jeremy.
Minutes:	**Camera and projector mount:** • Jeremy said that the mount is going to be manufactured using CNC. • Dr. Schwingshackl asked if the mount was for the projector or the camera and Jeremy replied that it was for both, with identical designs for both too. • Dr. Schwingshackl expressed concern that the cantilever system seems dangerous because moments are exerted in 2 orthogonal directions. He suggested putting the platform over the centre of the rods to take away one of the moments. • Jeremy mentioned that the motor causes some vibration which would affect the position of the projector and camera so Dr. Schwingshackl said that the settling time will need to be checked as it could be sufficiently short such that the scan is unaffected. • Dr. Schwingshackl asked if there were two cameras on each side and Jeremy said that there is a projector and camera, separated by a distance of approximately 50 cm. Dr. Schwingshackl also said that he was unsure of how important this distance is and that the group needs to decide.

- Jeremy said that he calculated the projector/camera can change lateral position via the slot mechanism by 7 cm but the slot can be extended on CAD to allow even closer positioning to the scanned object.
- Dr. Schwingshackl asked what the stand-off distance was and Siew replied that it was 0.5m. He also asked if two different positions between the camera and projector was okay and Taha replied that this should not affect the scan.
- Jeremy said that the camera can be orientated differently to the direction of the mount and clamped. Siew added that the initial idea was to use mounting holes specific to the projector but this was discarded as it did not agree with one of the fundamental objectives that the design should be modular.
- Dr. Schwingshackl was concerned that this would mean that moving the projector/camera closer or further away from the object would require an additional rotation to keep it facing the centre of the turntable. Consequently, he suggested that the mounting brackets actually face the centre of the turntable rather than be perpendicular to the frame so that lateral change in position is easier.
- Dr. Schwingshackl asked why the maximum lateral position change was only 7cm and said that if re-calibration is required after a change in position, then the change should be much larger to make the extra effort worthwhile. Taha said that positional change depends on the size of the object but Dr. Schwingshackl reiterated that moving the components closer needs to have a good impact like covering more area during scanning or better resolution. Another concern was that making the arms longer would create more bending so a possibility is to use two arms instead of a cantilever.

Clamps:

- Dr. Schwingshackl asked what the clamps were for and Siew replied that the purpose was to 'sandwich' an object between the 2 clamps for secure placement onto the turntable.
- Dr. Schwingshackl asked what commercial solutions do and Siew said that some use robotic arms that move around the object so clamping is unnecessary while others use no clamping at all.
- An issue Dr. Schwingshackl had was that the clamp would cover parts of the object so parts of the model would be lost so an effective but small clamp is difficult to design.
- One suggestion provided was to use a pattern of tapped holes, e.g. multiple rings of M6 holes, so that the user can decide how to clamp the object.
- Another option would be to just use the casing on the turntable, holding the object in place as long as slip is not an issue. Dr. Schwingshackl asked what the material of the turntable was at this point and Jeremy replied aluminium.
- Siew continued and showed the different ways to use the clamps, depending on the shape of the object. Dr. Schwingshackl said, again, that the clamps cover the bottom of the object which is sometimes the most important part eg. the root of a turbine blade.
- Dr. Schwingshackl said that a clamp may not be necessary if the acceleration and therefore slip is small but for demonstration purposes, a clamp can be built if useful.

Frame:

- Hussain described the frame design which consisted of 12 metal rods to form a box shape with insertable acrylic sheets to block out light and transparent acrylic lid.
- Dr. Schwingshackl said that a height of 50 cm may not be high enough given that the object could have a width of 50 cm and then be turned on its side. The angle of for the projectors may also be too shallow if the height is too low.
- Hussain said that the rods can be bought from the Mechanical Engineering (ME) stores and slots can be cut in the STW. Dr. Scwhingshackl said that if there is enough money in the budget, group could just purchase aluminium profiles as they have slots and holes already prepared.
- Hussain continued to say that Solidworks gave an estimate of 2.5kg as the mass of the turntable system so a bending moment calculation was performed and it was found that aluminium, mild steel and acrylic are strong enough to support the weight of the system but the metals, especially mild steel, are heavy. This led to the choice of acrylic for the base plate as it was the lightest.

- The base plate could potentially have a latching mechanism to attach/detach the base plate from the frame to reduce the vibration effects, if any, from the motor. Dr. Schwingshackl was worried that placing the frame over the base plate after calibration has been completed could interfere with the calibration by moving one of the components and require a repeat of the calibration procedure. Siew assured Dr. Schwingshackl that the calibration would be unaffected as long as the relative positions between the components are the same.
- Dr. Schwingshackl advised the group to check for vibration of the motor and add damping mechanisms to isolate the source if necessary. He added that the components should be fixed to the base plate and he liked the idea of a removable frame but care will need to be taken to prevent hitting one of the components during set up. The acrylic will also need to be checked for cycle fatigue from the vibration of the motor.
- Dr. Schwingshackl said that the frame should be made to be as light as possible but still strong enough. Jeremy said that the frame should be able to withstand the forces during transportation with the use of handles on the side.
- The base plate should also resist bending as the lab surfaces may be uneven or have objects like bolts present so the frame/base should not collapse if conditions are not ideal.
- Dr. Schwingshackl did not like the idea of having the camera and projector attached to the frame and said a separate frame could be made around the camera and projector to keep the main frame lightweight.
- An important thing to remember was that if the cover is removable, the transmission should not be exposed and the motor may not take a finger off but can still cause damage. In this case, maybe a cover could be 3D printed.

Scanning progress:

- Siew explained that in his experiment, he used a projector with a 0.6 m throw distance, which he borrowed from a friend, and a camera phone to scan a toy car.
- He added that preparation of the sample is common, such as dusting or using baby powder so Dr. Schwingshackl said that the group should produce a short operating guide for the scanner so other users can understand how to use the scanner without having to read all the reports.
- The calibration procedure was completed using a checker box pattern and a scan was taken of the toy car. The object was only a small section of the overall scan due to the large screen size of the projector, emphasising, again, the importance of the projector distance from the object.
- Siew was unable to form a mesh for the scan as only one side of the car was scanned so the point cloud was open. There was a grid-like pattern present on the surface of the model due to the projector resolution being too low at that particular distance from the object. This highlights the importance of choosing the correct projector.
- Open-source code was used and proved useful but further improvements are necessary. Dr. Schwingshackl approved of this approach and said that it was unnecessary to reinvent the wheel and other work should be utilised to save effort.
- Siew spoke about trying to automate the entire process but said that it is proving to be quite difficult. Dr. Schwingshackl responded saying that lots of different software should not be needed, ideally, but otherwise a laptop with all the relevant software installed can be used to accompany the set-up permanently.

Prototype Testing - Electrical:

- Jeremy showed a video of the operating turntable. The issue with vibration was apparent and could be heard clearly throughout the demonstration. The turntable rotated one-quarter of a revolution per increment.
- Dr. Schwingshackl said that the source of the vibration/noise should be found. The vibration was probably due to the bolted down motor so a rubber washer could be used for damping.

	• Jeremy and CS said that the belt vibrated significantly so they thought that the source must be there but Dr. Schwingshackl said that vibration of the belt would not produce any noise. • CS stated that manual rotation of the turntable produced no noise. • Dr. Schwingshackl said that the pulley should be taken off and the motor should then be tested for noise. If noise is still present, the motor should be removed and tested in isolation and this process should be followed until the source is found. • Jeremy showed another video where a heavy tray of nuts and bolts was placed and rotated on the turntable and in this case, less noise was present. He also tried placing objects underneath the turntable to attempt to damp the vibrations. • Dr. Schwingshackl pointed out that the turntable overshot at times but since the scanner merges the scans from different angles, the accuracy of these increments is of low importance. • He recommended that the acceleration of the turntable be found and tested for slip. If slip occurs, it should be prevented using things like sticky tac or rubber. • CS said that he could not get the correct rotational increments, possibly due to slip, and this is made clear as the same position is not reached after one revolution. • Dr. Schwingshackl said that the group needs to decide if this is important as scanning may still be possible but group might need to be more accurate with the angles. • Siew mentioned that a table was considered to show the rotational increments for different masses. Dr. Schwingshackl reminded the group that the motor does not show the steps taken during rotation so alternatively, a label could be used to identify certain angles, e.g. 60°, to analyse rotation. An encoder may be needed but the design should become overcomplicated. **Prototype Testing – Mechanical:** • Taha asked for suggestions in testing the turntable. Dr. Schwingshackl said that a camera phone could be used with DIC and masses should be placed on the edge of the turntable to measure deflection with a ruler. The results could then be scaled up. • An even simpler method could be to use a dial gauge and measure the deflection but the group should speak to Luke in the Dynamics Lab for more information. • Dr. Schwingshackl said that the buckling test is unnecessary and that a group member could probably stand on the shaft before buckling occurs. • To test the vibration, an accelerometer would be used but, again, speak to Luke. • Siew asked if there was a standard format for the testing plan and Dr. Schwingshackl said that there was no standard format but be clear and organised. • Jeremy asked if all the calculations need to be experimentally validated and Dr. Schwingshackl said that for large safety factors, the experiment would probably be unnecessary but for small safety factors, validation is required as there could be a mistake in the calculation. • Dr. Schwingshackl reminded the group that testing should have a good reason and this is the difference between a good and a bad report. **Design Review:** • Siew asked if there was anything specific to focus on. Dr. Schwingshackl said that the group should ask Dr. Cinosi what he would like to see during the review. • Some assessors care about the engineering drawings and like to check that all the tolerances are correct while others prefer to understand the reasons for the overall design. • Dr. Schwingshackl said that he, personally, prefers to hear the story of why each decision was made and the general process. • The review should be split 35 minutes for the presentation and 25 minutes for discussion.
Filled in by:	Hussain

Date & Time:	Tue 21st Jan, 0900

Agenda:	Prototype electrical and mechanical testing results, turntable loading issue, complete CAD assembly, procurement, turntable control, power supply step down, blackboard file submission.
Members present:	Dr. Schwingshackl, Hussain, Siew, Taha, Cs, Jeremy.
Minutes:	**Mechanical testing results:** • Siew explained how the turntable was tested for deflection by placing objects of increasing mass at the edge of the turntable. • The deflection was calculated analytically and with finite element analysis (FEA). • Deflection values were shown to be off by a factor of ten compared to the analytical solutions but of the same order of magnitude as the FEA values. • In conclusion, the experimental values were different, most likely due to the leeway in tolerances in the manufactured components, allowing the turntable to tilt, while the FEA values were smaller due to the inherent assumptions. • Dr. Schwingshackl asked if the 20 kg load producing a 5 mm deflection was within expectations and Siew replied that it was still within the elastic region but a fatigue analysis was required. Dr. Schwingshackl said that was not needed because the object should, hopefully, not be placed off-centre. He did point out, however, that the object may be angled and asked if this would affect the scanning. Siew responded by saying reconstruction of the model should not be an issue but two scans would still be needed to produce a mesh so the software would deal with this, not the mechanical side. • In response, Dr. Schwingshackl suggested that a user guide be made to make clear the correct position of the object on the turntable. • Dr. Schwingshackl pointed out that the tests were carried out using different masses but at the same position so the tests should also be carried out at different positions to identify any eccentric behaviour. • Dr. Schwingshackl asked whether the tilting of the turntable was caused by the bearings. Consequently, the group should use a dial gauge to check if the plate is bending or tilting by moving the dial gauge backwards and forwards from the centre of the turntable. • Siew asked whether Dr. Schwingshackl meant placing the dial gauge at the end and Cs replied that the dial gauge needs to be moved to see if the deflection/tilting was uniform. • Dr. Schwingshackl said that the testing should be carried out and then the group should decide whether this is important or not. • Another suggestion was to add a mesh of beams to support and stiffen the plate. The group should check if there is space because this is something to think about as a 5 mm deflection is a lot so justifications are needed. An example would be that the deflections are large but unimportant. A potential issue is that the motor could seize up or there could be other issues. Cs agreed at this point and confirmed that the motor had seized up during testing. **Electrical testing results:** • Siew explained that the turntable was loaded at the centre and the motor produced a certain step length to rotate the turntable with the aim of measuring whether the rotation angle changes for different masses. • Dr. Schwingshackl asked how the angle was measured and Cs replied that a software called Tracker was used. • Dr. Schwingshackl's next question was whether the turntable moved more or less as the object got heavier and Siew said that the rotation angle stayed, more or less, independent. • Dr. Schwingshackl pointed out that the range of rotation for the turntable was 85 and 95 ° which is about a 10 % error and this could be large. He asked what error in angle was in the product design specification (PDS) was and Cs replied 2 to 3 %. Dr. Schwingshackl asked if this was important or not and said that the group could argue that the scanning device chosen does not require a high accuracy for the rotation so

	this is not important but the group does need to justify it. He identified that there were three repeats but questioned how repeatable the values were. • Cs continued to say that he did not have time to calculate the overshoot of the turntable on MATLAB. • Why the values of the angle in the table were consistent with each other but the graph shows less consistency was asked by Dr. Schwingshackl and Cs pointed out that the table shows the average values. Dr. Schwingshackl said that there must be significant variation between the values then but standard deviation should not be calculated since there are only three repeats. • Siew showed the results for the turntable rotation with the object placed off-centre and said that the angles were, again, consistent with each other. • Dr. Schwingshackl asked about the slip and Cs said that the transmission slipped at approximately 11 kg so 20 kg was not tested. It is likely that the motor is not powerful enough. • Dr. Schwingshackl said that a likely cause could be that the bearings are being loaded off-centre so the group should try placing a 10 kg mass opposite to the original mass to test if the bearings are tilting. However, if this does not solve anything, other options would be to make the shaft longer or buy a new motor. • The turntable moves slowly so inertia is not an issue. Another alternative would be to buy self-aligning bearings which should help with the tilting but may cause more deflection. • Overall, the group should come up with an engineering solution rather than a tacky solution. • Cs suggested a change in the pulley to change the torque ratio so that the turntable does not struggle to turn. • Dr. Schwingshackl asked what the maximum speed of the motor was. Hussain said that he did not know; Dr. Schwingshackl said that this needs to be checked and the correct speed range should be used to make full use of the motor. • He also asked what the current torque ratio was and Jeremy said that it was 1 to 1. Dr. Schwingshackl then asked what the largest available torque ratio is, given the constraints of the system, and Jeremy replied 5 to 1. • Currently, Dr. Schwingshackl agreed that choosing a new pulley was the best solution so the pulley should be ordered as soon as possible. Since the pulleys are not too expensive, it would be worth having a back-up motor too but check if this will exceed the budget. • Since the largest mass tested off-centre is 10 kg and not 20 kg, it might be worth specifying that a counter weight is needed above a certain mass. This would interfere with the scan though so an engineering solution is preferred. • Dr. Schwingshackl said that the group should be prepared to explain why this motor was chosen and which assumptions may have been incorrect. Cs said that the motor had a rated current of 2.8 A but the driver provides a current of 2 A and this could be the issue. Dr. Schwingshackl said that the group could say that the torque needed was calculated but the tilting causes more friction than expected, explaining the increase in torque needed. **CAD assembly:** • Siew showed the CAD assembly and spoke about the 3D printed cover over the transmission which can be assembled from three separate sections. • Siew spoke about the reflective object sensor for positional control of the turntable but Dr. Schwingshackl said that the results clearly show that this is not necessary and would overcomplicate the electronics. It may be useful to keep this as a back-up for the Design Review as the angles still vary by about 10 %. **Turntable control:** • Dr. Schwingshackl asked about the electronics of this sensor and Siew said that it needs an input card which was mutually agreed to overcomplicate things.

- Dr. Schwingshackl asked how the motor was controlled and Cs said that an Arduino was used. Siew added that the computer reads all the information but could be modified to act as a button to stop and start the process easily.
- Next, Dr. Schwingshackl asked how the turntable is stopped for each rotational increment and Siew replied that the computer should know the settling time but this has not been programmed yet.
- Then, Dr. Schwingshackl asked if a step input is used for the motor, which the group confirmed, and he suggested to use a ramp input instead to speed up and down but this would make the belt slack slightly so the group would need to play around with the speed.
- Dr. Schwingshackl said to stick with passive control but keep these set in place for more accuracy if necessary.
- Cs wanted to clarify if the motor needs to communicate back with the computer and Dr. Schwingshackl replied that it will not be necessary as long as the other procedures are set up to ensure accuracy.
- Dr. Schwingshackl asked who will be attending the Design Review and Jeremy said that Dr. Salles, Luke and Dr. Cinosi will be attending. Dr. Schwingshackl asked about Dr. Cinosi's areas of specialty and Siew said that he focuses on computing. Dr. Schwingshackl said that the Design Review should focus on the mechanical aspects and have a small section on the software.

CAD assembly:

- Siew continued that a frame has been designed as a box surrounding all of the components with an added feature of carrying all components during transportation. A tripod has replaced the mount for convenience and ease of adjusting position.
- Dr. Schwingshackl said that a box idea is nice but is mainly empty space and the Dynamics Lab is a tight space. He suggested finding a clever way of folding the box or other alternatives, such as attaching the tripod to the box itself or fixing the turntable to the frame. Maybe even fold into something suitcase-like.
- He also liked the use of the aluminium profiles.
- He mentioned making something like a tent or a pop-up box to cover the components.
- Dr. Schwingshackl asked what the mass of the frame was and Hussain said 5 kg, Siew said that the turntable was about 3 kg and the projector and camera was 1 kg so the total was around 10 kg, which should be easily transported. He reminded the group that the system needs to be portable.
- Dr. Schwingshackl reminded the group that the electronics are sensitive so during transportation, there needs to some method of securing the components to prevent damage.
- For the Design Review, the group should say that they have thought about these things but have not had enough time to implement them. Some reviewers care about why the design has been chosen to be that way while others want to look at all the engineering drawings. The group should ask Dr. Cinosi whether he wants to see an overview of the design or prefers to see the design in detail. The group should leave about 30 – 35 minutes during the Review to explain the design decisions with the remaining time for discussion.

Procurement:

- Taha said that the camera and projector are available on Amazon Prime and are eligible for next-day delivery. For this, a one-time credit card would be required. Dr. Schwingshackl said that the group should just contact Peter Higgs as he can easily purchase the items on the group's behalf.
- Dr. Scwingshackl said that the Logitech webcam can be found on BT's website – dabs.com.
- Siew said that the projector has a 0.5 m throw distance, which is why the frame is so long. Dr. Schwingshackl was concerned that the frame could know the components as it is being set in place but Siew assured him that the calibration will be unaffected as the calibration relies on the position of the camera and projector relative to each other.

	• Dr. Schwingshackl said that
Filled in by:	Hussain

Date & Time:	Fri 24th Jan, 1500
Agenda:	Design Review – Task overview, design choices, design refinement, purchasing and manufacturing, test plan, project management, review of drawings.
Members present:	Dr. Salles, Dr. Cinosi, Luke, Hussain, Siew, Taha, Cs, Jeremy.
Minutes:	**Project overview:** • Jeremy introduced the client as being the Imperial College London Dynamics Lab and the task is to design a 3D scanner that can scan engine components of the size 50 x 50 x 30 cm height. • Current solutions on the market are usually limited in terms of maximum scannable object size and often involve the use of proprietary software. For appropriate accuracies, the scanners are also too expensive. • Supervisors said that an additional £1000 can be provided to buy a scanner if it improves the accuracy of the scan but the software must be open source. • Market research carried out to identify a gap in the market for an inexpensive but accurate 3D scanner. • EORA 3D scanner is an example of an existing product that has good accuracy and is relatively cheap but, unfortunately, cannot measure heavy objects, relies on a smart phone and uses proprietary software. • Matter and Form is another relatively cheap product with good accuracy but can only scan small objects and, again, involves using proprietary software. • EinScan-SE 3D Scanner is a high-end scanner on the market with very high accuracy but its biggest drawback is the proprietary software. • The GOM Atos Scanbox 5 has very high accuracy but exceeds the budget of this project, costing over £100,000, and requires the use of proprietary software. • Dr. Cinosi asked why the scanners were so expensive since it is just a camera and projector/laser and Dr. Salles replied that the software they use is very good which is why it is so expensive. • The Peel3D Scanner is a handheld scanner with very good accuracy but requires the use of proprietary software and also exceeds the budget. • The main aspects of the PDS are that the software must be open-source and available for modification, must be modular so that components can be replaced and the position of the scanning device can be adjusted in relation to the platform. **Design choices:** • Hussain explained that the group listed the features of buying a commercial scanner or trying to make one. • The commercial scanner means a better user experience since the product comes with an all included software package, which also means that the group focuses more on the mechanical side. However, scanners with a resolution greater than 0.5 mm and are appropriate for this application cost more than £1000. Another issue is that the scanner comes as a full package so future improvements cannot be made, conflicting with the objective that the design should be modular. • DIY scanners allow the complete freedom in choosing components so that products with the optimal features can be bought or designed. The design is also modular but much more effort is required on the software side. • There were three main methods of 3D scanning: 1. 1D laser uses pulses of laser beams to measure the distance to an object but the accuracy can vary up to 5 mm. Since the laser only measures the distance to a point, the object must be rotated and the laser itself must be moved vertically. 2. 1D/2D laser triangulation has much better accuracy but is more expensive than the budget allows. 1D laser triangulation would still require the simultaneous movement of the laser and object.

3. Structured light scanning projects lines onto the surface of the object and the shape of the lines is analysed to model the object. The choice of the projector and camera is down to the group's decisions and can be chosen to acquire the best features for this application.

- The three options were evaluated:

1. 1D distance sensor has low accuracy and the time taken to scan the object would be over ten hours due to the slow vertical movement of the laser.
2. Optical triangulation has very good accuracy but exceeds the budget by a large margin.
3. Structured light scanning allows greater freedom in choosing components with the correct features for this set-up and allows for a simple mechanical design. The main drawback is that the software side must be implemented by the group.

- After consideration, decision was made to go with structured light scanning. The next requirements for this method to work were to design a mount for the camera and projector, automatic repositioning of the object to achieve a 360° view of the model and to control the lighting conditions.
- The overall structure was initially designed to be a metal box but this would have been too heavy so instead, a frame was designed using metal rods that could have insertable panels to block out light.
- The torque required to overcome inertia along with the torque to overcome friction in the worst-case scenario where the object is placed at the edge of the turntable.
- A DC motor was considered which had sufficient torque capabilities but significant control was required to rotate the object in steps correctly plus it was extremely difficult to position a rotary encoder to measure the rotation of the turntable.
- The obvious choice was to buy a stepper motor. The motor chosen had sufficient torque to overcome the calculated values and had a low ratio of load inertia to rotor inertia.

Design refinement:

- Hussain started by describing the initial design of the transmission. A thrust bearing and a Lazy Susan bearing was used to support the main shaft and turntable, respectively, and bevel gears were used. This raised the height of the turntable. The thrust bearings are not ideal for radial loads such as those from the gear backlash. The main shaft also required a second bearing to constrain it correctly.
- The second iteration of the design used a belt and pulley transmission. This reduced the height of the turntable and minimised backlash since the pulleys were in a 1:1 ratio. The Lazy Susan bearing was removed and the thrust bearings were replaced with ball bearings.
- A motor driver was used to control the stepper motor and the Arduino was used to control the electronics.
- Siew explained the scanning prototype and the main aims he had: trying to understand the structured lighting method and the necessary changes required for the mechanical design as well as check if the available code actually works.
- The camera and projector were calibrated using the method described by Moreno and Taubin (2012); this involved projecting patterns of stripes onto a checker-box pattern at different orientations.
- Following calibration, the object was placed before the projector and scanned from one angle.
- The point cloud and subsequently the model was obtained but since only one angle was used, a closed mesh of the object could not be shown.
- Siew realised that the object to be scanned should take up a large proportion of the screen and the projector needs to have a high resolution. The exposure and focal settings should remain fixed throughout the whole process.
- He also pointed out that the focal length should be as low as possible to save space in the overall design and the ambient lighting must be controlled.
- Cs spoke about the mechanical testing of the turntable by placing a mass at the edge and using a dial gauge to measure the deflection. After removal of the load, the reading returned to zero, showing that there was no plastic deformation.

	• The highest deflection was 5 mm but this should not be an issue as the turntable is not deformed permanently and it is unlikely that an object would be placed off-centre. • This deflection value differed from the 1.23 mm obtained from FEA probably due to leeway in the tolerances and also tilting of the turntable. • Next, Cs went on to speak about the electrical testing. The angle of rotation and time was measured for different loads using the Tracker software. The results show that the average angle varied from 87 to 95°. This is not an issue as the rotation angle is not important for structured light scanning. • Dr. Cinosi asked where the camera and projector would be positioned since the previous models shown had not shown them and Jeremy pointed to the physical prototype and showed where they would be. • Dr. Cinosi asked why the group was interested in the speed of rotation since the scanner would only scan the object after it became stationary. Cs said that the speed was not measured but, rather, the angle was. Dr. Cinosi then wanted to know why the time was important since the time should be irrelevant. Dr. Salles told him that the group had been given a time constrain in regards to scanning time. Luke also said that the test was performed to see how repeatable achieving the final angle was. He added that 11 seconds was too long for rotation if there are going to be 50 to 100 scans plus most of the process does not even involve actually scanning the object. • Cs continued to speak about off-centre loading of the turntable and the issue that the turntable did not have enough torque to turn. Cs said that the group speculates that the tilting of the turntable increases the friction in the bearings, causing slip. • Dr. Salles suggested using a counterweight to test whether the issue is resolved and Siew said that this was included in the future testing plan. • Dr. Cinosi asked why the group decided to move the object instead of the camera, since keeping the object stationary would remove the need to worry about eccentric loading and torque etc. Hussain replied that the moving the camera would require re-calibration and this is a long process. • Cs spoke about the third version of the design where a box was to surround the components and reduce ambient light and a tripod was to hold the camera and projector. The downsides of the box were that the box was mainly empty space and was, therefore, unnecessarily heavy. • Dr. Cinosi asked why there was no lid on the frame in the frame assembly engineering drawing. Jeremy replied that the drawing shows the latest version which does not have a lid. • Cs said that the turntable had slots to allow clamping and that the camera/projector was separated from the turntable set-up to isolate vibrations from the motor. • Luke said that the motor will not be running when the scan is taken so does the vibration matter? Siew said that the vibrations were isolated from the camera/projector. • Instead of using slots, Luke suggested using a rubber sheet to improve grip on the turntable but also said that this may not be necessary as the turntable moves slowly. Cs said that Dr. Schwingshackl wanted to scan small objects too which meant clamping may be needed. Luke opposed the slots because he said that this would weaken turntable so he suggested coming up with another clamping design. • Cs described the latest design which has a reduced base plate area. • Dr. Cinosi said that the deflection of the turntable would ruin the calibration but Siew explained that calibration was dependent on the positioning of the camera relative to the projector so that as long as the positioning remains the same, calibration is retained. Dr. Cinosi asked why the group was even worried about the deflection and Siew replied that the tests were carried out to check the structural integrity. • Cs spoke about the 3D printed cover that consists of three pieces: two sides to surround the intermediate and motor plate and a middle piece to cover the belt. There are holes to attach all three sections together. • The pulleys have been changed from 24 teeth (1:1) to 60 and 20 teeth (3:1).

- Next, Cs said that the frame had been modified to include hinges which allow the legs to fold, increasing the portability of the design. Removing the acrylic sheets reduces the overall weight and a cloth will be used to reduce ambient lighting instead.
- Luke liked this idea as he said that a large box would not be used in the lab as it is too inconvenient.

Purchasing and manufacturing:

- Taha listed the different components available from suppliers and said that most components were cheaper on Amazon.
- He continued onto the manufacturing plan and said that the group has had experience manufacturing in the Autumn semester so should be able to manufacture at a good enough level now.
- The actions required for each component were shown in a table along with expected durations and deadlines.
- Luke pointed out that there was no mention of the 3D printing on the manufacturing plan and Siew replied that this was not essential and can be done closer to exhibition date. Luke disagreed and said that it should still be included in the manufacturing plan.
- Afterwards, Taha spoke about possible risks to the manufacturing of components and the contingency plans in place.
- Dr. Salles asked about the increase in torque ratio and wanted to confirm which pulleys were being changed. Jeremy said that the pulley on the main shaft was increased from 24 to 60 teeth while the pulley on the motor was changed from 24 to 20 teeth. Luke pointed out that 60 teeth is the maximum size allowable given the space constraints and asked what the smallest pulley size is. Jeremy replied that 20 teeth was actually the smallest available.

Testing plan:

- Taha mentioned the different testing still required for the components including deflection, vibration and mesh resolution.

Project management:

- Jeremy showed which stage the group was currently at on the Gantt chart and said that what remains is to order parts next week if granted approval, to focus on the software side and finish all remaining manufacturing.
- He mentioned the different changes made to the Gantt chart since the submission of the PQP to account for delays or changes in circumstance.
- Jeremy spoke about the risk assessment such as the software not being completed on time so he has allocated more time to focus on the software side. Another issue is that the turntable breaks upon loading so stress calculations have been carried out to prevent this and a portion of the budget has been designated for a replacement if needed.
- Other issues include parts not arriving on time so alternative suppliers have been considered for each part but this should not be an issue as most components have short lead times.
- A big issue is making a mistake during manufacturing which means that any CNC parts must be re-submitted or even made manually. To prevent this, a clear manufacturing plan has been laid out and engineering drawings are checked by two other members of the group to identify errors.

Discussion:

- Dr. Cinosi said that overall the review was good but was unusual. The PDS specified quite a few things involving software yet the review focussed on the hardware side. Dr. Salles said that he was told that the DMT is mainly mechanical so he told the group to focus on the mechanical side. Dr. Cinosi added that he felt like the group was concentrating on small issues instead of the software.
- Luke asked if the entire group had been working on the software and Siew said that he had worked on the initial prototype. Luke remembered that Siew had told him that he already had the code from a paper.

	• Siew added that the group still needs to automate the scanning and meshing process. Luke said that a mesh might not be necessary as the point cloud can be analysed directly. • Dr. Cinosi asked if the choice of camera was important and Siew said that it was which is why the same camera as other experiments was chosen. • Luke asked if the focus was important, prompting Taha to show how he had taken pictures using his smart phone with different focus settings to make the object sharp and the background blurred. Dr. Cinosi responded saying that this is what the eyes see and the group needs to check what the computer sees. • Luke suggested setting a DSLR far away from the object and adjusting focus from there. Siew said that the idea of focus is why the group chose to use a tripod but Luke said that this does not give a high level of control to the focus. • Dr. Cinosi said that the distance of the camera must be fixed during scanning as there cannot be too many independent variables. • Dr. Cinosi asked if there was a difference in scanning different surfaces such as dark, shiny or transparent. Siew said that he encountered problems with scanning shiny objects but it is possible to prepare the surface before scanning using chalk or some other material. Dr. Cinosi conceded that turbine blades may not have this issue so preparation of the sample may not be necessary. • Luke said that he could provide parts if necessary but Dr. Salles said that he had already given the group a small turbine blade. • Luke said that the group should check if the scanner has issues with lots of identical objects like rows of turbine blades. If that is the case, maybe identify the object using a blue line etc. • He continued to go on to say that the group should first work on making the scanner operational then making it fancy can come afterwards. • Dr. Cinosi asked Luke if the scanner would be used to analyse cracks etc. Luke replied that he has an old engine in the lab from the 1960s and the engineering drawings are all hand-drawn so making a CAD model is difficult. • Dr. Cinosi asked if linear interpolation can be used to increase the resolution after the point cloud has been acquired. Luke replied that resolution can be increased by using a better camera, such as a 25 megapixel camera. He said that if the group can achieve a 0.5 mm resolution using a webcam, he could probably achieve a 0.05 mm resolution using a DSLR. • Dr. Cinosi asked if a spline can be used to improve the resolution but Luke responded that a spline is not always applicable e.g. around sharp corners. • After being asked about the resolution by Dr. Salles, Siew said that the resolution is sometimes given as the distance between points on a point cloud while at other times is given as the difference between the dimensions of the model and the real object. • Jeremy said that the more expensive scanners, like GOM, give the distance between points on a point cloud. • Dr. Cinosi asked why two cameras were not used instead of just one for stereoscopic scanning. Siew said that setting up the scanner using a single scanner was difficult enough so using two would make it even harder. Also, the code that is currently being used is for one camera only. • Dr. Salles asked how the scanner is calibrated and Siew explained how a correspondence is found from the checker box pattern. He used the gray code method as it is the most robust. • Luke asked about the projector and Siew said that it has a very short focal distance (0.5 m) and small screen size, which Luke said was tiny. Luke asked about the resolution of the projector and Cs said that it was 1280 x 720. • Jeremy asked if there were any issues with the drawings and Dr. Salles commented that manufacturing has already been done. • Luke said that the base plate could be shaped differently so instead of a cross-like shape, could use angled legs like a Y shape. Dr. Cinosi agreed.

	• Luke added that the bending is actually small but the turntable tilting is an issue, maybe in the bearings. Dr. Cinosi questioned whether this was something to actually worry about. Luke also said that the dowel pins on the turntable need to be sorted out. • Luke said that the software still needs more work so the group should focus less on integrating the mechanical and software side and work on both sides simultaneously so that integration can take place later.
Filled in by	Hussain

Date & Time:	Tue 28th Jan, 0900
Agenda:	Update on current design, questions for Progress Report.
Members present:	Dr. Schwingshackl, Taha, Siew, Jeremy, Hussain.
Minutes:	**Current design:** • Siew started off by showing the CAD (Computer Aided Design) model for the latest design. He spoke about the 3D printed cover that consists of three sections, the new base plate that has been modified to reduce area and therefore lighter and the new pulleys to increase the torque ratio. • The tripod sub-assembly has been modified so that one hole at the end of the respective platforms for the projector and camera is used alongside a nut and screw to constrain the platform. Dr. Schwingshackl opposed this idea and instead said that two holes are needed to constrain the platforms better. He said that a wingnut would also be preferred as it is easier to tighten/untighten. • Jeremy said that most commercial solutions that he has looked at uses a single hole in the middle for constraining but Dr. Schwingshackl said that this is susceptible to a change in position if someone accidentally knocks the tripod. He added that the platforms could be made fixed and not adjustable if the projector and camera are permanently part of the set-up so changes are not necessary. At the end, the group needs to show that they have though about this issue and have tried to find a clever solution. • Dr. Schwingshackl asked how the projector and camera was going to be clamped onto the platform and Jeremy replied that a G-clamp would be used since the projector only had a height of about 400 mm. Dr. Schwingshackl said that this was not a nice engineering solution and that someone could accidentally tighten the clamp too much and squash the projector. Instead, he suggested using the hole that was already a part of the projector/camera but the thread should be checked as it could be unusual (probably UNF). The group should follow something that has been thought about and used for many years since he was worried that the electronics could be damaged. Also, using a G-clamp makes storage difficult. • Siew showed the new design of the frame and said that the previous design used up lots of space. • Dr. Schwingshackl wanted to clarify what the new torque ratio was and Siew said that it was 3:1. Dr. Schwingshackl questioned whether this was enough and then asked what torque was required and what was provided by the motor. Hussain said that the torque calculate was less than 1 Nm, around 0.5 Nm, while the motor provided about 2 Nm. He added that this was an estimate because using coefficient of friction values of 0.1 resulted in the calculated friction to exceed 15 Nm. • Dr. Schwingshackl said that this friction problem needs to be reverse engineered so the group can estimate what the current torque needed is to rotate the 10 kg mass at the edge of the turntable and compare to the torque provided by the motor to attain a friction factor. From there, the torque needed to rotate a 20 kg mass at the edge of the turntable can be estimated. • Dr. Schwingshackl asked what the pulley sizes are on the prototype and Jeremy replied 100 mm. Dr. Schwingshackl said that there is still plenty of room available so 1:3 should be enough to rotate the 10 kg object and, assuming a linear relationship, a 1:4 ratio would at least be needed to rotate the 20 kg object. He said that this was

	important to look into as the group does not want to change things and the motor still is not able to rotate the turntable. • To clarify, Siew asked whether Dr. Schwingshackl was trying to say that the 10 kg object is not moving as it needs x amount or torque, so the 20 kg object needs 2x amount of torque and Dr. Schwingshackl confirmed this and added that the calculation should be carried out so that the group can say that despite the test failing, adjustments have been made based on the results. • Furthermore, Siew asked if it could have been the shaft being made out of aluminium instead of steel that could have caused the tilting, as this was a mistake made during manufacturing. Dr. Schwingshackl asked what the thickness of the shaft was and Jeremy said 12 mm and Taha said that the flange had a diameter of 50 mm. Dr. Schwingshackl said that the shaft should be made out of steel anyway because aluminium has low cycle fatigue. • Siew then went on to speak about the frame and said that hinges have been attached so that the frame can fold up to save space and the acrylic sheets have been removed and a cloth will be used as a replacement. Dr. Schwingshackl wondered in any of the group members knew how to sew and Siew said that he could. Siew continued saying that a rubber stopper has been attached to the frame to stop the leg from overextending, prompting Dr. Schwingshackl to say that a rubber stopper should also be added to the legs of the frame to prevent scratching if the frame is placed on top of a table. • Dr. Schwingshackl asked what material would be used and Siew said that a day curtain would be used, not blackout, which Taha said only costs £12. Taha questioned whether the cloth needs to be sewed and asked whether it could just be placed over the frame as it is already. Dr. Schwingshackl reminded him that one of the marking criteria is engineering professionalism so throwing a curtain over the frame may do the job but does not look aesthetically pleasing. • In light of what was said, Siew decided that the HPC gear order will be retracted from Peter Higgs. • Taha said that he had spoken to Andrew, the STW manager, about 3D printing the cover and he was told that the total cost would be approximately £200, worrying the group. Dr. Schwingshackl told the group that this was due to the large size of the cover and asked why the group was using 3D printing methods instead of just bending metal sheets or using flanges. He suggested that the group re-design the cover since 3D printed covers normally look ugly anyway or alternatively, use a single metal plate for the intermediate and motor plate since the user would probably not need to access the pulleys but Siew showed on the CAD model that the plates were at different heights. • Overall, Dr. Schwingshackl said that the cover was too complicated, too expensive due to its large size and not needed, meaning that the group should find a simple solution instead. In industry, 3D printing would not be used and a more likely method would be injection moulding. He suggested using plexiglass or PVC as thin panels. • In the lab, there is a rotating rig and a mesh is used like a cage to prevent people from touching the set-up. • The cover would also rattle and produce noise if metal used but the group has no choice but find another solution rather than rely on 3D printing. Options could be making the pillars longer so that the cover can be screwed to the plates more easily or to be permanently attached since the tensioner can be adjusted from above. If any replacements need to be made, the user can take the cover off themselves. • Next, Siew said that the group was planning on laser cutting the base plate and to CNC the main shaft. • Siew then went to show a pie chart of the main budget. Dr. Schwingshackl said that if the group goes over budget, himself or Dr. Salles will take care of the excess required but the group has managed to do a good job so far in managing the money. After getting asked, Siew said that the remaining budget is £340 so far.

	• Afterwards, the manufacturing plan was shown by Jeremy and he explained that the biggest risk was making a mistake during manufacturing so that a CNC'd part would then have to be manufactured manually. Taha assured Dr. Schwingshackl though that so far, all the parts for laser cutting and CNC have been accepted. **Progress Report:** • Jeremy asked what conclusions meant in the report under the discussion heading – to focus on the management side or on the technical design, to which Dr. Schwingshackl replied both. • Dr. Schwingshackl said that the scene setting should be good as the rest of the report does not make any sense without it. • Plus, the conclusion should explain how far the group has progressed to achieve the objectives and there should be an honest representation of how the Design Review went – the good and the bad. The group should also mention the comments made about the scanning device. • On the management section, say that changes have been made to ensure that the group is still on time and manufacturing will be completed. Write about any efforts made to account for delays and if there were any changes to the scope of the project. • Moreover, if there are any major risks that are likely to take place, explain what the group has done to prevent this, such as working harder to make the deadline or maybe having a back-up design in case the first design fails. • Siew asked about the literature review and wanted to know whether this was referring to scientific papers or the market research. Dr. Schwingshackl asked if all the research carried out was all web-based or if any papers were looked at but then he remembered that the group had looked at some papers and spoke about them. The group is allowed to mention the lecture notes for things like the stress calculations. • Just web-based sources are not great but can be tolerated for the progress report. However, for the final report, both the market research and web-based sources must be used in conjunction with scientific papers. • In addition, Jeremy asked about the weighting of each section (background, work done, discussion) since this was not made clear in the marking criteria. Dr. Schwingshackl responded saying that the marks are evenly distributed among the sections but the background is important because the objectives must be fully explained to ensure that the report makes sense. There should be about two pages on the background, leaving seven pages left for the work and the discussion. • Jeremy was concerned that apart from the Gantt chart, was there anything else that should have been done to track the progress and changes of the project timeline. Dr. Schwingshackl said that he should just talk about the initial Gantt chart and any changes made to try and meet the objectives. Mention the progress made and whether the objectives will, in fact, be met because the marker must judge how far through the project the group has come. • Siew asked if there were any preferences in citation style and Dr. Schwingshackl said that the group should use the style involving square brackets with the author since the method using the other is mainly for medicine and other sciences. Siew and Jeremy said that he was referring to IEEE and Harvard style, respectively. **Other:** • Siew asked when Dr. Salles would return and Dr. Schwingshackl said that he would return on Feb. 17th but the group can email him if necessary. • Dr. Schwingshackl also said that he was unable to attend the meeting next Tuesday (4th Feb) and the following Tuesday (11th Feb) so the meeting was re-scheduled to Thursday 6th Feb at 4pm.
Filled in by:	Hussain

Date & Time:	Fri 7th Feb, 0930
Agenda:	Updated model, new hardware, turntable tilting, schedule changes.

Members present:	Dr. Schwingshackl, Siew, Hussain, Cs, Jeremy, Taha.
Minutes:	**Updated model:** • Siew started off by saying that the transmission ratio has been chosen as 4:1 to compensate for the motor stalling when the turntable fails to rotate as a 10 kg object is placed at the edge. • The acrylic cover has been modified with slots and bolts to fix the plates together. • Dr. Schwingshackl was concerned that high levels of vibration will make the cover rattle and produce lots of noise so he suggested using rubber dampers or to clamp the cover to the base. • He also said that he did not like the look of the top cover and told the group to use a more elegant method of fastening the cover pieces, like a spring-loaded pin instead of the weird nut and bolt setup. • He asked if the cover is attached to the base and Siew replied that the cover is not and is instead constrained by the pillars of the motor and intermediate plates. He added that bending metal sheets was difficult to keep orthogonal. • Dr. Schwingshackl asked CS to show a cross-section through the top of the CAD model and he pointed out that one side of the acrylic cover is in contact with all four pillars of the motor plate whereas the other side does not. Siew said that this is just a mating error and can be easily corrected. • Dr. Schwingshackl reminded the group to sort out the rattling and then asked how someone would hold the turntable setup. He said that the turntable should not be grabbed and maybe the group should add handles to clearly indicate how someone can carry it. • He also asked the group which other materials could also be used for the cover as metal sheet bending is ugly but acrylic is fine. Wood could used too. His main issue was that the bolts look weird. Gluing is an option but is permanent so he advised the group to research how acrylic plates could be attached. • One of Dr. Silversides' previous DMT groups had an elegant method of mounting acrylic plates so he suggested that the group contacts him to find out what they did. • Dr. Schwingshackl added that one of his previous groups drilled holes everywhere and used bolts which looked very messy. Another alternative was to cut slots into the pillars so that the covers can be inserted. He said that this is not something to focus on too much but try not to let the design look messy. • Dr. Schwingshackl noticed that the Arduino was on the side and asked where the wires were. • CS explained that the power supply is connected to the AC/DC converter, the converter is connected to the Arduino and motor driver which is connected to both a kill switch with LED to show that the scanner is in operation and the laptop. The laptop is also connected to the projector and camera. • Dr. Schwingshackl said that most laptops only have one USB port so asked if it was possible to use Bluetooth with the Ardunio. CS said that the Raspberry Pi can use Bluetooth but he will have to look into the Arduino. Siew also suggested using a multi-USB extension if necessary. • Dr. Schwingshackl said that lots of wires looks messy and unprofessional so any wires must be fixed in place. • Focusing on the 3D model, CS showed that the motor and converter are next to each other as the cover below does not allow enough space for the converter to be placed there. Dr. Schwingshackl asked why the converter was not placed on the opposite fin to the Arduino as this would make the design symmetrical and would reduce the moment. • Furthermore, he was concerned that the wires will interfere with the transmission so wire management was suggested to tidy the wires e.g. make the wires go through the cover and stay flush to the wall. Dr. Schwingshackl then asked if this would be an issue if the cover was taken apart and the group said that this would be an issue so another option would be to make the wires fixed to the base plate instead.

	• CS showed how the PCB connection has been made flush to the wall of the Arduino cover so that the female connection can be easily attached. • Dr. Schwingshackl added that the base plate could be tapped so cable ties or hooks can be used to constrain the wires. • Next, Dr. Schwingshackl asked how the electronics would be cooled and mentioned that he used fans and heat sinks in a past project. Siew asked if a slot in the electronics box would be sufficient and Dr. Schwingshackl replied that it would be fine. Siew then asked how the group could justify this and Dr. Schwingshackl said that the group should just say that they thought about it and decided to put holes in for this purpose. If the group wanted to, they could do heat transfer calculations. • With regard to the motor driver, a heat sink in open air could be used for cooling. • He added that the fins should be aligned with the slots/holes for cooling and the holes should be on the side to prevent dust falling in. • Siew asked if a mesh was okay instead of using holes and Dr. Schwingshackl said that a mesh could be but would need to very fine. He gave an example of the computer and said that they normally have a foam-like mesh to prevent dust entering. For the acrylic cover, however, the dust can just be blown off. • The converter already has lots of holes for cooling, indicating that it must heat up significantly during use, so just make sure that the holes are not blocked. • The terminals of the converter are exposed which is dangerous so that would need to be looked into. The design should be ran past Leroy to test for electrical safety. • Dr. Schwingshackl asked how the mains power would be supplied and Siew explained that it would be connected directly to the converter. Dr. Schwingshackl suggested using an intermediate connection with a switch to reduce the risk of electric shock if mains supply was accidentally disconnected. This has the extra benefit of being compact and keeping the wires tidy. • Dr. Schwingshackl said that instead of 3d printing, lots of boxes can be bought on RS etc. so a good justification is needed. He reminded the group that in the Design Review, it was said that the group should aim to not 3d print anything and should buy if they can. • CS explained that the Arduino shield is like a breadboard and the pins can be soldered onto the Arduino. Dr. Schwingshackl asked if there was any support for the breadboard but CS said that there was no loading since the weight is small anyway. Dr. Schwingshackl realised that the Arduino was not cantilevered so the lack of support is fine. • Siew said that printed circuit boards were considered but this would require the Arduino to be replaced. Dr. Schwingshackl was against this idea and said to keep the design simple. He said that one of his previous DMT groups did use printed circuit boards but this is because they were considering how to mass-produce their product. • Dr. Schwingshackl said that if the box is see-through, keep the wires and components tidy as it will not look nice. Alternatively, do not make the box see-through. • About the kill switch, Jeremy said that they were considering using a box with the kill switch and LED on the surface. Dr. Schwingshackl said that anything that dangles is a pain but Jeremy explained that since the scanner is inside the enclosure, the user cannot see what is happening so the kill switch and LED must stick out to show if the scanner is operating or not. A male/female connection is used again here. **Turntable tilting:** • Hussain said that Dr. Schwingshackl mentioned 2 or 3 weeks ago that a dial gauge should be used at different radii to check if the turntable is deflecting or tilting when the 20 kg object is placed at the edge. • Hussain calculated for different radii and different tilt angles the deflection reading due to bending of the turntable and due to the tilting of the turntable, then superimposed the values to get a total deflection. • The measured deflection was 5.5 mm which corresponded to a tilt angle of approximately 0.75°.

	• Dr. Schwingshackl asked if the deflection would affect the scan and Siew said that the scan should not be affected. • Siew said that the main shaft was incorrectly specified as aluminium when it should have been steel and asked if correcting this would fix the tilting issue. Dr. Schwingshackl responded that steel is stiffer so bending would be less but tilting would be the same as this is caused by the clearances in the bearings. He asked about the floating face of the bearing and CS showed the CAD model. Siew said that a H7 reamer was used for the hole but Dr. Schwingshackl said that clearances would still be present. • A suggestion was to make the turntable stiffer or to make the shaft longer so there would be less tilting but this is up to the group to decide if it is important or not. • Dr. Schwingshackl asked how much of the total deflection was caused by tilting and Hussain said that it was around 50-60 %. Since the upper bearing has the floating face, there is not much the group can do to reduce clearances as using a lower clearance would make it difficult for the bearings to roll. But since the tilting causes about 50 %, making the turntable stiffer could reduce the total deflection from 5.5 mm to maybe 3 mm. The group needs to say that they have thought about it and decide if changing the design is or is not worth it. **Hardware:** • The base plate, projector, camera, steel shaft and tripod have arrived. • Siew said that the new camera works and he has managed to connect it to MATLAB. • The projector has not been tested yet and he plans to do this next week. **Schedule changes:** • If the current design is approved, manufacturing will continue next week. • Jeremy said that the turntable cannot be made thicker as 5mm is the maximum thickness offered by ME stores. Dr. Schwingshackl proposed the idea of using Aluminium rods in a cross-shape to support and stiffen the turntable but if this is unfeasible, the group should say that they have considered the idea but have decided against it. • Another option would be to use aluminium profiles in a cross-shape with an interface plate to stiffen the turntable but this may cause extra tilting due to overhang so decide if this is important. • Dr. Schwingshackl asked when the assembly will be complete and Jeremy replied early March. The electronics affected the mechanical design more than expected. Dr. Schwingshackl said that both need to be done at the same time and sometimes more time is needed on the other if too much time has been spent on one. • Now, Dr. Schwingshackl advised that the group: tries to scan an object and test if the mesh works as expected; check how new hardware works and how to finish the project with a workable product e.g. a user guide or a CD/USB will all software included.
Filled in by:	Hussain

Date & Time:	Mon 17th Feb, 1400
Agenda:	Update Dr. Salles on new torque ration, features of current design, obtain approval to start manufacturing, new hardware.
Members present:	Dr. Salles, Siew, Taha, Hussain, Jeremy.
Minutes:	**Torque ratio:** • Dr. Salles asked why the group changed the torque ratio from 3:1 to 4:1. Hussain replied that since 1:1 was not enough, Dr. Schwingshackl suggested that a 4:1 ratio might be more suitable using the values of friction and motor torque as a basis. **Current design:** • Jeremy ran through the changes to the design and started by showing the boxes for the Arduino and AC/DC converter to be 3D printed followed by the new pulleys.

- The entire transmission is covered with an acrylic cover using a T-joint. Jeremy added that these joints are not critical but were added since bolts sticking out do not look nice from a design point of view.
- Handles have been added to make carrying the turntable easier for the user.
- A cloth is to be placed over the frame to control the lighting conditions. Dr. Salles asked what the colour of the cloth would be and Taha replied that it would be a regular cloth. Hussain added that it would be black or some other dark colour.
- Jeremy finished by saying that the group is currently waiting for approval to submit the manufacturing requests.
- Dr. Salles asked if the group was planning on buying the tripod and Jeremy said that it had been purchased already.
- Dr. Salles was concerned that the webcam would have a resolution too low but Siew responded that he had already tested it and it seemed good enough. Jeremy added that the previous experiments used these cameras. Taha also said that the resolution can be upgraded from 2 to 3.5 megapixels (MP).
- Dr. Salles asked which software would be used and Jeremy said that currently Meshlab is being used to mesh the images together. Dr. Salles then recommended using computer vision which is available on MATLAB.
- Siew said that the software side has not progressed much since the mechanical design has been the main priority so far. Dr. Salles said that the group needs to get a move on as the software side is important.
- Dr. Salles advised the group to use GitHub to save software files as this can be made accessible to Imperial's GitHub which makes things easier for the Dynamics team.

Approval for manufacturing:

- Taha asked if Dr. Salles was willing to expand the budget in case a mistake was made during manufacturing as a few plates were already sent to be laser cut but then the design was changed, so the parts are now unusable but the group plans to test the overall design by the end of March.
- Dr. Salles asked said that there are no risks during manufacture except for the pulleys.
- He asked what the masses of the boxes were and Jeremy said that the Ardunio box is about 300 g and the converter box is less than 600 g. Dr. Salles said in that case, the base plate is stable so the group does not need to worry about re-designs.
- Jeremy said that the last two weeks has been busy with deadlines and re-designing components, which has set the group behind slightly, so many parts are going to be laser cut to reduce manufacturing time.
- Dr. Salles asked if the pulley was going to be manufactured manually and Jeremy said that all transmission components are going to be bought.

New hardware:

- Siew said that the tripod in the CAD model was obtained online but is the not the exact model of the tripod purchased but Jeremy is still waiting for the company to send him the model.
- Jeremy said that initially, the rail that the projector and camera rest on was going to be fixed to the tripod using a single screw but after consulting Dr. Schwingshackl who pointed out that the rail could still rotate, Jeremy plans to manufacture a replacement component for the tripod that has two holes to restrict rotation.
- Dr. Salles was worried that the fan inside the projector will make the camera vibrate if they are both attached to the same rail. Siew said that the projector would be connected to the computer but Jeremy clarified the question to him. Siew then said that he did not notice any vibration of the projector when he tested it and he said that it should not be an issue as even large projectors do not show noticeable vibration.
- Dr. Salles asked who was in charge of the software. Siew said that he has been working on the software so far but the plan is to split into two teams: Data acquisition and meshing.
- Dr. Salles recommended using GitHub and sharing with Imperial's GitHub account to allow the Dynamics team to be able to make different versions of the software. The

	group should make it private and share with Dr. Salles. He gave Siew his GitHub username. • Jeremy wanted to check with Dr. Salles if computer vision was the software he mentioned. Dr. Salles said that was correct but it would be better to use Python and OpenCV which is easier over time but difficult at the beginning since the group will need to learn the language. • Siew said that this should not be an issue because code can be found online and modified for the application. • Siew showed the acrylic cover with the new T-joint as Dr. Schwingshackl did not like bolts sticking out but Dr. Salles said that in these types of joints, countersunk screws are more common rather than socket head screws. Siew questioned if the plates would be thick enough for countersunk screws but Dr. Salles said that it appears thick enough from the CAD model. Siew then asked if acrylic could be machined. • Jeremy finished by mentioning the Arduino to control the motor with the newly added bluetooth module for wireless compatability, using the USB only as a failsafe, to reduce the number of wires. • Siew ran through the circuit diagram with the inputs and outputs for each component. • Hussain added that a kill-switch and LED to show the scanner in operation was included.
Filled in by:	Hussain

Date & Time:	Tue 25th Feb, 0900
Agenda:	Update on manufacturing and ordered components, software progress, testing plan and feedback for progress report, updated model.
Members present:	Dr. Salles, Dr. Schwingshackl, Hussain, Taha, Siew, Cs, Jeremy.
Minutes:	**Updates on Manufacturing and Ordering Components:** • All parts to be laser cut have been completed such as the acrylic sheets and all plates. • 3D box for AC/DC converter has been completed. • Base plate holes all need to be made countersunk and bearing hole needs to be bored out to correct tolerance in the intermediate plate. • The STW technicians said that the tripod mounting piece cannot be CNC'd as it is too simple so will need to machined manually. • Taha spoke about the webcam that has been purchased with variable resolution up to 2304x1536. • All components have been ordered except the rubber stoppers for the frame as there has been some complication with the supplier. The last part to arrive will be the pulleys on the 11th March. **Software Progress - Mesh/Reconstruction:** • Jeremy said that he produced a mesh of a toy car from the point cloud but he needed to manually clean up the point cloud by removing points not belonging to the object. • He said that the process needs to be optimised and then ran again. • Dr. Schwingshackl asked about the focal length. • Dr. Salles asked if calibration was needed and Siew said that it was. Dr. Schwingshakl asked how calibration was done since he could not remember if this was explained already. Siew showed a previous presentation where the checkerbox pattern was used as a reference and the projector displayed stripes corresponding to grey code onto the pattern. The software would then find the position of the corners using software. The Python script used is from Taubin and Lanman, Brown University. Dr. Salles asked Siew if the script is on OpenCV and Siew replied yes so Dr. Salles said that this is not Python then as OpenCV is a library and different to Python. • Jeremy continued to say that it was difficult to align points because some points looked very similar so it was hard to tell them apart so he suggested using reference markers to help identify certain sides. Dr. Schwingshackl suggested adding an object

onto the turntable itself to act as a reference and Dr. Salles said that a line could be used.

- Siew responded saying that reconstruction is performed after clean-up has been carried out so the reference should be on the object. Dr. Schwingshackl was concerned that this would hide part of the body but Jeremy showed the reconstructed Amazon box that had the glue from the sticker still detected by the reconstruction. In that case, Dr. Schwingshackl said that a reference would work e.g. a different colour on surface of the object.
- Jeremy asked whether this information should be included in the final report or the user manual. Dr. Schwingshackl said that it should be explained that the group has thought about it and has come up with a solution but the full details should be included in the user manual.

Software Progress – Image Acquisition:

- Hussain said that he tested the camera and projector over the weekend with the MATLAB script to see how it all works.
- The main aim is to make the camera and projector repeat the scanning process after the motor has rotated the turntable so once this has worked on MATLAB, the group will progress onto Python.
- Dr. Salles asked if any Toolboxes are needed and Hussain replied that there were quite a few, such as the Communications. Siew added that the Psychometric Toolbox was required. Siew said that CV2 could be used but Dr. Salles clarified that OpenCV and CV2 are the (*see Tue 3rd March*) same thing.

Testing Plan:

- Siew said that to test **transportability**, users external to the design group will be used to test the system.
- The **resolution** testing is ongoing and will be tested further as the group progresses. Dr. Schwingshackl asked about the screen size and how this would affect the resolution since using a larger size should mean more data points collected. He suggested plotting a graph to show the different sizes along with the different resolutions achieved instead of a table.
- **Scan time** is also ongoing and the Python script is still being written to produce the grey code patterns onto the object and rotate the turntable. Siew clarified for Dr. Schwingshackl that the grey code pattern is a form of binary so is one line that splits into lots of different lines as the binary number increases.
- For the **lighting**, Siew said that during testing, he found that the room cannot be too dark as the checker box pattern cannot be detected or too bright as the scanner cannot differentiate between the light and dark patterns, sort of a 'Goldilocks' effect.
- Dr. Salles expressed concern about the 50 Hz AC power supply and said that the human eyes cannot detect the flickering in the lights but the camera may be able to pick this up. He encountered this when he was experimenting with previous work.
- Siew asked if the lights in the Dynamics Lab were the same as in the Rolls-Royce meeting room and Dr. Schwingshackl said that all the lights are the same.
- Since a cloth is being used, Dr. Schwingshackl said that blackout material could be used and a high quality light can be used to provide sufficient lighting, such as a bike light. Alternatively, ambient light could be used. Just try things and see if the scan is messed up or not.
- Dr. Salles asked what the picture time was and Siew said that he set the exposure time to 0.5s which meant that he did not detect the 50 Hz flickering of the light and the total scan time was 20 seconds per revolution.
- To test if the system is **safe electrically**, the plan is to go to the mechatronics lab or the supervisors to obtain approval. Dr. Schwingshackl said that the system will need to be PAT tested by Leroy which should be sufficient for the electrical safety.
- With the safety in regards to the sharp edges etc, all the group can do is make sure that no one would cut themselves when handling the system.

- Dr. Schwingshackl said that Leroy's office is either next to Vim's or he shares the same office. The group should talk to him and tell him about the project then ask him what should be done.
- In regards to the **project management**, Jeremy said that Taha already mentioned that the pulleys have been delayed. Today will be the first day of manufacture.
- Dr. Salles said that the complete assembly is not essential for software as the turntable could be moved manually.
- Jeremy said that manufacture should be complete by the last week of March, leaving some time for testing.
- Dr. Salles asked about the parts to be 3d printed and Jeremy replied that all parts which needed to be laser cut, 3D printed or CNC'd have already been completed in the workshop. The only exception is the tripod mount. Jeremy reminded Dr. Schwingshackl about preventing rotation of the rail by designing a new mount that has two holes.

Feedback:

- Siew asked exactly how the group will be assessed on the software aspect since the marking criteria is clear on the mechanical aspects but is vague about the software side.
- Dr. Schwingshackl said that this project does not focus on software development but rather integration. In this case, there was a lot of focus on the software initially because it set the boundary conditions for the mechanical design. This is something that the group should write about in the final report.
- Siew asked, since there will be other markers for the project, if the group will be marked down for having less focus on the mechanical side. Dr. Salles replied that this is the twenty-first century and he has worked with mechanical engineering departments over the world.
- Dr. Schwingshackl added that the group has still done a lot of mechanical design such as choosing the motor, basic analysis, supports, turntable and bearings.
- Dr. Schwingshackl asked how the group was planning on validating that the object has been scanned correctly. Jeremy said the point-cloud resolution would be used but he was unsure.
- Dr. Schwingshackl said that this is for the model but how will the group validate that the points are accurate with respect to the real-life object. Siew said that there was something he saw online where the distance between points can be placed on a Gaussian curve to statistically analyse how accurate the points are. Dr. Salles disagreed and said that Siew was talking about the accuracy of the system.
- Dr. Schwingshackl gave the example of scanning a remote and how to validate that the scan is accurate. One suggestion he gave was using a calibration or reference object of known dimensions and to compare to the dimensions of the model. Dr. Schwingshackl said that it might be possible to find something from the Dynamics Lab but Dr. Salles said that, instead, the Metrology Lab may have a reference object. In the end, the user needs to know that the scan will produce an accurate depth of the objects.
- Siew questioned the 'AGILE' feedback and said that it was very general.
- Jeremy said that the Gantt chart specifies milestones for software progress and wondered if this was sufficient. Dr. Salles said that this was fine as the group will learn from their mistakes. In software design, a prototype is developed and still does not work sometimes which is how it works.

Updates on Manufacturing and Ordering Components:

- Taha spoke about the budget and said that the group has currently spent £890.
- He was concerned that the camera was purchased from BT where it is £84 but it was specified from Amazon where it was £56. He asked if it was okay to mention the intended price in the final report instead of the higher price but Dr. Schwingshackl said that this was not okay since Dr. Salles' account is still charged. Instead, the group should write what the original budget was and say how much was spent in the end and whether this was close or not.
- Siew asked if it was okay to write about the theoretical price if all components were purchased from where they were supposed to be but Dr. Schwingshackl advised the

	group to use the approach where the report shows the method of making the scanner but the user can choose the exact equipment, which affects their own budget accordingly. • Dr. Salles said that this would also give the option to upgrade the camera. Dr. Schwingshackl said that the resolution of the webcam used in the demonstration was quite good and the issue with cameras is mainly the focal length and distortion. • If the group goes over the budget, this is normal. If the group wanted to, they could actually remove the camera and projector from the budget list (£350) and instead assume that the user has their own equipment, taking the group back to their previous standing with the budget. This approach should be used over removing items. • Taha said that the delivery charge was also £10 or £20 with VAT added after this charge. Dr. Salles said that things like this must be considered. Dr. Schwingshackl recommended that the orders are clustered together to prevent multiple delivery charges since some previous groups ordered items every week as they kept forgetting things so stacked up delivery charges. **New Model:** • Jeremy wanted to quickly run through the updated model with Dr. Schwingshackl since had not been shown the changes since the last meeting. • The acrylic cover had been changed so that the bolts are no longer sticking out and is smooth. Siew said that the screws can be changed to countersunk if there is enough time. Dr. Schwingshackl said that this would look nicer. • Jeremy showed the AC/DC converter box with the output of the converter, switch and the holes for the wires. • The Arduino box has a slot-in lid. • The flanges of the base plate have been extended to allow placement of handles. Dr. Schwingshackl said that this could cause significant bending but Siew said that the system is only 4 kg including the turntable. Dr. Schwingshackl then asked what the thickness of the base plate was and Jeremy said that it was 5 mm. Dr. Schwingshackl said that bending should not be an issue but FE could still be used for analysis. • Siew asked if FEA could be used and Dr. Schwingshackl said yes but the model could be simplified to include just the base plate with loads acting on it. • Dr. Schwingshackl was concerned that the tripod is orientated at a steep angle which could cause issues with scanning but Jeremy said that the model was not accurate and was also fully extended whereas the real tripod will have different dimensions and will also not be extended so the angle will not be as steep.
Filled in by:	Hussain

Date & Time:	Tue 3rd March, 0900
Agenda:	Updates on manufacturing and software.
Members present:	Dr. Salles, Hussain, Siew, Jeremy, Taha.
Minutes:	• Dr. Salles mentioned that in the minutes for the previous meeting, it was written that openCV and cv2 are not the same thing when, in fact, they are. Siew said that the minutes will be changed accordingly. • Taha started off by saying that most parts for manufacturing have been completed and the tripod component should be finished by the end of this week. The pulleys should arrive next week and can be modified in the workshop also. • Siew spoke about his and Jeremy's efforts to reconstruct models and found that the reflectivity was very important when it came to image quality. • One example he gave was a scan of the turbine blade provided by Dr. Salles last year where the blade was very shiny in the middle so there was an issue with reconstruction at these positions. • Dr. Salles asked if the level of light could be reduced but Siew replied that the projector itself is a source of light which means it cannot be eliminated.

	• Jeremy went on to speak about the meshing process and found that he needed thirty to forty images per scan because the rotation increments are large so more overlap between the different orientations was needed. Some points were also redundant. • Siew said that to improve the point-cloud resolution and reduce noise, sample preparation may be required. He showed an example where the spray disappears after a few hours and home-made solutions are available e.g. mixing baby powder and alcohol. • Siew continued onto the Python script that was written for image acquisition without the turntable rotation. Hussain added that the script including the turntable has been written but cannot be tested as the motor and Arduino have been disassembled. • Siew said that he tested the webcam for scanning but found issues with over-exposure and was not sure how to set the exposure using a script. He plans to speak to Dr. Muscutt about this and ask about the optical equipment available in the Dynamics Lab. Dr. Salles agreed with this as it may be possible to test using a better camera. • In regards to the sample preparation, Dr. Salles said that it would be possible to just use chalk or something similar. • Siew asked if these issues could be resolved in the post-processing stage but Dr. Salles said that this is typically not possible unless advanced algorithms like Machine Learning are used so need to be fixed prior to scanning. It may be a good idea to use a better camera. • Taha said that one of the manufactured parts was damaged so he needs to order another piece for £1.49. For this, he required Dr. Salles' signature. • Based on the timeline, the project is on track but a little more time will be required for the manufacture of the rail. • Hussain said that he found a script on GitHub that used C++ to get a very nice scan but he was unsure if he should look into it further since it was not Python. Dr. Salles said that Python was suggested because it is easier but C++ is fine to use. He asked Hussain to send him the link so that he can take a look. • Siew asked Dr. Salles that when using Python, does he use a Python Shell or something like Spyder. Dr. Salles said that most people in the Dynamics Lab use Spyder.
Filled in by:	Hussain

Date & Time:	Tue 10th March, 0900
Agenda:	Manufacturing update, software progress, Gantt chart.
Members present:	Dr. Schwingshackl, Dr. Salles, Cs, Hussain, Taha, Siew.
Minutes:	**Manufacturing Update:** • Siew started off by saying that the pulleys have arrived so will need to be modified in the workshop over the next two days. • The electronics still need soldering but that should be completed in time for testing next week. **Software Progress:** • Siew has already spoken to Dr. Muscutt about getting the scan working and he and Jeremy have managed to produce a reconstruction of an Amazon box. • They opted not to scan a shiny object since this posed an issue during meshing and reconstruction. • However, the sides of the reconstructed box were not orthogonal which they think is due to knocking the camera-projector set-up during scanning, resulting in an obtuse angle of the box corners within the model. • CloudCompare was used to process all point-cloud data and produce a preliminary mesh of the Amazon box. Dr. Salles asked Siew which level this was. Siew was unsure of what this meant and Dr. Salles explained using a diagram where an image is split into a series of boxes.

	• Siew then said that the resulting mesh was exported to MeshLab and he showed how the sides of the box were not orthogonal. He also said that MeshLab was used as it was able to generate higher quality meshes which can be exported as .STL files. • He said that the quality can be improved by increasing the reconstruction depth, which he assumed to be the same as the level depth. Dr. Salles said that this can be checked if the group looks into the software files. • Siew said that increasing the reconstruction depth increases the processing time so he plotted a graph of reconstruction depth against time. Jeremy and Siew also found that increasing the reconstruction depth above fourteen showed no noticeable improvements in quality. • Dr. Salles recommended using a level-set for the corners. • Siew said that currently, the plan is to reconstruct the model using the point-cloud data on CloudCompare and export to MeshLab to improve the quality then export to SolidWorks manually. • Dr. Schwingshackl asked if both software are open-source and Siew confirmed that they were. • Siew added that an Octree depth is available but better results can be achieved if reconstruction depth is used instead. • Dr. Schwingshackl said that a reference object with sharp corners should be used to test the scanner. Taha then showed him a photograph of a component that he machined in the workshop. Dr. Schwingshackl said that Taha deburred the object too much so the object does not have any sharp corners. • Taha added that he spoke to the Metrology Lab to obtain an object of standard dimensions and Dr. Schwingshackl responded saying that it was fantastic to get a calibrated object. • Siew showed the result of a structured light scanning project by 'jhdewitt' on GitHub but most of the code is written in C++. He showed a CAD model of a shell which had a resolution of less than 0.5 mm using two million points from seventy-four point clouds. They used pcl and opencv2 with a Raspberry Pi compatible camera. • Siew said that he has looked at global library so far and asked Dr. Salles if he knew of any way to automatically align points. Dr. Salles said that the group would have to align the principal axes of inertia to get an approximate alignment then can use iterative close point method to fully align the points. He added that openCV has this function. • Siew said that he also looked at OpenGR to automatically align points but Dr. Salles said that the method he mentioned would also do it automatically. He said that this is used in data mining and machine learning. • Dr. Schwingshackl said that the main thing for this design project is to get the mechanical side working so a basic version of the software would be sufficient but Dr. Salles may not agree. • Dr. Schwingshackl continued to say that initially, 60° was thought to be enough to achieve the desired accuracy but if 5° is needed instead, this will need to be considered during testing. • Dr. Salles said that he would share a paper with the group on point clouds. Furthermore, he said that Imperial has a world-renowned Computer Vision Lab situated between the Computer Science and Dyson School so it might be useful to ask them for advice. • Siew returned to the model and Dr. Schwingshackl said that the overlapping section has been nicely reconstructed. Dr. Schwingshackl then asked what is obtained after exporting to SolidWorks e.g. can he add things to the model, measure the mass, slice things etc. • Dr. Salles asked Siew if the model is exported from the point cloud. Siew seemed unsure so Dr. Salles asked him if he knew what an .STL file was and he explained how points are triangulated. He was concerned that if files are exported from the point cloud, it will be very large. • Siew said that the reconstructed object is not perfect but the basic idea can be seen.

	• Dr. Salles said that a cap needs to be used so a spline needs to be used and then a function to vary the geometry. Siew asked how this can be done on SolidWorks but Dr. Salles replied that he did not know how to do it on SolidWorks. • Dr. Schwingshackl advised the group not to go too crazy and instead to find a clever way to obtain the point-cloud and reconstruct a model, even if manual. • Dr. Salles said that for the demonstration, an .STL is fine. • Siew then asked if it would be enough to just specific in the user manual how to obtain a model manually since the PDS did not specify that this process had to be automatic. Dr. Schwingshackl said that this would be fine and even for the demonstration, the process can be carried out manually for a single scan but do not repeat for seventy-four scans. • Siew said that he had already spoken to Dr. Muscutt about scanning shiny objects and has considered preparing the samples prior to scanning using talc powder or alcohol. • Dr. Salles asked if using a different camera position would remove the reflection of light captured in the photo but Siew said that there is a limit to the distance between the camera and projector so some reflections will always be present. • Siew said that Dr. Muscutt could not give any alcohol to take out of the lab but it can be used inside the lab so he plans to try it next week. • Dr. Schwingshackl asked whether the cloth would be blocking the light anyway but Dr. Salles reminded him that the projector generates light which causes the reflection. Dr. Schwingshackl apologised that he had forgotten the working principle of the design. • Siew said that the object rotates so the reflected line moves but still interferes with the model. Dr. Salles said that even GOM scanners use treatment on their objects e.g. powder. • Siew said that he had issues with camera exposure so he borrowed a Nikon DSLR from Dr. Muscutt for testing. Dr. Schwingshackl asked if the camera belonged to him but Siew said that the camera belonged to the lab. He is currently working on trying to connect the camera with a Python script. • Siew previously tested his phone using IP Webcam which set-up his phone like a webcam. Dr. Schwingshackl asked what this was for and Siew replied saying that this allowed him to adjust the resolution and exposure. • Dr. Schwingshackl suggested using a filter on the camera to reduce the reflection but Siew responded with concern that the image may warp or become distorted. • Dr. Schwingshackl said that it would be good to get on with the testing as soon as possible and check that the overall set-up works. **Gantt Chart:** • Siew showed the group's current position in the Gantt chart and said that the group is on track. • Still need to assemble the AC/DC converter which should be completed in the next two days. • The pulleys arrived on Friday [6th March] so still needs to be bored out.
Filled in by:	Hussain

Date & Time:	Thu 19th March, 1025
Agenda:	DMT Submission, final report.
Members present:	Dr. Salles, Hussain, Siew.
Minutes:	• Siew started off by saying that the design has been assembled and left in the IDEAS space with a document attached to the assembly explaining each component's role along with all completed tasks and anything that has been left incomplete. A copy has also been sent to Dr. Salles. • Testing could not be completed as it was supposed to take place during the final week of the semester. • Siew asked how the marking of the project will be affected and Dr. Salles said that he is not too sure. He has received an email that gave some guidelines due to the

	Coronavirus but nothing specific yet. Also, Dr. Salles said that this should have been considered in the risks to completion of the project. • Siew went on to say that he still has the camera, projector and his phone so asked if the group should continue working on the software. Dr. Salles said that the group can continue to work on it but it will be more difficult now since the turntable cannot be used. • Siew was concerned about being penalised for taking the camera and projector since they were bought with the College's money but Dr. Salles said that this is not an issue. • Siew was also unsure about returning the camera borrowed from Dr. Muscutt and whether he should return it in the next academic year. Dr. Salles said that it would be best to email Dr. Muscutt directly. • For engineering excellence, Siew asked if the supervisors would be contacted since the supervisors would be better able to explain if the design is correct and to the appropriate standard. Dr. Salles said that he received an email from Dr. Bluck which said that engineering excellence will be reviewed externally i.e. by those other than the supervisors and he does not have any extra information. • Lastly, Siew said that Taha left London last Saturday [14th March] while CS and Jeremy left yesterday [18th March]. Siew will be leaving in two days and Hussain will be staying in London. • Future meetings will be of the format of a video call and this will continue indefinitely due to the pandemic.
Filled in by:	Hussain

Date & Time:	Thu 2nd April
Agenda:	Remaining DMT Work
Members present:	Dr. Salles, Dr. Schwingshackl, Hussain, Siew, Taha, Jeremy, CS.
Minutes:	• Siew asked if supervisors had seen the previous minutes which detailed what had been done and what had been left incomplete. • Siew said that this meeting was called because of Dr. Silversides' email which set out the options for groups to choose from that would form the remainder of the DMT project. The group wanted advice about what to do. • Dr. Schwingshackl asked if the group still had the camera and if the group is continuing work on the scanner. Siew replied that since it is Easter break, the group is studying for exams. He is still trying to get a script working with the camera since Luke said that it was okay to bring it back in fourth year. Dr. Schwingshackl said that the camera is quite old so it might be difficult to connect. • Dr. Salles suggested manually taking images and importing them to the computer. • Dr. Schwingshackl reminded the group that this was a Design, Make and Test project so it is possible to say that the group focused on the mechanical side so far and did not manage to complete the software aspect. One option could be to leave the software for next year where another DMT group or a fourth-year student could continue the project as long as the turntable still works. • The final week of the semester was supposed to be an intensive week of testing but did not take place. CS added that the mechanical testing was complete but there was not enough time for the electrical testing. It might be worth estimating how many hours would have been spent on testing and use it for the project in another way since the last three weeks after exams will probably not be spent only writing the final report. The group could continue working on the software since the entire group cannot be involved in testing or FE analysis could be carried out. • Dr. Salles said that if any help is needed or if the group would like someone to check the code, he would be able to help. • Siew continued by asking if there was anything that should be included in the final report that the supervisors felt previous groups lacked. Dr. Schwingshackl responded that the reasoning behind design decisions is sometimes not clear and it appears that

	students just went for it and hoped for the best. He recommended that key decisions are explained but this does not mean everything. For example: an explanation for the choice of turntable decision might be relevant as well as any tests performed along with the results and how they influenced decisions. Group could also include the lessons learnt from any mistakes and if the upgrades implemented did, in fact, fix any issues. • Dr. Schwingshackl added that, personally, he would like to see an overview of the basic concepts of the design in its initial stages and then more detailed considerations pertaining to motor selection etc. and then any changes that were needed e.g. transmission. In this case, it is not possible to prove that the design works but the group can instead say that the transmission almost provided enough torque in the last iteration so by doubling the torque, quite certain that the torque requirements have been met now. Students tend to lack this. • Furthermore, Dr. Salles
Filled in by:	Hussain

Date & Time:	Wed 20th May
Agenda:	Additional work package, timeline, final report.
Members present:	Dr. Salles, Hussain, CS, Taha, Siew, Jeremy.
Minutes:	• Siew started by asking if the user manual could be submitted after all the deadlines and Dr. Salles replied that this was acceptable but this would have to be stated in the final report. Jeremy asked if there was any deadline for the user manual submission and Dr. Salles said that it should be submitted before the end of the year. **Additional work package:** • Siew asked if any additional work package would be necessary since the manufacturing was completed last semester. If yes, some proposals were shown based on what the group could think of but it is possible to carry out alternative work if these options are not suitable. Dr. Salles looked over all the options and said that the group could work on the integration of the DSLR. • Siew wanted to clarify that Dr. Salles wanted the group to automate the scanning process for the DSLR as this is a repeat of what was carried out for the webcam. Dr. Salles then asked Siew to run through all the options • Siew said that the first option is to automate the scanning process using the DSLR, the second option writes a script to include multiple cameras so that different angles can be incorporated into the scanning process and the third option is more related to testing the scanning process under different conditions and surface finishes. • Dr. Salles asked what the current state of the scanning was and Jeremy replied that not much testing had taken place since the testing object is not with him but Dr. Salles said that under these circumstances, a different object can be scanned in its place. • Siew said that the point cloud resolution is less than 0.5mm but this is difficult to test without the testing object. • Dr. Salles said that the third option seems to be the best because the second is outside of the scope of this project and the first means that the scanner becomes dependent on the camera. • Dr. Salles added that the group should also show a model. Jeremy questioned this since a model was already shown in March but Dr. Salles said that the group showed pictures from different angles, a point cloud and a model or STL file. Some defects were present but this was expected as it was a work in progress. **Timeline:** • The overall timeline was shown with the hard deadlines highlighted in red. **Final Report:** • Dr. Salles said that he cannot give any specific feedback. • The overall structure of the report was shown and Siew asked if there was anything that the report seemed to be focussing too much on or lacking. Dr. Salles asked what

	project organisation meant and Siew explained that it referred to the different roles allocated to group members as well as the design methods used like the double diamond and iterative processes. • Dr. Salles questioned whether two pages would be sufficient for the prototype testing. Siew replied that the testing procedure and results would be contained within that section but discussion of the results and the subsequent changes to the design would be written in the following sections. • Dr. Salles asked what the budget section would contain. Taha explained that the amount debited from the supervisor account was £829.92 but the ME stores is unable to process any invoices at the moment. As a result, an estimate was made to bring the total to £971.38 which is still within budget. • Overall, the report outline looks fine according to Dr. Salles. Siew asked if there was anything that should be included based on what groups lacked in previous projects. Dr. Salles responded that he has no previous experience with DMTs but he did say that the executive summary should contain the key points from the conclusion. Additionally, Dr. Salles said that there is no need to include a script as this should be put into the repository instead. • Siew asked if the GitHub repository should be made public as the external marker will be unable to access the scripts if left private. Dr. Salles said that the scripts are still a work in progress so should be kept private and the external marker can request access from the group. However, Siew pointed out that the group should not know who the external marker is so instead, it was suggested to give Dr. Salles administrative control so that Dr. Salles can provide the external marker access. • Taha wanted to clarify that for the budget, processing costs have not been included that would be incurred in real-life, such as for laser cutting or CNC. Dr. Salles said that this is unimportant but he understands that what the department wants may be different since they are training students to work in industry. • Siew said that the meeting minutes and slides will be sent to both Dr. Salles and Dr. Schwingshackl. He added that written confirmation of the additional work package would be necessary so that will sent along with the minutes.
Filled in by:	Hussain