UNIVERSITY OF CAMBRIDGE

DEPARTMENT OF ENGINEERING

1B Integrated Design Project

Michaelmas 2016-2017 - Block M1

MOBILE ROBOT

LOGISTICS
WEEK ONE TASKS
TIMESHEET

Team:- M1...... (......)

If found, please return to/notify:

Name:- ....

College:- ....

CrsId:- ....

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Issue date : 01/10/16

The Department would like to thank the many companies, organisations and individuals who have supported the course since its inception in 1996, in particular:-

Boeing	-	www.boeing.com	Cambridge-MIT Institute	-	www.cambridge-mit.org
iEndian	-	www.iendian.com	Martin-Jones	-	www.martin-jones.com
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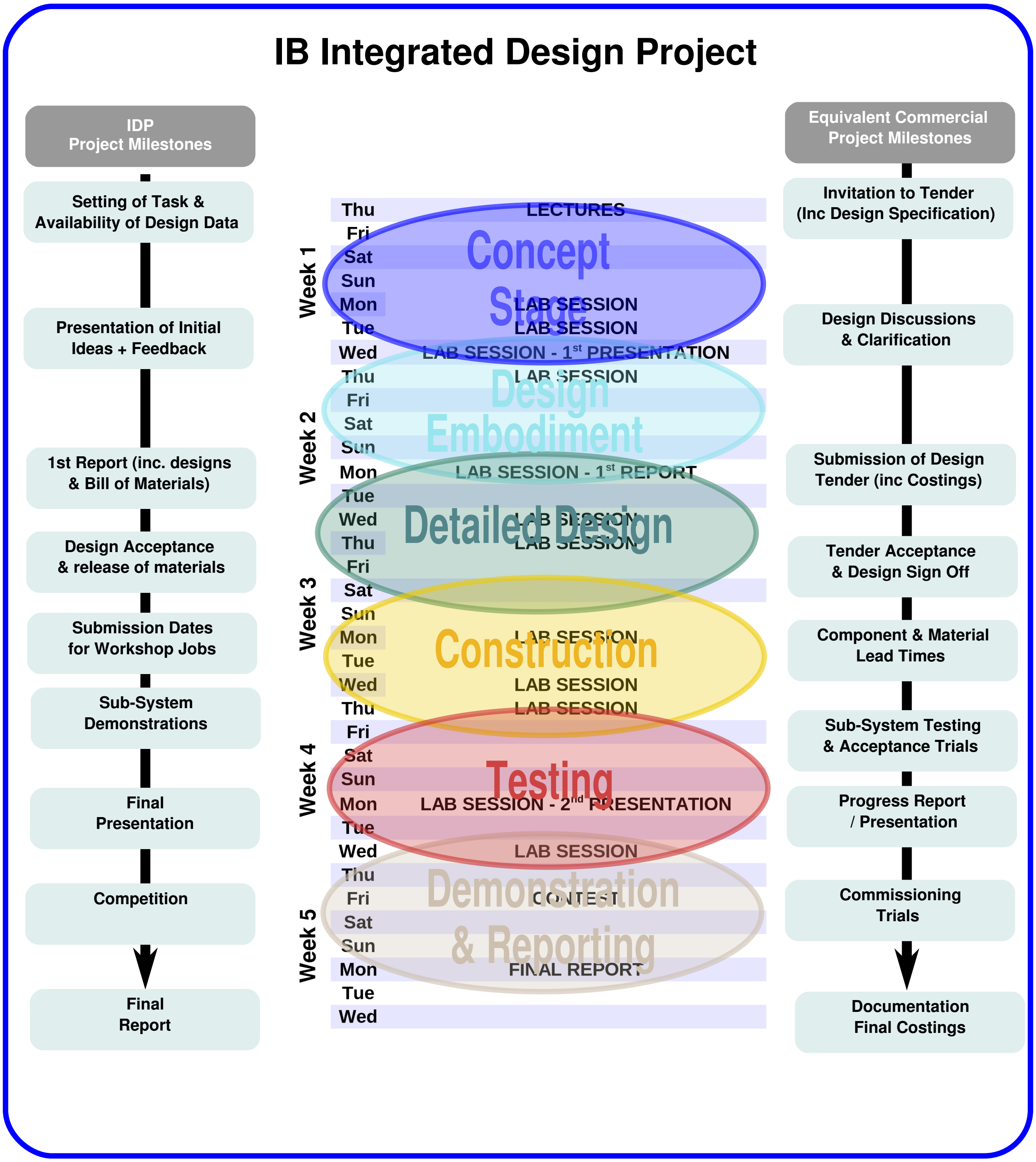
Robin Jackson (1937 - 1995) was a major influence in the development and implementation of the IB Integrated Design Project and was responsible for much of the Logistics and Electronics material contained within.



Contents

LOGISTICS

L.1 Introduction

Modern design often requires an integrated system to be designed by a multi-disciplinary team. This design, build and test project is intended to simulate this situation. The disciplines represented are Electronic, Mechanical and Software Engineering.

This document describes the overall aims and objectives of the Integrated Design Project and sets out the logistics for its organisation. It also in some cases (for example the sections on report writing) provides an overview to be read in conjunction with more specialised material in the other documents.

The project involves designing and building a model Autonomous Guided Vehicle (AGV) or mobile robot from a kit of parts. It is a mechanical device with associated electronic circuits and control software. The combination is often categorised by the term mechatronics. The task to be undertaken by the AGV is given in a separate problem statement issued at the start of the project.

Credit is given for the planning and execution of the design and construction process, the quality of the complete vehicle and its performance of the set task. Performance is assessed in a competition held shortly after each four week project period.

The documentation in this handout plus a large amount of other material is available on the IDP Web site: `http://www.eng.cam.ac.uk/DesignOffice/idp/`.

L.2 Aims and Objectives

The underlying aim of the project is to develop system design skills. In parallel, it aims to develop design project management skills and to create an appreciation of the interaction between design and production.

The project should help you to:

- appreciate the nature of systems design.
- appreciate the importance of co-ordinated teamwork and project management.
- apply and integrate the engineering principles taught in Part I.
- understand how to produce detailed design proposals.
- gain experience of building and testing a system once it has been designed.
- produce design and construction documentation.
- write and present reports on a design and on the resulting system.

L.3 Project Organisation

The Integrated Design Project runs in four Blocks in the first and second halves of the Michaelmas term (Blocks M1 and M2) and the first and second halves of the Lent Term (Blocks L1 and L2). In each Block there are up to 15 Teams, each of six students. The Team Identifier (which is used to identify robots and kits of components and is required on reports) comprises the Block and a two digit Team number, e.g. M205 (for team 5 in Block M2).

The whole team is responsible for the overall systems design and for the integration of the electronic, software and mechanical sub-systems to form the complete AGV. Each team will also need to organise itself into sub-teams responsible for the mechanical, electronics and software aspects. The division of people between subteams may vary according to differing requirements at different stages of the project.

L.3.1 Project Management

An important factor in the success of a team in this project and in the success of all engineering projects involving more than one person is effective team management. Some aspects of the project management have in effect been predetermined: the teams have six members, work areas are preallocated and the short unalterable overall timescale imposes constraints on project timing. Other aspects are left to the teams to organise, for example:

- allocation of people to sub-teams and management of these sub-teams
- communication between sub-teams to ensure that the individual components are compatible
- detailed timetable (e.g. in the form of a Gantt Chart) to ensure that one sub-team does not delay the others
- redeployment of manpower between sub-teams in the event of slippage in some area
- best use of manpower during integration
- team organisation during the competition
- production of coherent documentation throughout the project

When defining the project timetable it is important to list all the key tasks to be undertaken, to estimate their duration and resource requirements and to identify prerequisite and dependent tasks. Careful planning at this stage can save a great deal of time later, particularly during system integration.

It is clearly important for the members of the team to meet regularly throughout the project to co-ordinate the work in the sub-teams and to ensure that the overall design objectives are met. The project timetable should provide a useful basis for discussing progress. You are likely to find that the timetable has to be refined during the course of the project!

Each team is asked to select a team co-ordinator who can act as a contact for the team. In most teams, this person will also be responsible for providing the team management, though other less rigid structures may also be effective.

L.3.2 Work Areas

The project headquarters is in the Electrical and Information Engineering Teaching Laboratory (EIETL) and most of the project work is done there. The main exception is that, after the team activities concerned with the initial planning stages, the mechanical sub-teams move to the DPO and the Instrument Workshop (1st floor of the Workshops alongside the DPO) for the detailed embodiment design and construction stages of the project. Workstations are also reserved in the DPO for some sessions. The final integration and testing stages of the project, and the competition are again team-based and in the EIETL. Even when working elsewhere, you must still attend the EIETL to sign in (see section L.5.2).

Where possible, access will be provided to these work areas outside the timetabled laboratory periods; but, apart from the DPO, none will be open before 08:30 or after 17:30 and availability should be checked with a demonstrator beforehand in a timetabled session. You must plan on the basis of having only limited time in any of these areas between the end of the timetabled project sessions and the competition.

				Subteam working Loc		
				Mech	Elec	Soft
WEEK 1	**Thu**	**09:00-11:00**	**Lab Session**	L	L	L
		09:00	Introduction Lecture (LT 1)			
		10:00	EIETL Orientation			
		14:00	Management Lecture			
	Fri					
	Sat					
	Sun					
	Mon	**11:00-13:00**	**Lab Session**	E	E	E
		11:30	Workshop Orientation (Teams 1-7)			
		12:00	Workshop Orientation (Teams 8 - 14)			
		12:15	Software Talk (SAM Meeting Room)			
		12:15	Electronics Talk			
		14:00	CAD Revision talk (DPO)			
	Tue	**09:00-11:00**	**Lab Session**	E	E	E
	Wed	**09:00-11:00**	**Lab Session**	D	E	E
		09:00	First Presentations ♦			
		14:00	CAD Revision talk (DPO)			
WEEK 2	**Thu**	**09:00-11:00**	**Lab Session**	D	E	E
	Fri					
	Sat					
	Sun					
	Mon	**11:00-13:00**	**Lab Session**	D	E	E
		13:00	First Report Due ♦			
		13:00	Submission of Parts List			
	Tue					
	Wed	**09:00-11:00**	**Lab Session**	D/W	E	E
WEEK 3	**Thu**	**09:00-11:00**	**Lab Session**	D/W	E	E
		11:00	End of 100% for DA ♦			
	Fri					
	Sat					
	Sun					
	Mon	**11:00-13:00**	**Lab Session**	W	E	E
		13:00	End of 85% for DA			
		13:30	Chassis Painting Available			
	Tue	13:30	Chassis Painting Available			
	Wed	**09:00-11:00**	**Lab Session**	W	E	E
		11:00	End of 70% for DA			
		13:30	Chassis Painting Available			
WEEK 4	**Thu**	**09:00-11:00**	**Lab Session**	W/E	E	E
		11:00	0% DA			
		09:00	Robot/Sub-system Demo			
	Fri					
	Sat					
	Sun					
	Mon	**11:00-13:00**	**Lab Session**	E	E	E
		11:00	Final Presentations ♦			
	Tue					
	Wed	**09:00-11:00**	**Lab Session**	W/E	E	E
	Thu					
	Fri	**09:00-12:00**	**Competition M2/L2**	E	E	E
	Sat	**09:00-12:00**	**Competition M1/L1**	E	E	E
	Sun					
	Mon	17:00	Final Report Due M2/L2 ♦			
	Tue					
	Wed	17:00	Final Report Due M1/L1 ♦			

Table 1: Project Timetable showing critical events. [Locations L= LT1, E=EIETL, D= DPO, W= Workshop] (See following sections re details of sessions/submissions ♦ - Milestone)

L.3.3 Timetable

Table L.3.2 shows the complete timetable showing the approximate sequence of tasks in terms of team and sub-team activities is attached as an appendix to this document.

The project sessions on the coursework rota are on Monday from 11:00 to 13:00, and on Wednesday and Thursday from 09:00 to 11:00. As with other practicals, you are expected to turn up on time for these sessions.

Key intermediate milestones in the project are: the start of construction; and the start of system integration. You should aim to reach the first milestone in the middle of week 2 and the second milestone at the end of week 3, as suggested in the timetable referred to in L.3.3 above.

Each team will need to produce its own detailed timetable, including the action to be taken if the proposed timing for any stage of the project proves incorrect. This needs to ensure that **the three sub-teams can work in parallel**, i.e. that one sub-team does not have to waste time waiting for a sub-system to be delivered by another.

L.4 Deliverables / Assessed Work

The assessment is split in two with the qualifying standard for the design/build/test phases (Section i) being 28 marks and the reporting phase (Section ii) being 11 marks.

Section	Activity	Weight	Marked per
i)	Initial Presentation:	15%	Team (individual attendance required)
i)	First Report:	20%	Team
i)	Initial BoM	5%*	Sub-team
i)	Design Acceptance:	15 %	Sub-team
i)	Basic Functionality Demo:	9%	Team/Sub-team
i)	Final Presentation:	15%	Sub-team (individual attendance required)
i)	Robot Quality (sub-team):	6%	Sub-team
i)	Robot Performance:	15%	Team
ii)	Final Report (Appraisal):	65%	Individual
ii)	Final Report (Documentation):	35%	Sub-team

Sub-Team marks will be divided amongst team members in proportions agreed amongst the team members and specified in part of the Final Report Documentation. The distribution for a team of six is subject to the following constraints:

- the total contribution for a team member across the four areas will normally total 100% (except if the team agree otherwise). This total will also be used to apportion the team marks.
- the total contribution for all team members will total 600% (thus if one team member has made a less than 100% contribution, others must have made more than 100%, but this will be capped at 125%)
- the total contribution towards in any area must be less than 300%, typically between 100% and 300% in technical areas and below 40% in admin.

For teams of fewer than 6, the unfilled places will be treated as members making a 0% contribution (ie the total for all team members will remain 600%). For teams of more than 6, the totals will be scaled accordingly; e.g. for 7, the total available would be 700% and the total per technical sub-team would be in the range 175% to 350%.

Demonstrators have discretion to vary this distribution of marks if it is clear that it does not fairly reflect the contributions of some team members.

Each activity, apart from Design Acceptance and the Functionality Demos, is marked on the following scale:

Mark	Approximate Standard
70-100%	First Class (80+ exceptional)
60-69%	II.1
50-59%	II.2
40-49%	III
0-39%	Fail

Reports may be handwritten or word-processed. Each report will be marked by a demonstrator and returned with written feedback. **Marks are awarded for the content of reports not on a per page basis** and markers will deduct marks for excessive length. This applies especially to the Final Report, see section L.4.9).

L.4.1 First Presentation - [*15% Marks - Team*] (Individual attendance required)

An initial oral presentation is given by each team in the last session of the first week of the project, ie the Wednesday at the end of Week 1 (of Term) for M1 and L1 and of Week 5 for M2 and L2.

Each team has 10 minutes for its presentation + about 5-10 minutes discussion at the end. Each team member is expected to attend the presentation. A list giving the time and location of each team's presentation will be posted on the IDP noticeboard in the EIETL.

The presentation is informal but should be professional. Each team should produce between 5-10 printed slides, covering the topics below:-.

1 - Overall Plans, strategy and team name
2 - Mechanical design/Layout
3 - Plans for electrical Sensors/Interfaces etc
4 - Software layout/construction (inc Failure detection)
5 - Job allocation/timescales
\+ - Appropriate sketches, cardboard models etc

A printed copy of which should be handed to the demonstrator at the beginning of the presentation. An electronic copy must be posted in the teams area on the bulletin board immediately after the presentation.

You will need, as a team, to think about how the individual contributions fit together and the overall timing, so as to ensure a professional impression. A whiteboard and/or overhead projector will be available for sketches and notes done at the time.

L.4.2 First Report - [*20% Marks - Team*]

The first report is to be handed in to the demonstrators during the middle session of the second week of the project, ie the Monday of Week 2 for M1 and L1 and of Week 6 for M2 and L2. They will marked and returned with comments during the next or next but one session, ie on the Wednesday or Thursday.

The aim of the First Report is to provide written documentation of the team's work in the initial overall system design phase of the project. It thus covers similar work to the Initial Presentation but should include more detailed engineering documentation rather than a narrative description. It is marked primarily on the quality of the design process followed, in particular the clarity and scope of the specifications, selection and evaluation of concepts and the overall ability of the robot to perform the task.

The report **must** contain:

- A coversheet specifying the team identifier, team name and robot name together with the name, lab group and College of each team member
- A solution neutral problem statement
- A requirements specification (the requirements should be quantified wherever possible)
- Sketches of the concepts you have considered (which may be photocopied/scanned from your lab book)

- Evaluation charts of these concepts together with a **brief** discussion of the advantages and disadvantages of each
- Specifications of the interfaces between subsystems and an outline of the framework for their integration (e.g. electrical signals and their relationship to the software, the position of major electrical and mechanical components on the chassis, the major components of the software subsystem, etc.)
- An outline of project management plans, including a project timetable (e.g. in the form of a Gantt chart) and details of work allocation to team members within the framework defined by the timetable
- Initial calculations, test results, the output from any software packages used as a design tool , etc. as needed to support design decisions

Sub-Team Specific requirements for the first report

Mechanical

1. Scaled orthographic **Drawing(s)** (or sketch(s)) of the overall robot on A3 paper showing the:-
   - Overall dimensions
   - Location of major components, inc sensor positions

   (Sketching/ graph/ isometric paper is available in the EIETL and DPO)
2. Discussion/calculations as a result of initial experiments with test facilities and demonstration materials.
3. Initial **BoM** - see section L.4.3

Electrical

1. **Results** of the initial experiments (See IDP website for details)
2. **List** the sensors and actuator circuits required
3. **Discussion** of the trade off between using hardware/software
4. Initial **BoM** - see section L.4.3

Software

1. Results from Discussion of the significance for the design and implementation of the robot system of the results of those initial experiments (See website for details) so far conducted.
2. Discussion of
   - Overall software layout, inc sub-system/subroutine communication
   - Timing issues
   - Recovery strategies
3. Initial **BoM** - see section L.4.3

L.4.3 Initial Bill of Materials - [*5% Marks - Sub-Team*]

In the planning of a project it is useful to have a idea of the resources that will be required, to aid in costing and procurement. Due at the same time as the first report, each sub-team should submit an initial 'Bill of Materials'. If not supplied or the content is substantially different from the BoM supplied at Design Acceptance, see section L.4.4, the mark is reduced to 0%. The individual BoMs should contain

Mechanical - Estimation of the amount of raw material required to complete the construction, list/quantities of mechanical items required, inc gears, springs, wheels etc but excluding fasteners.

Electrical - List/estimated quantities of components required to complete the sensor and control circuitry, inc number of PCBs, sensors, active/passive components and connectors

Software - Estimate of the number of lines of code and number of source files

NB Each of the BOMs (Mech/Elec/Soft) must be supplied as separate documents and also an electronic copy placed in the teams bulletin board area.

L.4.4 Design Acceptance - [**15% Marks - Sub-Team*]

Sub-teams are required to have their detailed design checked by a demonstrator **before starting construction**. This is a relatively informal process with a *pass/try again* decision.

Design Acceptance takes place when a sub-team is ready; there is no fixed time for this (**other than being during a timetabled session**). A sub-team may wish to have the detailed designs for different parts of its system checked at different times. This is acceptable provided that an outline design for the complete system is available and is itself acceptable. It is not intended that design acceptance should be sought on a totally piecemeal basis, more than three separate elements would not normally be expected. The marks will not be awarded until the complete sub-team design has been accepted.

Design Acceptance completed before 11:00 on the Thursday of week 3 gains full marks; during the following week the available marks drop by 15% per session until 11:00 Thursday week 4 after which **no** Design Acceptance marks will be awarded. **If any sub-team gets no Design Acceptance marks, the entire team will get none.** This is to emphasise the whole team's responsibility for ensuring the timeliness of this process.

*N.B. As described in section L.4.3 the mark for the initial BOM is lost if it is substantially different from the BoM supplied with the DA documentation.

The purpose of Design Acceptance is to ensure that proper engineering practice is being followed and that the design is viable. The documentation must be sufficient that the sub-system could be constructed by a competent technician without the need to refer back to the designers. The amount of documentation is likely to vary with the specialisation, with mechanical (by the nature of the task) requiring the most. All documentation (Drawings, Circuit diagrams, listings) should be clearly identified using a label containing, at least, the information shown in the example below:

Drawing No:	Title:
Team:	Scale:
Drawn by:	Accepted by:
Date:	Date:

A design being passed should not be regarded as a guarantee of quality other than that it is adequate to prevent sub-team expending a large amount of effort constructing something which is **clearly** not viable or is **likely** to prevent the team as a whole completing the project.

Sub-Team Specific requirements for Design Acceptance

Mechanical Design acceptance is given on the basis of the manufacturing drawings you produce which should include:-

- Overall assembly and sub-assembly drawings
- Manufacturing drawings of ALL individual parts
- *† Document including a final/updated parts list/BoM]
- *† A list of three sub-systems, (one normally the rolling chassis), which will be demonstrated as part of the 'Basic Functionality Demonstration', see section L.4.5.

See the IDP website and posters in the EIETL for examples of the drawing standards required. In addition to drawing quality, the demonstrator will also consider the viability (both operational and manufacturing), the safety and the adaptability (how difficult it will be to modify later, if required) of your design before accepting it.

Before you prepare these drawings, you may find it helpful to review the "Assembly Drawings" handout from your 1st year notes, and the various CAD/Creo support materials available on the IDP website.

Electrical Design acceptance Electronics is a two stage process:-

1. **Initial stage** The demonstrator will:
   - Check the circuit diagram is prepared according to the guidelines given (see examples in EIETL and on the IDP website)
   - Check the functionality of each block (without giving a guarantee that a given circuit will work), and that it is designed with reasonable efficiency of component usage.
   - Check that the power supply estimates for all functions have been completed, and that the available power is not exceeded.
   - Check for some evidence of testability, eg test points, diagnostic leds, possibility of injected test signals if appropriate.
   - Check that attention has been paid to the interfaces with the software and mechanical aspects of the design.

   You should be prepared to explain and justify your design to the demonstrator, as well as show supporting calculations e.g. to determine component values.
2. **Final stage** The demonstrator will check
   - †Wiring layout diagram
   - *† list of three sub-systems, (one normally the line following board), which will be demonstrated as part of the 'Basic Functionality Demonstration', see section L.4.5.

Software Before accepting your design, the demonstrator will expect to see documentation sufficient to allow a competent team of programmers to produce a working system conforming to your design,
Your documentation should include:

1. the overall function of the software system (e.g. using flowcharts);
2. its structure in terms of the interaction of the component parts (e.g. datatypes, functions and procedures);
3. its interface to the other subsystems (e.g. pin allocation on chips);
4. example datatypes and low level procedures (e.g. those developed during the initial testing process).
5. *†'BoM', list of subroutines + associated size
6. *† A list of three sub-systems operations, (one normally line following >0.75m), which will be demonstrated as part of the 'Basic Functionality Demonstration', see section L.4.5.

†, electronic copies of all documents marked with a 'dagger' should be posted on the teams bulletin board. Any subsequent modifications to these documents should be submitted as separate documents.

L.4.5 Basic Functionality Demonstration - [*upto 9% Marks - Team/Sub-Team*]

Timely completion of sub-systems significantly improves the chance that the overall project will be successful and is a common requirement in industry. Credit can be obtained for the demonstration of upto 3 subsystems to a demonstrator before the end of the final Monday session.

4% of the total marks are available to all the sub-teams if a combined completed chassis/Line following circuit/line following program (inc a turn) is demonstrated by the end of the first (Thursday) session of the 4th week of the project. (The mark is reduced to 3% if the functionality is not demonstrated until the final Monday session. If the functionality has to be demonstrated on the test chassis only 50% of the available marks will be awarded and only to the Electrical and Software sub-teams)

An additional 5% of the total marks (4% if demonstrated by the end of the final Monday session) are available to sub-teams who demonstrate two further individual sub-systems (i.e. 2.5% [2%] for each) e.g.:

Mechanical Completed/working mechanisms, working actuators systems.

Electrical Demonstrable sensor conditioning, working actuator drive circuits, discrimination circuits.

Software

Line-following (inc corner/junction), Alignment for pickup, control of actuators (where appropriate), alignment for delivery.

If the robot is not fully integrated, simulation by injection of signals or trial data will be accepted. Only two chances/session to demonstrate an operation will be given and the demonstrators' decision is final! [**NB Only sub-systems/operations listed in the documentation submitted with the design acceptance documents will be accepted for demonstration**]

L.4.6 Final Presentation - [*15% Marks - Sub-Team*]

Each team is required to make a final presentation of its work on the project in the penultimate project session, ie the Monday of the fourth week of the project. (Week 4 of term for M1 and L1 and of Week 8 for M2 and L2.) This presentation should concentrate on the detailed design work of each sub-team and the subsequent production of the robot.

The arrangements for the Final Presentation are similar to those for the Initial Presentation except that each team's session lasts 25 minutes. The presentation should last approximately 15 minutes leaving a 10 minute discussion period at the end. The presentation is done as a team but different marks may be awarded to each sub-team depending on the quality of their contribution.

As with the first presentation a printed copy of the 5-10 slides used should be handed to the demonstrator at the beginning of the session. An electronic copy must also be posted in the teams area on the bulletin board immediately after the presentation.

The presentation should cover the following topics:

- Brief review of the overall design strategy
- Sub-team designs
- Problems encountered during implementation
- Changes to the original design and reasons for these
- Remaining problems *
- Brief statement of likely performance in the competition.

*- If a team still has technical problems after the presentation please place a posting on the 'Ask the Experts' bulletin board before 5pm on the final Tuesday to aid scheduling during the last session on Wednesday.

L.4.7 Competition - [*15% Marks - Team*]

The competition for blocks M1 and L1 takes place on the Saturday morning and for M2 and L2 on the Friday morning following the end of the project.

Each member of a team whose robot successfully performs the task set will receive a First Class mark (typically 75%, higher for the best robot or robots). Performance marks will be reduced for teams whose robots are not completely successful in completing the task, require manual intervention or incur penalties during the competition. Teams whose robots fail to attempt the task will normally receive Fail standard marks for Performance.

Following the competition, photographs will be taken of the robot and put on the IDP Web site, whence they can be downloaded for inclusion in the Final Report.

L.4.8 Robot Quality - [*6% Marks - Sub-Team*]

Quality will be assessed and marks allocated by the demonstrators following the competition at the end of each block. Team quality will focus on the overall concept and its embodiment.

Mechanical

- Quality of construction
- Appropriate simplicity
- Robustness
- Ease of assemble/disassemble to accommodate repairs and modifications

Electrical

- Neat, logical component layout.
- Good use of wire colour-coding, routing and test points in order to aid diagnostics and circuit de-bugging.
- Quality of soldering and other circuit construction techniques such as correct use of IC sockets and other connectors.

Software [N.B. A complete printed copy of the listing must be supplied at the end of the competition]

- readability and maintainability of the program
- smoothness and speed of movement especially when line following
- provision for error recovery

NB The Assessment will take into account if the team has made use of the loan of any pre-built parts, e.g. Line Following boards, during the design and construction phase of the robot.

L.4.9 Final Report [*65% Marks - Individual, 35% Marks - Team*]

The final report comprises two elements: an individual assessment of the project as a whole; and a team report consisting of a compilation of design and implementation documentation produced during the project. Both reports are to be submitted on the Wednesday after the project ends for blocks M1 and L1, and on the Monday after the project ends for blocks M2 and L2. The reports will be marked and returned at the beginning of the following term.

L.4.9.1 Engineering Assessment of the Project - [*65% Marks - Individual*]

The assessment must be written individually and a signed statement is required to confirm this (see below). You may refer to factual material, drawings etc, contained in the team report. Where these are essential to a reader of this report, copies should be included as an appendix. A photograph of the robot should be included.

The report should be a critical technical assessment of the work done and the outcome achieved, including

1. team management aspects of the project – **not** a narrative describing how you did the work on a day to day basis.
2. Major decisions made during the project should be reviewed and comment made on their correctness.
3. discussion should be put in the context of the robot's performance in the competition and that of other different designs.
4. Short discussion (1 paragraph) on the cost of producing the prototype and possible savings for a production run of 100 - 1000 units. (See the inside of the back cover for a personal time sheet and the IDP website for a spreadsheet to help analyse costs)

Your report **must include on the cover**:

- your name, lab group and college;
- your team identifier;
- total word count for the report excluding appendices; and
- a signed statement **declaring the report to be all your own work**. (Any shared material should be included in appendices to the report with references to it in the main text.)

The length of the report should be equivalent to approximately 5 to 6 sides of A4 typescript, including diagrams but excluding appendices. The report **must not** either exceed 6 sides or exceed 2,400 words.

L.4.9.2 Project Documentation - [*35% Marks - Team*]

The Project Documentation should primarily be a compilation of design and implementation documentation and should comprise the following:

- Coversheet (using template on project Web site).
- Table of contents.
- Photograph of the robot (Available from the IDP website following the competition) .
- Sub-team sections containing
  - Documentation submitted for Design Acceptance
  - Any changes to the above should be noted and explained.
  - The material should be divided into sections and indexed so that the reader can find particular items as easily as possible
- Final Gantt Chart (or similar).
- Completed project cost spreadsheet
- Appendix 1: The First Report.

N.B. Project handouts should be used as reference material and not be reproduced in the reports.

L.5 Additional Logistics Information and Equipment Provided

L.5.1 The 1B Robot Desktop Environment

The desktop environment for the project is accessed via the green arrow icon at the bottom of the Teaching System screen and then clicking on the `1BRobot` icon. This environment has desktop icons similar to those for the 1A and 1B Programming Classes plus Pro/Engineer, project management software and a link to the IDP Web site.

If you need help remembering how to use this environment, the online help available via the `CUED Help` icon and thence via the `Introduction to the Teaching System` and `C++` links may be useful.

A special shared group file space is set up for each team for the project. Within this there are folders (or directories) for each team member (named with their login identifier) and a `Common` folder:

- Each team member can read and write files in their own folder and the `Common` folder; and read files in one another's folders.
- There is an icon on their desktop for a team member's own shared folder as well as the usual icon for their private home folder (for unshared files). Double clicking on this shared folder launches the file browser providing access to the folder and to the others in the shared group filespace.
- There is a link created in each team member's private home folder named *idp_shared* pointing to the team's shared folder. This is useful for accessing this folder from programs like a terminal window which start up in the home folder.

L.5.2 Penalties for Lateness

You must ensure that you are signed in by a demonstrator in the EIETL at the start of every timetabled project session. You are required by the Department's Coursework Committee rules to attend these sessions punctually, ie arriving by 09:05; lateness by up to 10 minutes, ie 09:15, will carry a **penalty of one coursework mark**; any later than this the penalty will be **two coursework marks**.

In general work submitted late will not be accepted. The one exception is the Final Report for which **one mark will be deducted for every day late that it is submitted, up to a week (5 working days) ; work will not be accepted more than a week late**.

If you are penalised for late arrival or late handing-in of work due to circumstances beyond your control, you should apply for the recovery of the marks via your College Tutor or Director of Studies using the standard Allowance procedure administered by the Department's Teaching Office.

L.5.3 Laboratory Notebook

You will be issued with a Laboratory Notebook. This is to be used: to record day-to-day activities; to record details communicated to other sub-teams, eg interface specifications; as a sketch book for conceptual design work; and to record calculations relating to the design steps.

The notebook will not be handed in for marking, but demonstrators may check that there is adequate supporting material for things described in the reports and that it has been used correctly with entries properly laid out and dated.

L.5.4 Inventory and House Keeping

At the end of the project you are expected to

1. Clean and clear your teams area in the Workshop
2. Clean and clear your teams area in the EIETL
3. *Complete a inventory checklist of the major kit items and tools supplied to you during the project.

*There will be a charge made if any items are missing. You will be required to supply a cheque made payable to **University of Cambridge** attached to the inventory form to cover the cost of the missing item(s).

L.5.5 Reports

The 1A Exposition Course document *A Guide to Report Writing* by J D Lewins and J A Williams sets out some guidelines for undergraduate reports on experimental and project work. You should reread this document before writing your reports.

Diagrams and other graphical material form an important part of any report (a picture is worth a thousand words).

L.6 Suggestions and Feedback

Suggestions for improvements in the organisation and structure of this project, and for future problem specifications which might be set for later projects, will be very welcome. The Fast Feedback mechanism should be used for this purpose. **Please also complete the section of the on-line survey relating to the IDP as soon as you have finished the project.**

MECHANICAL

MT.0.1 Mechanical - Week 1 Tasks

It is important that the overall size and geometry of a product is defined as early as possible. To aid this requirement you should complete the following tasks during the first week.

1. Investigate/document the materials available and possible structures with suitable strength/stiffness This may require simple calculations based on 1A structures etc and/or simple experiments based on offcuts in the Dyson centre or DPO.
2. Discuss, with the rest of the team, and document the max and minimum size of the overall robot and individual sub-systems.
3. Demonstrate that the chosen size will enable all planned actions to be carried out. (This should be referred to in the presentation and demonstrated in the EIETL)
4. Complete a dimensioned drawing/sketch, and possibly model, of the overall unit and critical sub-systems/mechanisms.

ELECTRICAL

ET.1 Initial Inspection/Testing of Printed circuit boards (PCBs)

You are provided with two prototyping PCBs on which to construct your circuits as follows:

1. **PCB1** - Contains an area customised for the construction of 4 line following circuits, together with connectors for you to plug in the IR emitter/detector assemblies. There is also some area for the construction of other circuits. **You are strongly advised to design your line following circuits (see Figure 1) and to construct them on this area of PCB1**. You should aim to achieve this by the end of week 2 at the latest. This will facilitate a major part of the software and mechanical tasks, namely getting the AGV to navigate the playing area.
2. **PCB2** - Mainly prototyping area for the construction of the remainder of your circuits.
   Both PCBs incorporate customised areas for the PCF8574 chip and its addressing. This chip is used to interface between your circuits and the micro-controller. In addition, they have DB9 plugs (9 pin D-shaped plugs/sockets) which are used to physically stack the boards and to connect together common signals across the boards (ground, 5 V, 12 V, ± 15 V and the SDA/SCL [I2C data and clock] lines)

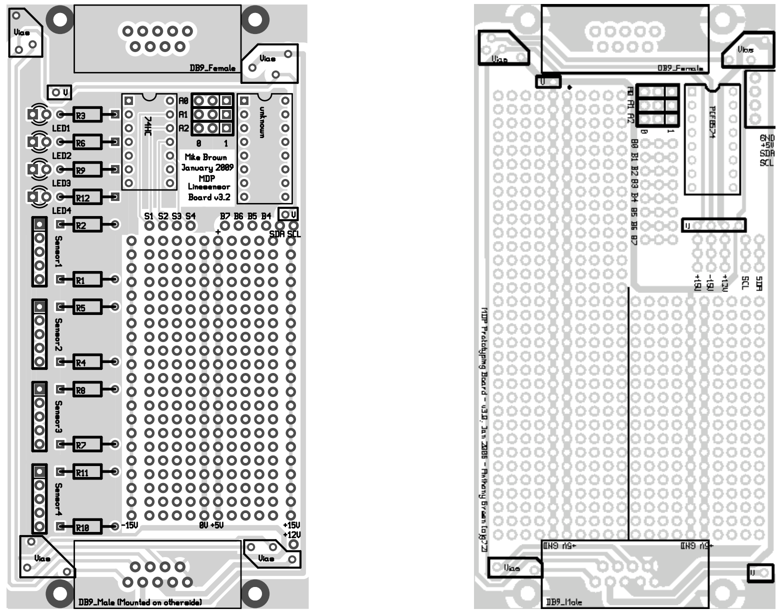
ET.1.1 Customised vs non-customised PCBs

Customised PCBs have copper tracks laid out so that when the various circuit components are soldered onto the PCB, they are automatically connected together as required by the circuit diagram. As such, customised PCBs require minimal construction work, and are therefore very reliable.

Non-customised PCBs (prototyping PCBs) are useful when attempting to design and validate a circuit. Typically they consist of rows of holes connected by copper tracks (in your case 4 holes) together with 0 V and 5 V tracks. Whilst this type of layout is highly flexible and customisable, and is therefore good for prototyping, you will generally need to make additional connections using plastic-coated copper wire. Hence the price paid for this flexibility is increased construction effort and potentially decreased reliability.

ET.1.2 PCB design and construction

Both PCBs are double sided, with tinned copper tracks on both sides, and with holes drilled so that you can insert and then solder components. Solder resist has been applied between the copper tracks to help prevent accidentally creating solder bridges between pairs of tracks. Some of the



(a) Line following PCB(b) Prototyping PCB

Figure 1: Supplied PCBs

PCBs' tracks, as mentioned above, must be connected so that they are common to both boards, and for this to work such tracks require a means of being connected to each other despite existing on opposite sides of the board. Vias are used to achieve this. They are simply holes which have been soldered through so that the tracks on both sides of the board are then electrically connected by the via.

ET.2 Week 1 Exercise and Questions

By performing a few simple exercises with your PCBs, and answering the related questions you will gain the understanding needed to successfully design the layout for your circuits, and hence build them. A good working knowledge of your PCBs will also facilitate any circuit debugging you may need to carry out in the latter stages of the project.

- **Exercise 1**
  Identify the 0V, 5V, SDA and SCL pins of the D-type connectors on PCB1

  PCB Interconnections (D Plug)

1	SCL	6 SDA
2	5v	7 +15v
3	12v	8 -15v
4	12v	9 Gnd
5	Gnd	

  Using a digital multimeter check for electrical continuity of the respective pins ie that the pins have virtually no resistance between them on opposite sides of the board. Find the vias that enable this continuity for each of these signals, and label them on a photocopy of the track layout of PCB1.
- **Exercise 2**
  Stack PCB1 and PCB2 together by connecting male and female D-type connectors together. Now ensure that there is continuity between the 0V, 5V, SDA and SCL tracks on both boards. (You may (if you wish) solder the D-Type connectors in place to help facilitate this task however, you must not solder any other items onto the PCBs without first obtaining design acceptance for the relevant circuitry - See on-line video for help on soldering technique).
- **Exercise 3**
  On PCB1 there is an area of the board devoted to the 4 line following circuits. By looking

at the circuit diagram for the line following circuits (Figure 2 and also the proposed circuit layout (Figure 1) identify and colour in on a photocopy of the track layout of PCB1 the 0V and 5V tracks on the underside of PCB1. Get hold of the data sheet on the Hex Schmitt inverter chip (look in the electrical pages of the IDP website), and by observing the tracks on the underside of PCB1, identify and write down the input and output pin numbers of the Hex Schmitt inverter chip corresponding to each of the 4 line sensor circuits.

- **Exercise 4**
  This exercise concerns the PCF8574P chip, used to interface between your circuits and the micro-controller. First of all, obtain the data sheet for that chip, so that you know what each of the 16 pins is for.

  1. Which are the 0V, 5V, SDA and SCL pins ? Perform continuity checks between the tracks connected to these pins on the underside of PCB1 and the respective pins of the D-type connectors.
  2. To the left of the PCF8574P chip you will see a 3 by 3 grid of pins plus three jumpers which are used to connect pairs of those pins together. By observing the underside of PCB1, find out which pins of the PCF8574P chip are connected to the central column of the 3 by 3 grid of pins. The outside columns of the 3 by 3 grid of pins are connected to 0V and 5V tracks. By performing continuity checks or by observation find out which is which. Hence explain how the jumpers are used to set the address of the PCF8574P chip, and draw on your photocopy of the track layout of PCB1 the jumper positions to set an address of 101.
  3. By tracing the paths of the tracks on the underside of PCB1 connected to the output pins of the Hex Schmitt inverter chip to the input pins of the PCF8574P chip, write down the bit numbers corresponding to each of the 4 line following sensors.

  Complete the above exercises, and submit in your first report:-

  - Annotated circuit diagram of the line sensor PCB
  - Annotated diagram of the component layout on the line sensor PCB
  - Documentation (e.g. tables/drawings) for use within the team showing;
    - Connector usage and pin outs
    - Jumper settings
    - PCF8574 Port allocations

- **Exercise 5**
  Use the sensor test box to confirm you calculations about the current limiting and load resistors in the IR sensor circuit work for **All** your available sensors in the condition they plan to be deployed. The specification given on the datasheet is typical and does not take account of different lighting conditions or damage to the IR filters.

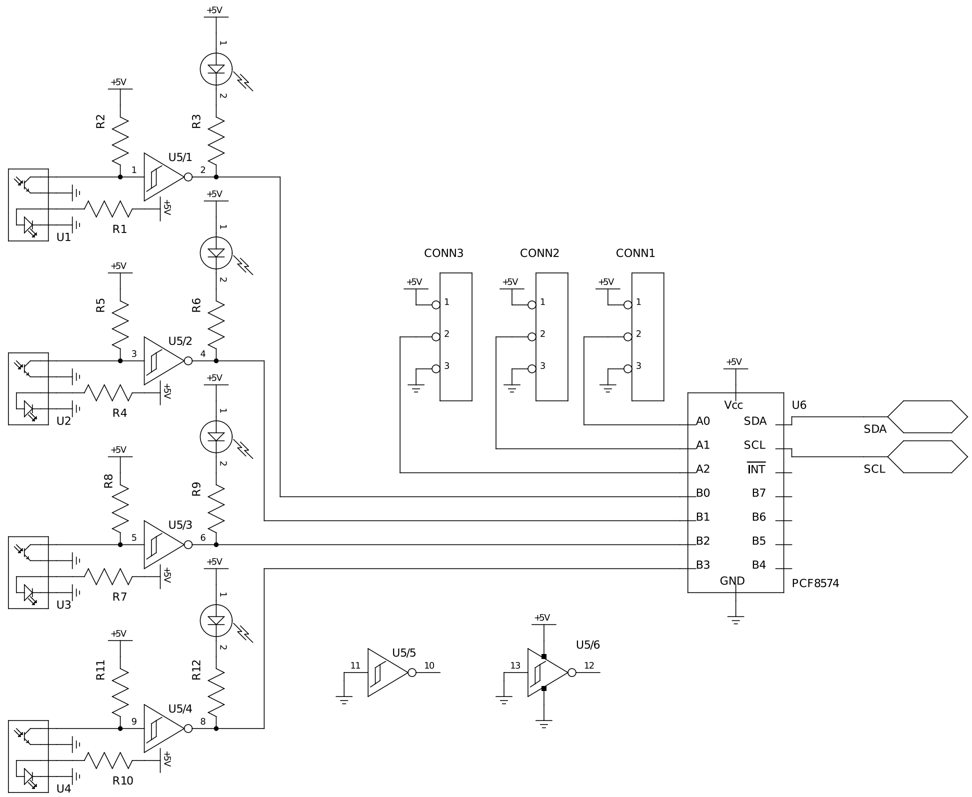


Figure 2: Line Following Circuit

SOFTWARE

ST.1 Week 1 Tasks and Experiments

ST.1.1 Formulating the Software Requirements

You should start to define the functionality of your software at an early stage both to ensure that the software you write can meet the evolving system specification and so that you can start to produce components of it (eg procedures and suitable datatypes) as soon as possible. Bear in mind when designing and writing your software that the design of other parts of the system may have to change due to unforeseen problems and that the software should be easily adaptable to these changes.

One aspect of the design which will need early thought is the line following algorithm since this will depend on such factors as response time and sensor placement.

ST.1.2 Initial Tasks and Experiments

The following tasks can be performed with the basic kit of parts and the test chassis before the mechanical team have produced the real chassis, i.e. starting as soon as the initial system design phase has been completed. Some of the electronics subsystem will be needed for the later tasks so it is important to discuss the scheduling of this with the electronics sub-team. The aim of these experiments is to provide useful design data, to provide a framework for gaining familiarity with the software task and to lead on to the production of software components for the final system. As well as conducting these experiments, it is essential to bear in mind that **most of the software must be written prior to integration with the completed mechanical and electronic subsystems**, i.e. you should aim to have all three sub-systems completed at roughly the same time.

1. Verify that the example test program given in the IDP Handbook will compile and run without

error on the workstation and that the "communications active" LED (see Technical Handbook) lights while the workstation is communicating with the robot. What happens if **i)** the robot is turned off and on while the program is running, or **ii)** the program is stopped and re-run without restarting the robot? Can you detect and recover from errors without restarting the program?

2. Determine the time taken for the complete operation of sending a test instruction from the workstation and receiving a response from the micro-controller. Hint: Use the facilities provided by the `stopwatch` class and, to minimise the effect of program startup time, use a largish number of repetitions of the robot test instruction.
3. Familiarise yourself with cross-compilation for the micro-controller, downloading programs and running these.
4. Familiarise yourself with the operation of the Sensor Simulator (see Technical Handbook). Verify that the simulator can correctly simulate the input and output of data at the addresses chosen for the PCF8574 chip(s) in the circuitry being developed by the electronics sub-team. Pay particular attention to the initialisation required to use **individual** bits (i.e. signals on the chip's input/output pins) as inputs and hence the possibility of using some pins as inputs and others as outputs. Discuss with the electronics sub-team the allocation of signals to the individual bits in these chips and hence develop the routines to read and write the chip(s).
5. Compare the speed of various operations, e.g. reading sensor and ADC values, using a program running on the workstation and one running on the micro-controller. Bear in mind that: the workstation processor is fast but the connection to the micro-controller is limited by bandwidth and traffic; whereas the micro-controller's ARM-based processor is much slower but commands and requests do not need to be transferred over the wireless network. What effect does output to the screen, e.g. for debugging, have on the speed in each case?
6. Calibrate the motor speed and acceleration against the values of the parameters to the motor and ramp commands for all the motors you intend to use (they will not necessarily be identical). This information will be of help to the mechanical designers in determining a suitable wheel size. You should discuss these results with them in light of the figures they have on the effect of load on motor speed.
7. Verify the operation and effect on the Status Register of the emergency stop commands `STOP_SELECT`, `STOP_IF_HIGH` and `STOP_IF_LOW`.
8. Consider, with the Mechanics team, the effect of controller gain and line-following sensor position on the damping ratio and motion of the vehicle. What constraints on sensor position are imposed by: **i)** control system stability; **ii)** cornering and reversing; and **iii)** the proposed construction? Controller equations for a simple system are given in the Systems Design section D.A. The test chassis may allow you test out some of these ideas and to start to develop line-following code.
9. Consider, with the rest of the team, the effects of motor dynamics and system inertia on stopping and starting the robot.
10. Develop prototype line following code, and hence test out your conclusions about sensor positioning, using the test chassis and interface circuitry produced by the electronics team for the sensors.

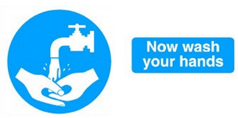
Team :- M1...... (......) **CRSid :-** ....

		Mechanical				Electrical				Software				Admin		
		Design	Construction	Testing	Docs	Design	Construction	Testing	Docs	Design	Construction	Testing	Docs	Meetings	Coordination	Presentations
		/hrs	/hrs	/hrs	/hrs	/hrs	/hrs	/hrs	/hrs	/hrs	/hrs	/hrs	/hrs	/hrs	/hrs	/hrs
Week 1	Thurs.															
	Fri.															
	Satur.															
	Sun.															
	Mon.															
	Tues.															
	Wed.															
	Total															
Week 2	Thurs.															
	Fri.															
	Satur.															
	Sun.															
	Mon.															
	Tues.															
	Wed.															
	Total															
Week 3	Thurs.															
	Fri.															
	Satur.															
	Sun.															
	Mon.															
	Tues.															
	Wed.															
	Total															
Week 4	Thurs.															
	Fri.															
	Satur.															
	Sun.															
	Mon.															
	Tues.															
	Wed.															
	Total															
Week 5	Thurs.															
	Fri.															
	Satur.															
	Sun.															
	Mon.															
	Tues.															
	Wed.															
	Total															

Working in the Dyson Centre and EIETL can be dangerous, please TAKE CARE!

WHEN WORKING IN THE EIETL, PLEASE

Beware of hot soldering irons
Do NOT flick solder



Wash hands after handling solder (See notice on wall re further precautions)

Do not put your hands near a moving robot

Beware of sharp edges to metal

Compressed gas is potentially dangerous; please use the airline and pneumatic control lines with care.

WHEN IN THE DYSON CENTRE, PLEASE ENSURE

Long hair is tied back
You are not wearing loose clothing

Any workpiece is securely clamped

You are wearing suitable footwear

You wear safety spectacles

(The IDP area is an EYE PROTECTION area)

THINK SAFETY