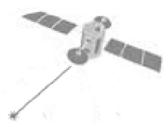
METR–SAT18

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

[METR2800] Mechatronic System Design Project I
Semester 1, 2011

DESIGN REPORT

Satellite Defence System Prototype



David Butterworth (Author)
Samuel Hinton
Jeevan Jangam
Kiaran Lawson

Project advisors: Ms L. LeGassick
Dr P. Jacobs
Mr D. Malcolm
Mr P. Bleakley

Date: Monday 11 April 2011

Executive Summary

Mechatronics Engineering students at the University of Queensland need to complete a team project as part of their second-year studies. The task is to design and build a working model of a satellite defence system. This report describes the proposed design for Group 18's solution.

The satellite will ultimately need to locate an IR (InfraRed) target, reorient itself in that direction and mark the target with a laser-beam.
The main design difficulties in achieving this goal are:

- getting all the components to fit inside the casing
- detecting the IR targets while ignoring ambient light sources
- utilising components that aren't too expensive (e.g. $20 sensors)

Full technical drawings have been produced and an assembly section shows that the proposed mechanical layout is suitable. The mechanical design has been compared too, and shown to meet, the required specifications. The system will operate in a straightforward manner and a User Guide has been written.

The proposed solution was designed as an integrated product, as opposed to a 'coming together' of separate parts. The design has been thoroughly analysed with the result being the optimal design contained in this report.

In conclusion, the design proposed by Group 18 will meet the required performance criteria and be delivered before the due date. Furthermore, the Group is on-track to deliver a result that exceeds specification.

Table of Contents

List of Figures & Tables

1 Introduction

As part of their second-year studies, Engineering students at the University of Queensland (herein referred to as the Client) undertake a team project. There are 18 teams, pre-selected groups of 4 students, whom are studying Mechatronics as their primary undergraduate degree.

The teams are competing to design and build a functional model of a satellite defence system that can identify targets about a single-axis and mark them with a laser beam. A solution is required by the end of a 3 month semester, on Monday 30 May 2011. Each team has a budget of $100 for electronics and fasteners (fabricated items are excluded) and the winner is the team that scores the most 'bullseye' targets in 5 minutes.

This project offers the first chance for students to gain some practical experience with engineering but the main goal of the exercise is to improve students' ability to work in teams. A separate “Report on the Project Plan” has also been submitted, covering management and planning issues for this project, and this “Report on the Paper Design” explains the technical details of the solution this group is building.

2 Problem Description

2.1 Outline

The problem appears quite broad, but possible solutions are limited by the following constraints:

- External housing (aluminium tube & plastic end caps) is supplied by client, see Appendix F.
- Steering is performed via an internal, rotational system, with a motor and gearbox (see Appendix D) being supplied by the client. This implies using a reaction wheel.
- The laser module, also supplied, must be permanently attached to the device.
- The device must hang from suspension cable at specific height (see Appendix B).
- Targets are an array of IR (InfraRed) LEDs (Light Emitting Diodes) with specific characteristics (see Appendix C) thus limiting the possible choices for sensors.
- Use an Atmel ATmega microprocessor because of supplied programming hardware.
- Manufactured parts must be easy to machine (low cost of labour to program or operate equipment) or small enough for production via rapid prototype printing.

Additional requirements:

- Acquire IR target, positioned at the 4 compass points (N, S, E, W) at distances of 0.5 – 3.0m
- Mark the target “bullseye” with laser for 2 seconds.
- Acquire a minimum of 20 successive targets as they are randomly activated, for a period of 5 minutes (1 target every 15 seconds)

2.2 Problem Analysis and Design Difficulties

Based on the constraints, the problem was analysed and distilled to a set of core requirements that are listed below. Each requirement is described with consideration to the difficulties of designing that component.

2.2.1 Mechanical Design

The reaction wheel	Sized to provide a mass such that ratio of wheel mass to other components creates a balance between acceleration (responsiveness) and stability (low jitter).
The motor bracket	Position the motor & flywheel with room for other components, simple to manufacture, strong while being not too heavy.
Other components	PCB (Printed Circuit Board) and batteries must be securely mounted but easy to remove during testing and for maintenance.

2.2.2 Electronic Design

Power supply	Internal battery the client can easily replace, provide a stable 5V supply for control electronics & higher voltage for motor, sufficient current capacity.
Microcontroller	A cheap ATmega chip with enough IO lines & program memory for the task.
Motor Control	Circuitry to provide direction and speed control for a high-current draw motor.
Sensing	Detect IR light amongst interference and noise from other light sources.
Switching & display	Switch outputs like laser, or an LED or buzzer for user feedback.
Development	Extra ports for debugging and programming the device.

2.2.3 Software Design

Sensor sampling and noise filtering	Sample sensors at high-enough rate for accurate target detection and filter out noise from ambient light sources.
Control algorithms	Implement feedback-control algorithm beyond simply running motor for 2 secs.
Speed	Fast enough to quickly acquire a rough target location and then switch to a slower, more accurate speed to achieve an accurate target “lock”.
Flexibility	Easily allow changing the number and sensitivity of sensors during testing, to self-calibrate against ambient light sources during boot-up.

3 Proposed Solution

3.1 Mechanical Layout

The proposed mechanical layout is shown in Figure 1. Detailed technical drawings of each component and a pictorial exploded view are included in the Appendices.

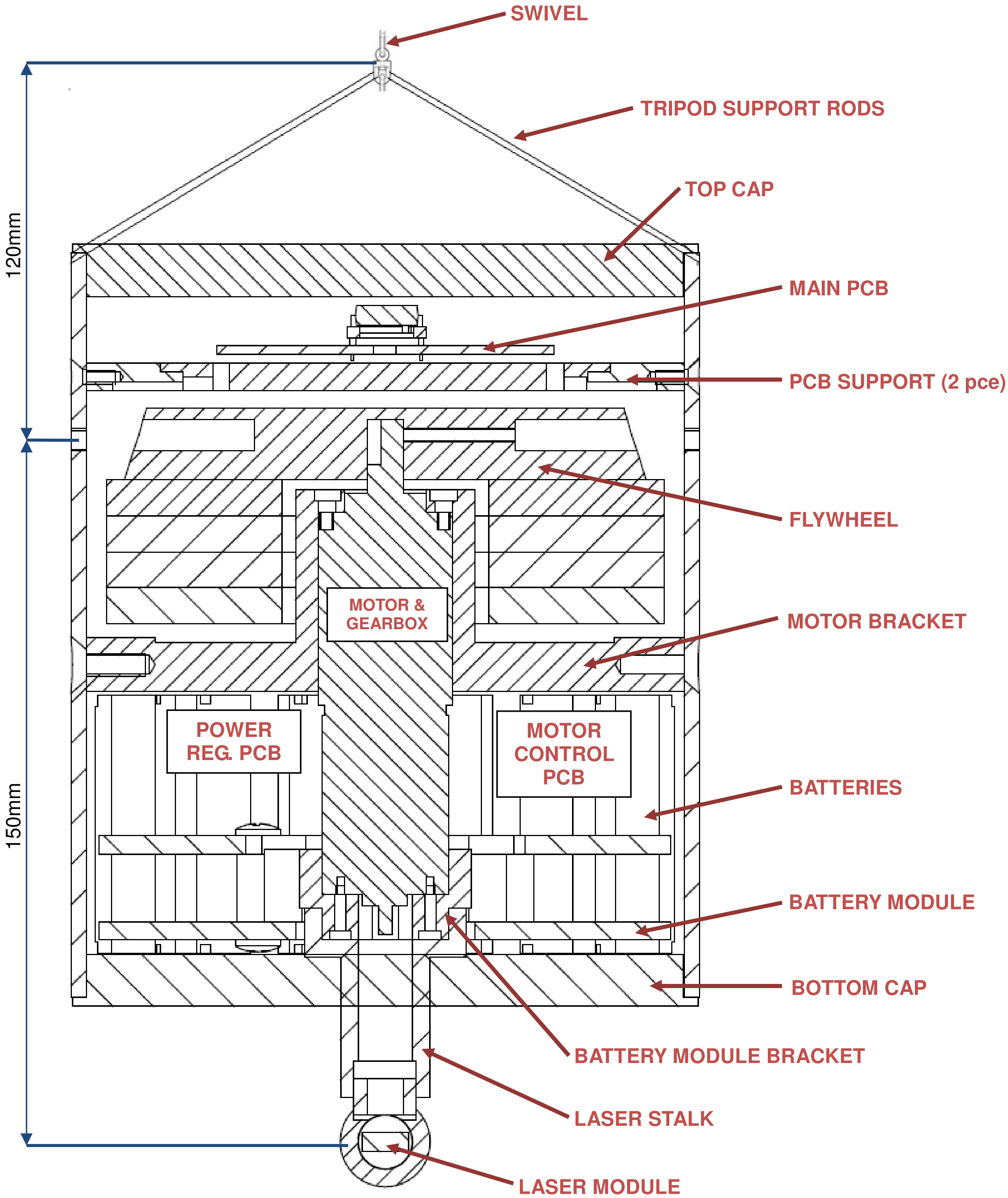


Figure 1. Proposed mechanical layout of the device (front section view)

3.1.1 Comparison of Mechanical Layout to Specifications

The mechanical layout has been compared against requirements to prove it meets specification (Table 2).

MECHANICAL SPECIFICATION	ANALYSIS
System must fit inside supplied aluminium casing	Figure 1 shows that all components will fit inside the body, with sufficient clearance for operation and to allow some adjustment.
Product to operate suspended from cable at correction height	See height dimensions in Figure 1.
IR Sensors at correct height	Components are positioned correctly, as shown in Figure 1.
Laser module permanently attached, at correct height	Laser emitter is mounted in a fixed housing, at fixed height shown in Figure 1, with horizontal alignment via a grub screw.
Internal, rotational system of steering	Rotational movement is induced by the motor and heavy reaction wheel that hangs down, around the motor and gearbox.
Mass ratio Reaction Wheel to other components	The reaction wheel is a heavy, cylindrical piece of steel. Other components are plastic. See mass calculations in the Appendices.
Secure attachment and easy access to other components	PCB easily accessible from top of device; simply un-plugs from base. Battery holders mounted in special housing that slides out the bottom.

Table 2. Comparing the proposed mechanical layout to required specifications

3.1.2 How the System will operate

The design of this device makes it easy to use by an untrained user. Based on the mechanical layout in Figure 1, a brief outline of how the system will operate is shown in Table 3.

A complete Walkthrough of the device's operation is given in the Operation Manual, see the Appendices.

Installation	The clip on the provided support cable is attached to the tripod-cables at top of device.
Power supply	AA Batteries are inserted in the battery module which is then installed in the bottom of the device. The bottom cap is screwed on and the laser fitted back on the end of its stalk.
Activation	A power switch on the laser stalk engages power to the circuitry. To activate the device, an IR light or signal (from consumer remote control) is shone at the primary IR sensor, causing the device to calibrate and begin operation.
Sensing	The device will remain stationary until one of its 4 secondary IR sensors detects a target. The device will servo, via the shortest arc, to the quadrant with the highest light reading. The 2 primary targeting sensors will finely position the satellite to point at the target, using differential measurement.
Motion	The satellite will rotate using a reaction wheel. The significant mass of the wheel means that when power is applied to the motor, the lighter mass of the satellite will rotate in an opposite direction around the wheel.
Targeting	The satellite will lase the target by switching it on for a timed period of 2 seconds.
Continuous	Detect next target, using 4 secondary IR sensors.

Table 3. Overview of how the system will operate

3.2 Design Description and Justification

Every aspect of the design has been considered and this section briefly describes the design decisions that were made with justification against other alternative ideas.

3.2.1 Mechanical Design Decisions

Refer to the mechanical layout shown in Figure 1 and the technical drawings in Appendix F.

Motor, Gearbox and Reaction Wheel orientation

Positioned in middle of device, motor shaft pointing upwards, flywheel hanging around the motor.

- Motor has D-profile shaft, flywheel must be attached with grub screw.
- The flywheel orientated horizontally, must hang over the end of the vertical shaft like a cap
- Middle position means other components have weight vertically distributed as they rotate.
- Wheel is hollow cylinder rotating round motor, the most efficient use of that space.

Motor bracket shape and material

- Bolt holes on motor are near output shaft, bracket is shaped to use these & allow for reaction wheel.
- Supports allow max reaction wheel size with space below for height of AA battery.
- Four supports are used (not 3 to match tripod cables) so lower PCBs are positioned 180º opposed.
- Made of plastic (machined or printed) so it is lightweight.

Plastic End Caps

To be primarily cosmetic, not used as mechanical support.

- Improved aesthetic appearance, unobstructed view of the control electronics.
- While testing, end caps are not installed, allowing easy access to the PCB and batteries.

PCB Support

A two-part bracket design.

- PCB not hung from the lid, separate bracket required. Located up the top so heavier batteries below.
- Four supports conceal wires to sensors (which are located in 4 places) by running them underneath.
- Comprises 2 separate parts because they need to be manufactured at different times. Main circular bracket provides the mechanical support required during testing. Inner disc fits into the bracket with holes to suit PCB plugs, therefore must be designed after PCB.

Modular battery holder

- Based on shape/quantity of batteries (see electronic design section), the most space-efficient way to distribute their weight is in a circular arrangement around the inside of the Satellite.

- Discs support batteries, cut-outs in middle allow Module to rotate and lock over matching bracket.
- Mechanism makes batteries easy to replace, but final product would have additional safety screw.

Laser mounting stalk

Shape and size of the case and stalk.

- Laser module enclosed in a plastic case to protect PCB.
- Laser stalk designed with fixed vertical height but allowing horizontal adjustment via grub screw.
- Two-part design means laser can be unplugged to fit bottom cap.
- Provides best location for power switch, not hindering removal of other components from device.

Tripod Support Rods

Three wire rods to hang the Satellite.

- Fishing-type swivel allows rotational motion, with low friction. Machining a bearing unnecessary.
- Stiff wire rods hang the Satellite on a level plane; can be un-hooked for better access into device.
- Rods better than wire at resisting compressive forces if Satellite makes sharp direction change. Metal arms unnecessary, only add extra weight, harder to get into top of device.

3.2.2 Electronic Design Decisions

Refer to the block diagram and electrical schematics in the Appendices.

Microcontroller

Atmel ATmega32

- ATmega16/32 chosen because it has 2 spare analogue inputs
- ATmega32 has double the memory, at little more cost.
- Through-hole DIP (Dual Inline Package) chip mounted in an IC socket because permanently-soldered surface-mount variant too risky, if damaged it would be costly to replace the PCB and chip.
- Final product would obviously use surface mount chip with minimum I/O lines and memory.

IR Sensors

Osram SFH3160F

- Have a sharply-defined spectral response to match the 880nm output of targets.
- Phototransistor with voltage divider is easy to connect to microcontroller, unlike a photodiode that requires a more complicated current amplifier.

PCB position and quantity

Having 3 separate PCBs: mainboard, power regulation, and motor control.

- Main PCB with large microcontroller is above flywheel, for mechanical reasons mentioned earlier. **Round shape is** purely for aesthetic reasons.
- Other PCBs are positioned near batteries to keep high-current power wires short, reduce interference, and lower the size of the circular PCB.
- Attaching secondary PCBs to motor bracket acts as an integrated heatsink.

Ports for ISP (In-System Programming) and RS-232 (Recommended Standard 232) Serial

Programming and debugging capability via an adapter-board rather than on main PCB.

- Moving them off the circular PCB saves money there and moves it to the development budget.
- Improved aesthetic appearance during operation as these ports are only required during testing.

H-Bridge Motor Control Chip

STMicro L298 Dual 2A H-Bridge

- Easiest way to implement speed and direction control of high-current motor.
- Chip is above requirements (Motor current: 0.4A to 2.5A stall) with extra H-Bridge, but this popular cheap is the least expensive in its **class. Position of PCB means space is not a concern.**

Battery type and voltage

12 x AA batteries with taps at 18V and 9V (14.4V and 7.2V for rechargeable batteries)

- Batteries not included in budget if consumable items that can be replaced by the client, thereby discounting soldered-in batteries and newer technologies like LiPo (Lithium-ion Polymer) packs.
- AA size is the most common and allows use of high-current rechargeable batteries for testing.
- Dual voltage taps provide filtering between the different voltage supplies. 7V supply is to suit power regulator, 13V supply for motor (after drops in diodes) will safely allow running at faster speed.

Power regulation

7805 variant linear 5V LDO (Low-DropOut) power regulator IC

- The motor (high-current inductive load) is directly connected to unregulated battery supply.
- Linear regulator is cheapest way to provide 5V supply, with lower min. voltage than non-LDO.

Other inputs and outputs

Laser switching transistor, status LEDs, piezo speaker, input switches.

- Laser module draws 32ma, ATmega max output current is 25mA, so switching transistor is used.
- Status LEDs & piezo indicate correct operation to user. Low current-draw allows direct connection.
- Input switches allow configuration, reset and calibration possibilities.

3.2.3 Embedded-software Design Decisions

Refer to the software block diagram in Appendix L.

Initial "Standby" State

Software will power-up into a standby state and wait until activated by Testing Remote (an IR light).

- Allows Satellite to settle on suspension cable, prevents user being startled by sudden movement.

"Self-Calibration" State

Satellite will automatically calibrate to ambient light conditions

- Operating conditions (ambient light) vary so device will adjust each time it is used.
- Take light reading from 4 secondary sensors, rotate slightly and take another reading. Having recorded a baseline reading, any IR target will have a distinctly higher light reading.
- Difference between ambient and IR light is stored in software, based on the min. target distance.

"Looking for Target" State

Software will sample the 4 secondary IR sensors to locate the approximate position of the target

- Take analogue reading from 4 sensors around Satellite. Repeatedly poll until 1 sensor shows a voltage reading preset-value higher than ambient light.
- Satellite will then rotate to that quadrant, which obviously will not line up with that target yet.

"Targeting" State

Satellite uses 2 primary targeting sensors, which are more directional (in-set) than the other sensors, to locate exact position of target.

- These 2 sensors are closely-spaced but respond to IR light at a smaller angle.
- Voltage difference between sensors is used to move device proportionally towards the lower reading.

Sensor Sampling

Software will take multiple readings and calculate average value.

- Sensors are quickly sampled, with 3 successive readings from each sensor. The 3 values are averaged which provides a more accurate result, with lower noise, than simply acting on a single reading.

Motor Control

Variable speed and direction control

- A "direction" flag is used to flip the status of 2 output lines that control the direction of the motor.
- To enable motor & control speed, a PWM signal is generated on a 3^{rd} output line from an 8-bit timer.

Heartbeat Timer

A timer generates millisecond interrupts

- A 2^{nd} timer on the ATmega32 acts as a general timer, to coordinate sampling & time the laser.

4 Verification of Solution

This product is small enough that it was designed as one cohesive unit with the design process involving a continuous feedback loop. For example, if two parts did not integrate then both were reconsidered until the optimal solution was found. Each modification was designed with consideration to the affect it would have on other components.

The required specifications (included in Appendix B) are mainly mechanical and Section 3.1 showed that these have been met by the proposed design. The other specifications relating to motion and sensing have been shown by the electronics design description in Section 3.2. Further details and calculations relating to the mass and moment of the mechanical components are included in Appendix M.

5 Conclusion

The proposed Satellite design is an integrated system that meets, and exceeds, the required specifications. This report has highlighted the fundamental problems and related difficulties that must be overcome, and this Group's design is an innovative and optimal solution to those problems. The combination of good planning and a well-engineered design mean the required performance will be achieved before the deadline, under budget.

Appendices

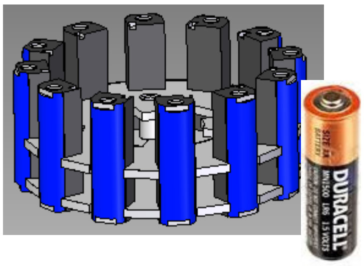
Appendix A

Operation Manual

1 Unpack Satellite from box

2 Check you have received all required parts:

The satellite device
2 x plastic end caps
6 x screws
Screwdriver
Battery Module
12 x AA Batteries
Laser
Stand
Testing remote (a consumer TV remote control)



3 Insert batteries

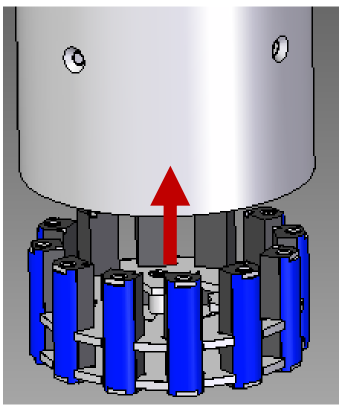
Install AA batteries into Battery Module with positive (+) end poin ting up.

See markings above each battery slot.

4 Carefully place Satellite upside down on testing base.

Position Battery Module so the slots are near the locking tabs inside the end of the satellite.

Take the loose wire inside the Satellite (marked “Battery”) and plug it into the connector on the Battery Module.



5 Insert Battery Module into Satellite

Slide the Battery Module into the Satellite by lining up the slots with the locking tabs.

Apply gentle downward pressure and rotate the Battery Module anti-clockwise (using the two finger holes) until resistance is felt.

6 Install bottom cap

Carefully slide the plastic end cap over the laser stalk and into the end of the satellite.

Align the holes in the cap and body

Install 3 screws.

7 Attach the Laser Module

Plug-in the Laser to the Stalk.

Slide the Laser housing into the end of the Stalk.

Gently tighten the plastic grub-screw.

Note: no manual alignment of the laser is required. You will notice a small notch in the laser housing which aligns with the grub screw.

8 Place Satellite right-way-up

Place device on testing base so the Laser/Stalk hangs between the legs on the testing base.

9 Set the battery type (skip this step for included batteries)

The device comes pre-configured for use with the supplied non-rechargeable 1.5 volt batteries. The device can also be used with high-current 1.2 volt NiMH (Nickel Metal Hydride) batteries but you must change the jumper setting on the main circuit board.

Looking in the top of the Satellite, locate the jumper (JP1).

Reposition the jumper so it is between pins 2 and 3.

Failure to do this step will result in lower performance from the Satellite.

10 Install top cap

Slide plastic cap into the top end of satellite.
Align the holes in the cap and body.
Install 3 screws.

11 Position the Satellite

Take the cable provided in the testing environment and hook it onto the tripod cable swivel on the top of the Satellite.
Gently hang the Satellite making sure it is secure.

12 Turn on power

Slide the switch on the rear-end of the laser.
The LED on the switch will glow red.
The “PWR” LED on the main circuit board will be glowing orange.

13 Activate the device

The device is in a standby mode and will remain stationary until activated.
Point an IR light source at the main IR sensor (either use the supply Testing Remote or flash one of the IR targets briefly)
The Satellite will give a single “beep”.

14 Satellite will self calibrate

Once activated, the device will wait 2 seconds then self-calibrate.
It will make some small rotation movements and sample the ambient light.
Once calibration is complete, the Satellite will give two “beeps”.
Note: you should now stand clear of the device, although it will not move unless it detects an IR light source. Position yourself so the laser beam will not aim into your eyes, although it is an eye-safe laser.

15 Satellite will locate a target

When an IR target is lit, the satellite will give a quick audible “blip” to acknowledge and rotate to point its primary sensors and laser towards the target.

16 Satellite will lock-on to target

When an accurate target 'lock' is achieved, the Satellite will sound a low tone and lase the target for 2 seconds.

17 Further targets...

As each successive target is illuminated, the Satellite will rotate in to position, acquire a target 'lock' and fire its laser.

18 On completing the test...

When you are satisfied with the Satellite's operation, you can turn it off.

Note: do not use the Testing Remote or IR light source to do this. The Satellite is still in targeting mode but is still safe to touch.

Ensure the target system is switched off first.

Approach the Satellite and hold it with one hand while sliding the power switch with the other hand.

19 Maintenance and Care

The Satellite requires no further adjustment and should be returned to the designer if it acts unexpectedly.

The batteries can be replaced by following the earlier procedure in reverse.

You can wipe the Satellite with a dry cloth but do not use any chemicals.

Ensure that dust or small particles do not enter the sensor holes around the outside of the device.

Appendix B

Client's Product Specification

METR2800 2011 Product description

The client requires a working model of a satellite defence system for demonstration purposes. This system is required to identify targets (in the form of light sources) and simulate their elimination by the accurate 'firing' of a laser pointer. Your design team is one of several competing groups that has been commissioned to design, build, and test a 'concept system' (known as 'the product').

Specification

1. The satellite is to be packaged into the form given by the drawings given on the METR2800 Blackboard page.

2. The steering system should rotate the package.

3. The steering system must be fully internal to the package. Propellers, thruster-jets, or other external propulsion methods are not allowed.

4. The laser must be rigidly fixed to the package.

5. Your product is required to operate while suspended from a thread that will be anchored in a frame simulating a low-gravity earth orbit. Your product must be suspended at the correct height by satisfying the dimensions given in Figure 1.

6. The suspension thread is for support only and cannot be used to enhance the performance of your product in any way. The mounting frame, suspension thread, and a connecting swivel will be available in the Mechatronics Project Labs (50-C404 and 50-C403).

7. Actuation must be via the electric motor and gear-box set supplied to each team. The mechanical and electrical specification for this motor will be provided via the course blackboard site. shortly. Your budget does not include the cost of this motor.

8. Your product is required to sense infrared light sources (representing targets).The selection of sensors is at your discretion, but all sensors are be mounted as indicated in Figure 1. Sensors can be mounted external to the package. The distance to any particular target will be in the range 0.5 - 3.0m.

9. An eye-safe laser pointer (provided) is to be used to indicate targeting. The laser must be mounted so that its beam is directed horizontally along an axis whose vertical position is indicated in Figure 1. The cost of this pointer should not be included in your project budget.

Targeting Performance Competition

The competition will evaluate the agility and targeting performance of your system. The test facility will comprise four light sources with associated targets. On Demonstration Day they will be activated in a random order.

Your product is required to servo to each active light and 'fire' its laser for a period of 2 seconds. When a 'hit' on that target is recorded, a new light will be activated. There will be a timeout for each target so, if your satellite gets stuck trying to lock onto a specific target for whatever reason, it will get a chance to locate another. The period before timeout will be on the order of 30 seconds.

The targets will be of a bullseye configuration, where a hit in the bullseye will be worth 10 points, the inner ring will be worth 5 points, and the outer ring 1 point.

If the laser moves between boundaries of bullseye while the laser is active, the lesser score will count. If the laser moves off target while the laser is active, it will not register as a hit.

Your competition score will be the number of points accumulated over a 5 minute test period.

Product Assessment

Management have stressed that:

1. The system must be delivered in a testable form by the due date. There will be a penalty of 1 mark deducted from the demonstration assessment for each hour (or part thereof) that the project is handed in late. There will be bonus of 1 mark for every full working day early that the project is handed in, up to a maximum of 5 marks.
2. The system must come in on or under a budget of $100. There will be a penalty of 1 mark for each $5 (or part thereof) over budget. There will be a bonus of 1 mark, to a maximum of 5 marks, for each $10 you are under budget. All costs must be included in the budget statement.

The assessment is based on the following criteria in order of importance. To receive a grade of 7 overall, your system must have exceptional performance in the targeting performance competition.

Functionality:

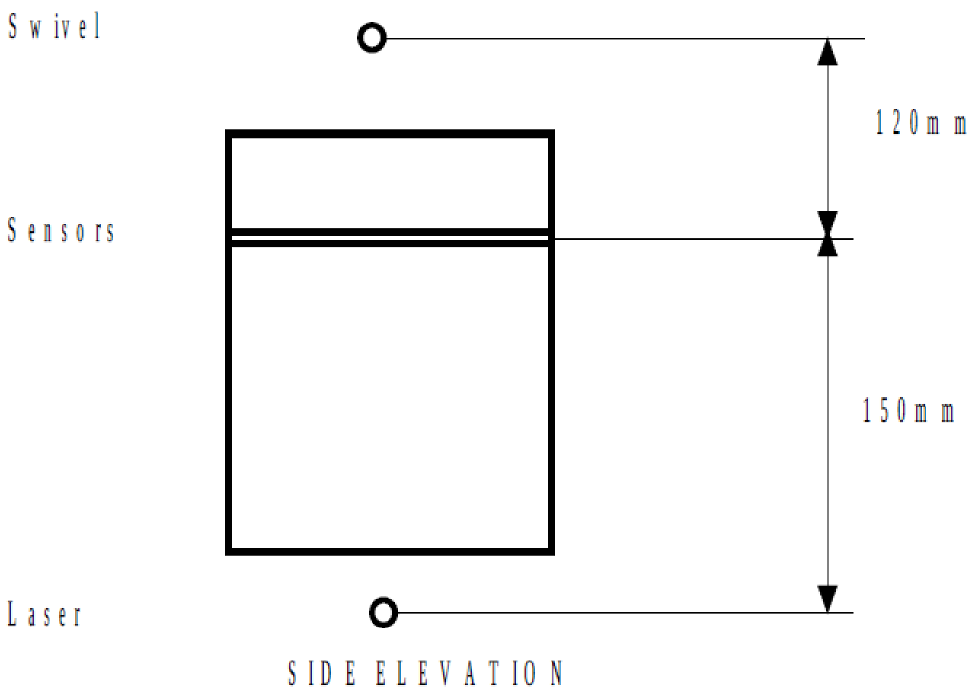
- Aligns with targets.
- Can actuate satellite.
- Can sense target.
- Actuates based on sensor data.
- Fires “laser”.

Performance:

- Grade of 7 - 200 points or higher
- Grade of 6 – 130 -200 points
- Grade of 5 - 50-130 points
- Grade of 4 - 1-50 points

Build quality:

- Reliability
- Mechanical construction
- Electrical construction
- Appearance



Appendix C

Target Specifications

High Speed GaAlAs Infrared Emitter OPE5587

The **OPE5587** is GaAlAs infrared emitting diode that is designed for high power, low forward voltage and high speed rise / fall time.
This device is optimized for speed and efficiency at emission wavelength 880nm and has a high radiant efficiency over a wide range of forward current.
This device is packaged T1-3/4 package and has narrow beam angle with lensed package and cup frame. Especially this device is suited as the emitter of data transmission without cable.

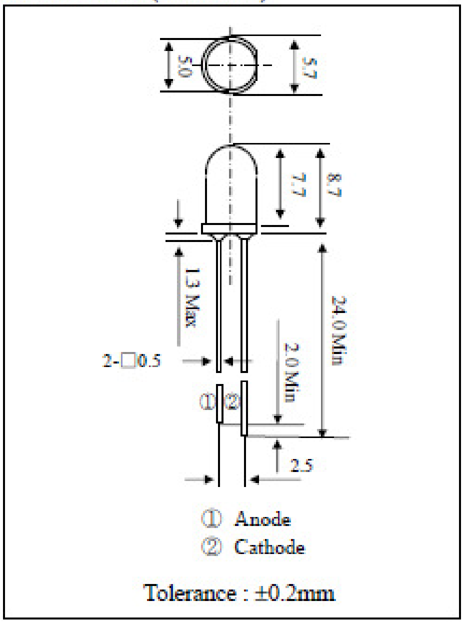
FEATURES

- Ultra high-speed : 25ns rise time
- 880nm wavelength
- Narrow beam angle
- Low forward voltage
- High power and high reliability
- Available for pulse operating

APPLICATIONS

- Emitter of IrDA
- IR Audio and Telephone
- High speed IR communication
- IR LANs
- Available for wireless digital data transmission

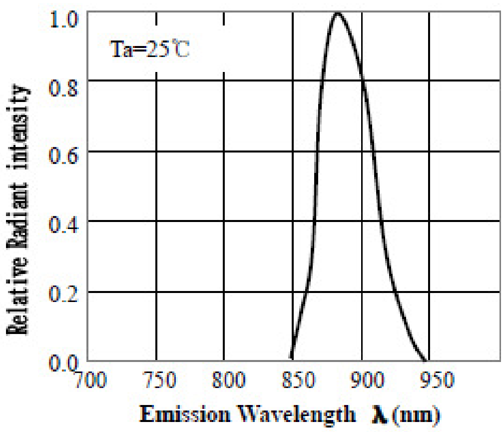
DIMENSIONS (Unit : mm)



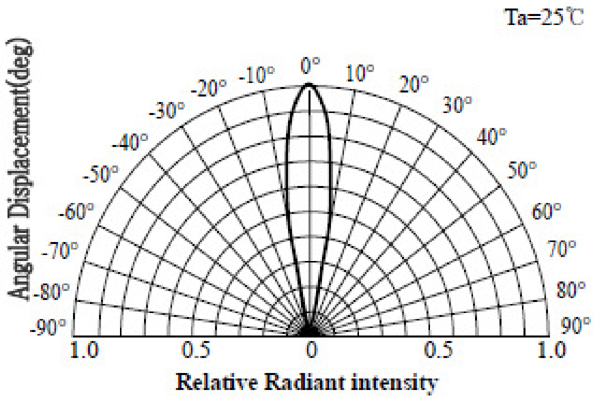
ELECTRO-OPTICALCHARACTERISTICS (Ta=25°C)

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
Forward voltage	V_F	I_F=50mA		1.5	2.0	V
Reverse current	I_R	V_R=4V			10	μA
Capacitance	Ct	f=1MHz		20		pF
Radiant intensity	Ie	I_F=50mA	40	90		mW/sr
Peak emission wavelength	λ_p	I_F=50mA		880		nm
Spectral bandwidth 50%	Δ λ	I_F=50mA		45		nm
Half angle	Δ Θ	I_F=50mA		±10		deg.
Optical rise & fall time(10%~90%)	tr/tf	I_F=50mA		25/15		ns
Cut off frequency *3	fc	I_F=50mA DC +10mA p-p		14		MHz

- **RELATIVE RADIANT INTENSITY Vs. EMISSION WAVELENGTH.**



- **ANGULAR DISPLACEMENT Vs RELATIVE RADIANT INTENSITY**



Appendix D

Specifications of supplied motor and gearbox

FAULHABER

DC-Micromotors

20 mNm

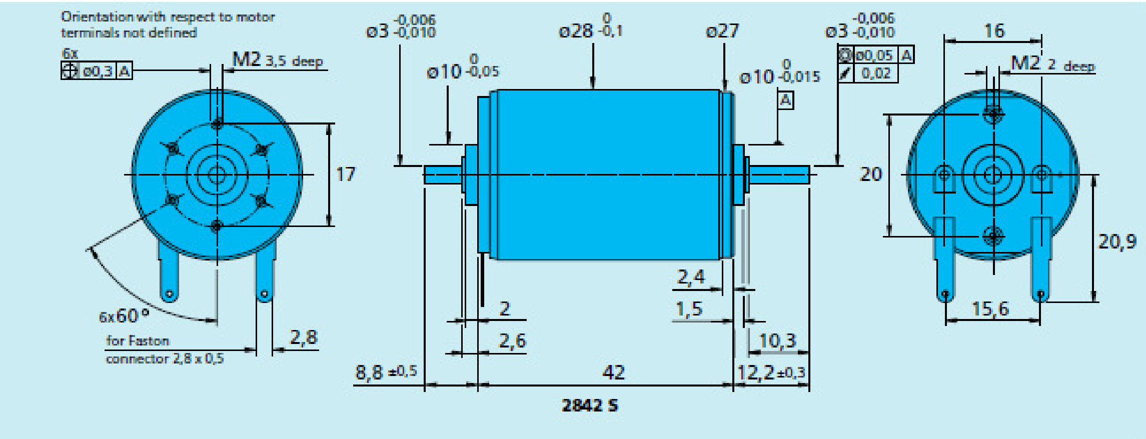
Graphite Commutation

For combination with:
Gearheads:
23/1, 26/1, 30/1, 38/1, 38/2, 38/3
Encoders:
10/09B, 10/09BP, 5500, 5540

Series 2842 ... C

			2842 S	006 C	012 C	024 C	028 C	036 C	
1	Nominal voltage	U_N		6	12	24	28	36	Volt
2	Terminal resistance	R		1,6	5,3	21,0	28,5	46,0	Ω
3	Output power	$P_{2\ max.}$		5,33	6,50	6,56	6,57	6,74	W
4	Efficiency	η max.		72	74	74	74	74	%
5	No-load speed	n_0		5 100	5 100	5 000	5 100	5 200	rpm
6	No-load current (with shaft ø 3,0 mm)	I_0		0,100	0,050	0,025	0,022	0,017	A
7	Stall torque	M_H		39,9	48,6	50,1	49,3	49,5	mNm
8	Friction torque	M_R		1,10	1,10	1,10	1,10	1,10	mNm
9	Speed constant	k_n		873	435	213	186	148	rpm/V
10	Back-EMF constant	k_E		1,150	2,300	4,700	5,370	6,770	mV/rpm
11	Torque constant	k_M		10,90	22,00	44,80	51,30	64,70	mNm/A
12	Current constant	k_I		0,091	0,046	0,022	0,020	0,015	A/mNm
13	Slope of n-M curve	$\Delta n/\Delta M$		128	105	99,8	103	105	rpm/mNm
14	Rotor inductance	L		145	580	2 500	3 200	5 000	µH
15	Mechanical time constant	τ_m		13	15	15	15	15	ms
16	Rotor inertia	J		9,7	14,0	14,0	14,0	14,0	gcm²
17	Angular acceleration	α max.		41	36	35	36	36	$\cdot 10^3$rad/s²
18	Thermal resistance	$R_{th\ 1}$ / $R_{th\ 2}$	2 / 16						K/W
19	Thermal time constant	τ_{w1} / τ_{w2}	8 / 831						s
20	Operating temperature range:								
	– motor		– 30 ... +125						°C
	– rotor, max. permissible		+125						°C
21	Shaft bearings		ball bearings, preloaded						
22	Shaft load max.:								
	– with shaft diameter		3,0						mm
	– radial at 3000 rpm (3 mm from bearing)		20						N
	– axial at 3000 rpm		2						N
	– axial at standstill		20						N
23	Shaft play:								
	– radial	≤	0,015						mm
	– axial	=	0						mm
24	Housing material		steel, zinc galvanized and passivated						
25	Weight		132						g
26	Direction of rotation		clockwise, viewed from the front face						
Recommended values									
27	Speed up to	$n_{e\ max.}$		5000	5 000	5 000	5 000	5 000	rpm
28	Torque up to [1]	$M_{e\ max.}$		20	20	20	20	20	mNm
29	Current up to (thermal limits)	$I_{e\ max.}$		1,550	0,870	0,430	0,370	0,290	A

[1] thermal resistance $R_{th\ 2}$ by 40% reduced



FAULHABER

Planetary Gearheads

4,5 Nm

For combination with (overview on page 14-15)
DC-Micromotors:
2342, 2642, 2657, 3557
Brushless DC-Servomotors:
2444, 3056, 3564

Series 30/1

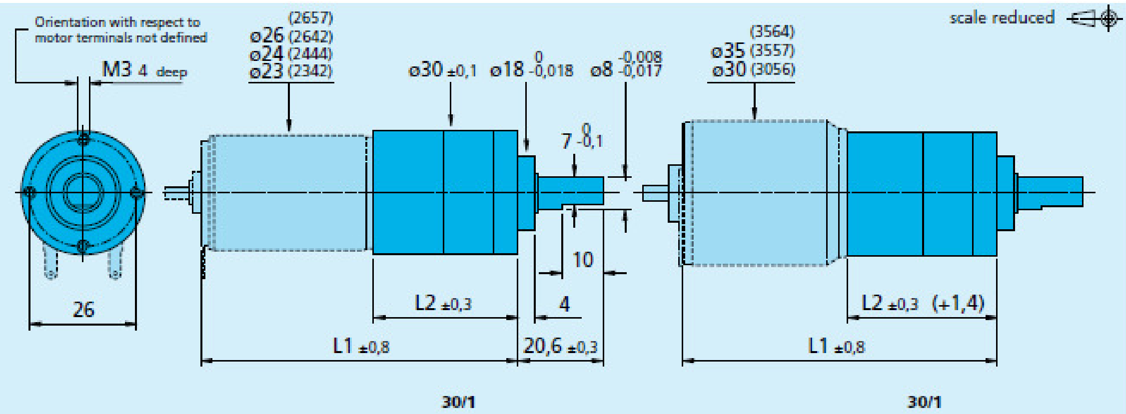
	30/1
Housing material	metal
Geartrain material	steel [1]
Recommended max. input speed for:	
– continuous operation	4 000 rpm
Backlash, at no-load	≤ 1°
Bearings on output shaft	ball bearings
Shaft load, max.:	
– radial (15 mm from mounting face)	≤ 150 N
– axial	≤ 150 N
Shaft press fit force, max.	≤ 200 N
Shaft play (on bearing output):	
– radial	≤ 0,015 mm
– axial	≤ 0,15 mm
Operating temperature range	– 30 ... + 100 °C

Specifications

reduction ratio (nominal)	weight without motor	length without motor L2	length with motor 2444 S L1	2342 S 2642 W L1	3056 K L1	2657 W 3557 K L1	3564 K L1	output torque continuous operation M max.	output torque intermittent operation M max.	direction of rotation (reversible)	efficiency
	g	mm	mm	mm	mm	mm	mm	Nm	Nm		%
3,71 :1	107	27,1	71,1	69,1	84,5	85,5	92,5	1,5	3,0	=	88
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
43 :1	171	43,1	87,1	85,1	100,6	101,6	108,6	1,2 (4,5)	1,6 (6,0)	=	70
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
134 :1	203	51,2	95,2	93,2	108,6	109,6	116,6	3,5 (4,5)	4,5 (6,0)	=	60
159 :1	203	51,2	95,2	93,2	108,6	109,6	116,6	4,5 (4,5)	6,0 (6,0)	=	60
246 :1	203	51,2	95,2	93,2	108,6	109,6	116,6	4,5 (4,5)	6,0 (6,0)	=	60
415 :1	235	59,2	103,2	101,2	116,6	117,6	124,6	4,5 (4,5)	6,0 (6,0)	=	55
592 :1	235	59,2	103,2	101,2	116,6	117,6	124,6	4,5 (4,5)	6,0 (6,0)	=	55
989 :1	235	59,2	103,2	101,2	116,6	117,6	124,6	4,5 (4,5)	6,0 (6,0)	=	55
1 526 :1	235	59,2	103,2	101,2	116,6	117,6	124,6	4,5 (4,5)	6,0 (6,0)	=	55

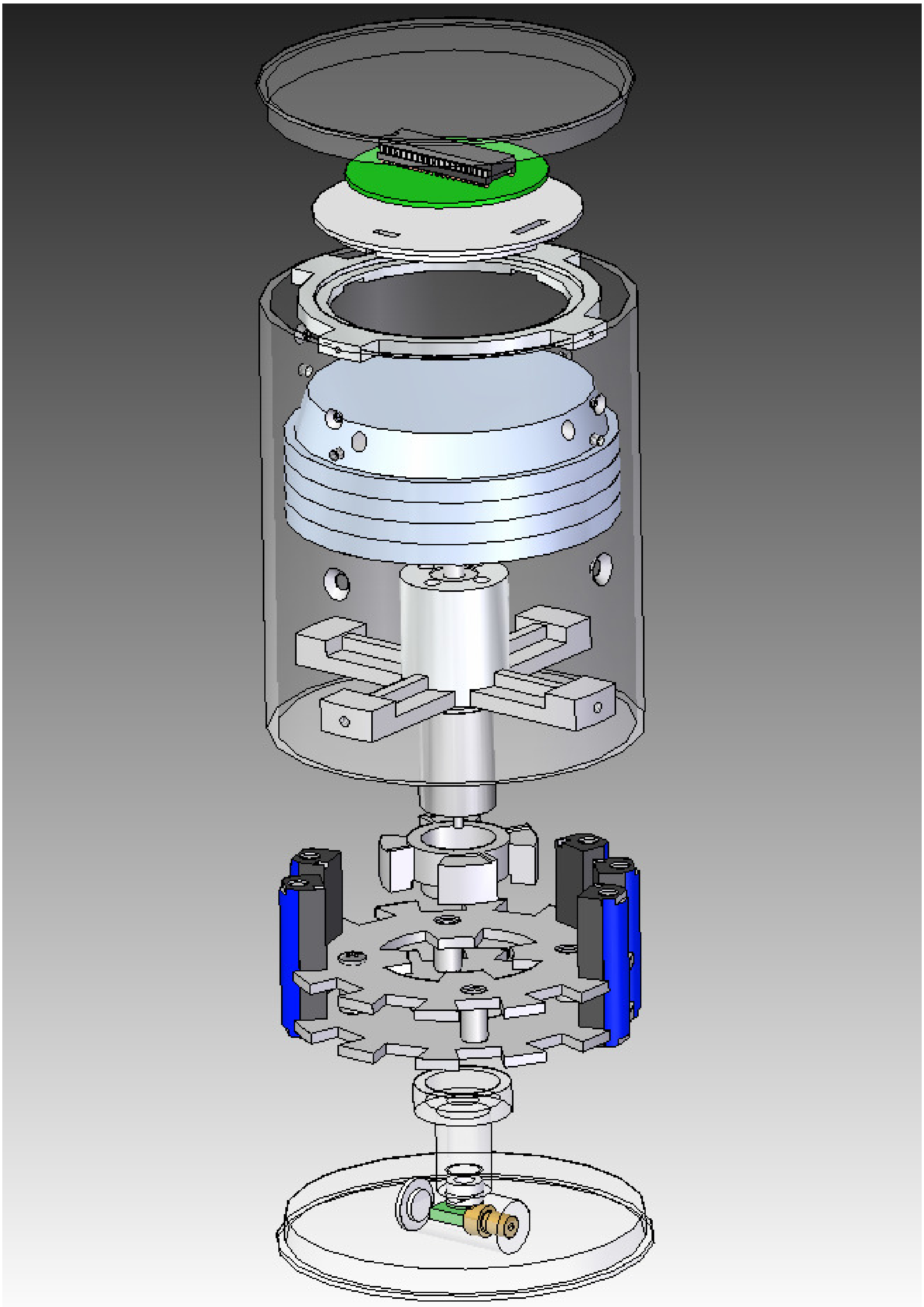
[1] Gearheads with ratio ≥ 14:1 have plastic gears in the input stage. For extended life performance, the gearheads are available with all steel gears and heavy duty lubricant as type 30/1 S.
The values for the torque rating indicated in parenthesis, are for gearheads, type 30/1 S with all steel gears.

Note: The reduction ratios are rounded, the exact values are available on request.



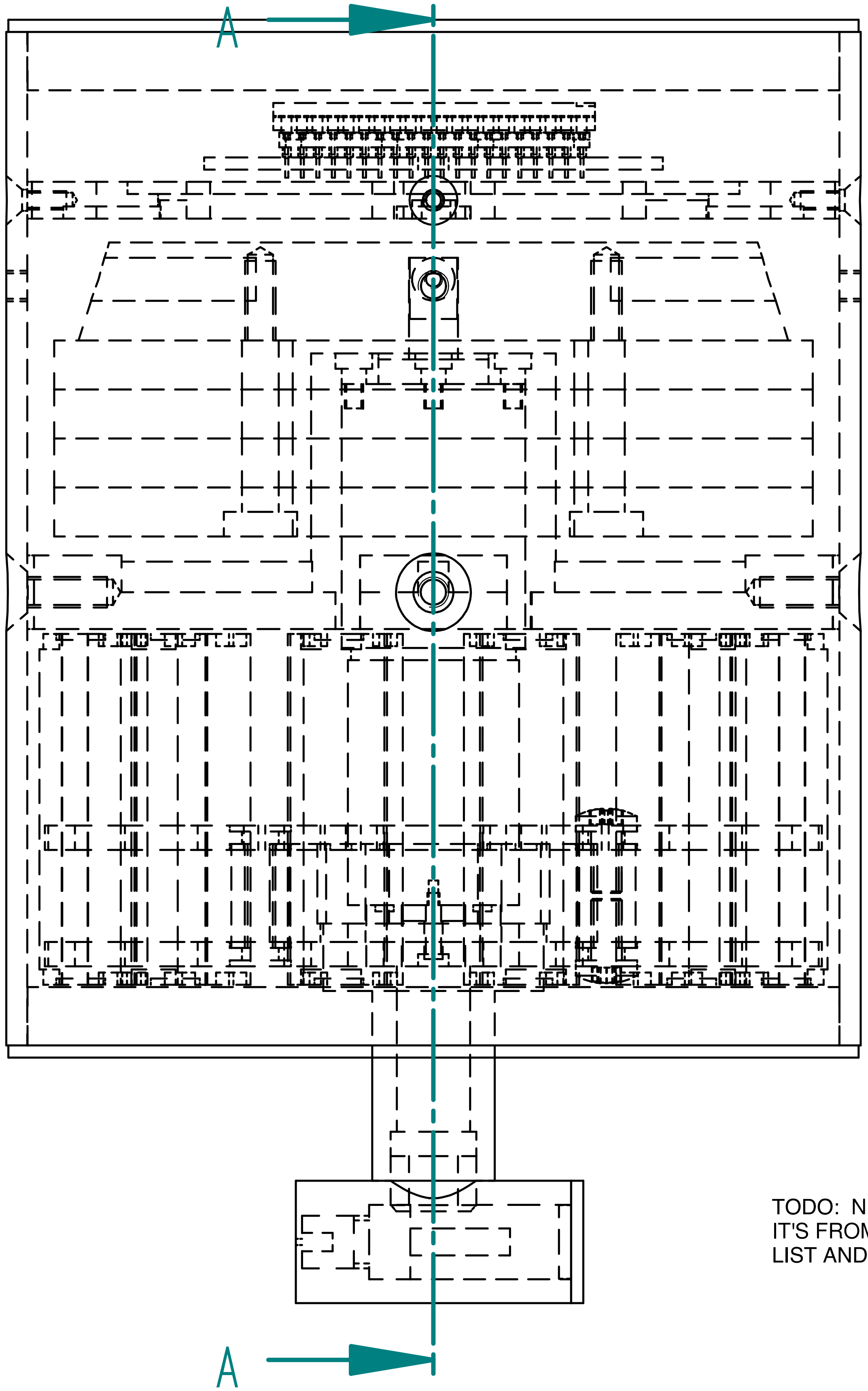
Appendix E

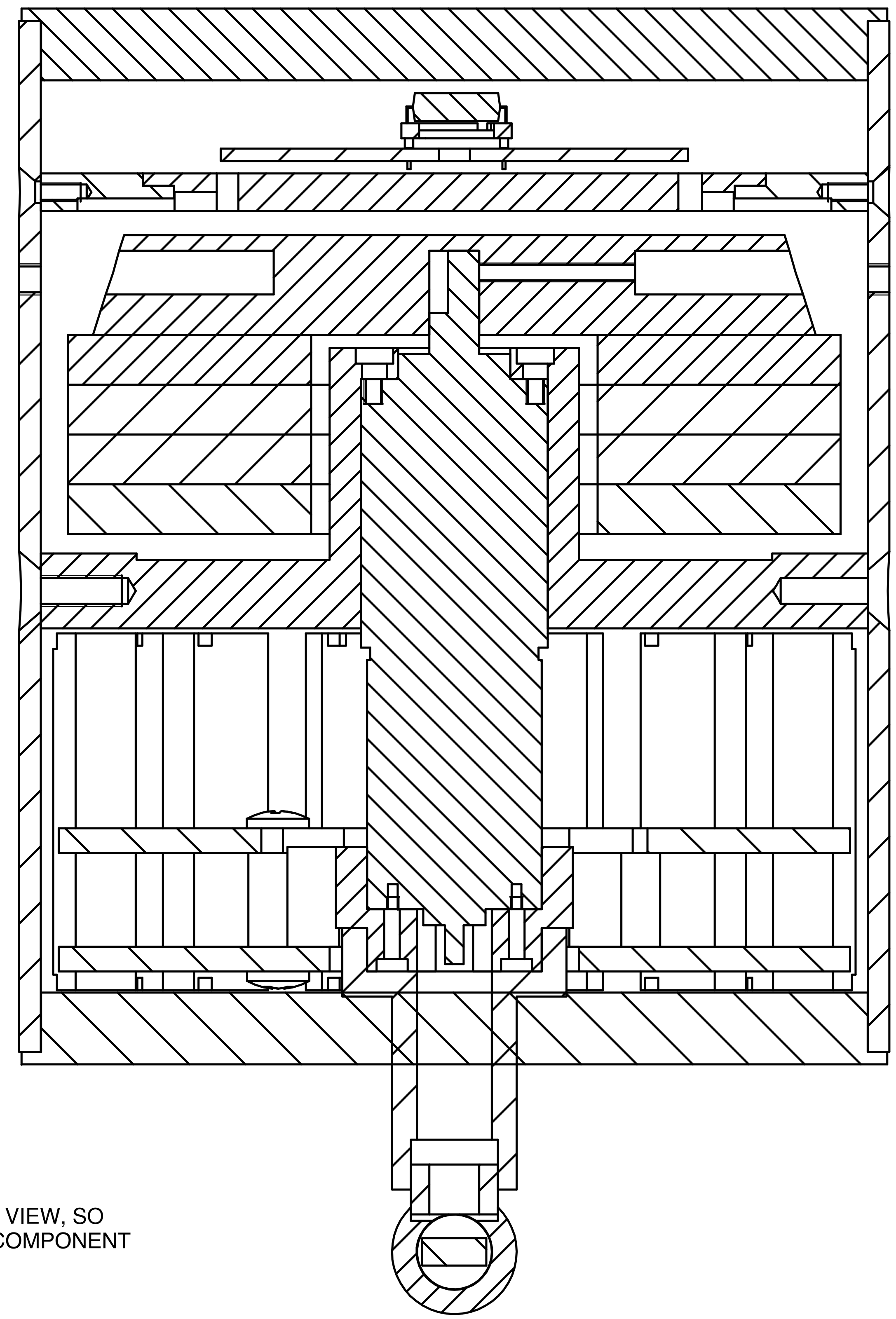
Exploded view of the proposed design



Appendix F

Technical drawings of proposed design
(19 pages)





SECTION A–A

TODO: NEED TO FIX FRONT VIEW, SO
IT'S FROM OUTSIDE & ADD COMPONENT
LIST AND FASTENERS.

dwg G18-01

NOTES:
ALL DIMENSIONS IN MILLIMETRES

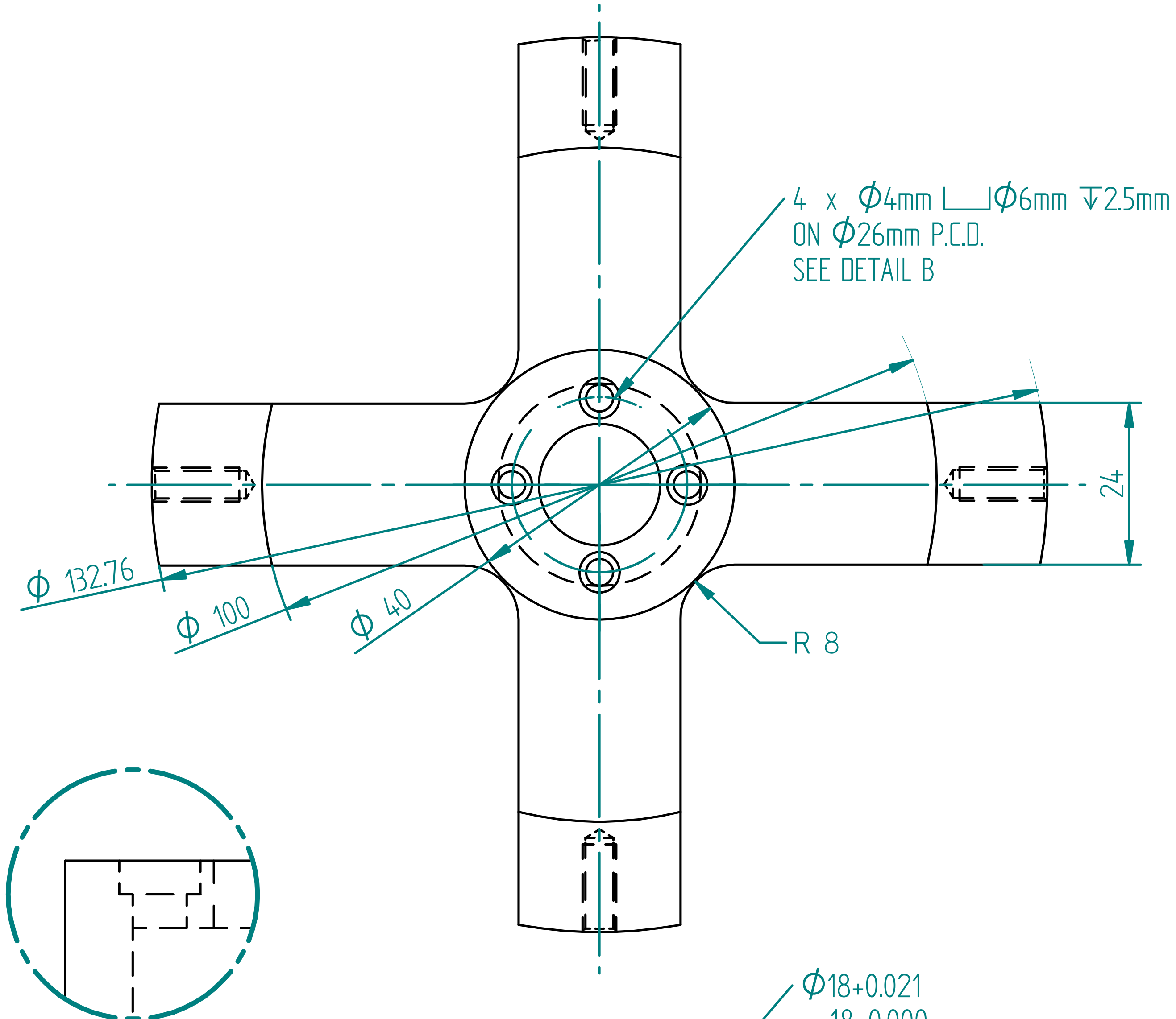
METR2800: GROUP 18

ASSEMBLY SECTION

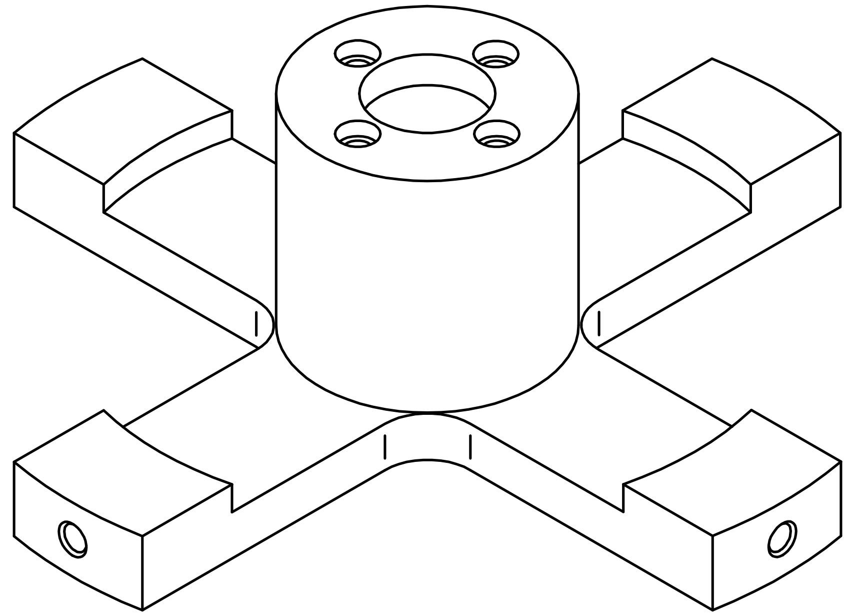
SATELLITE PROJECT

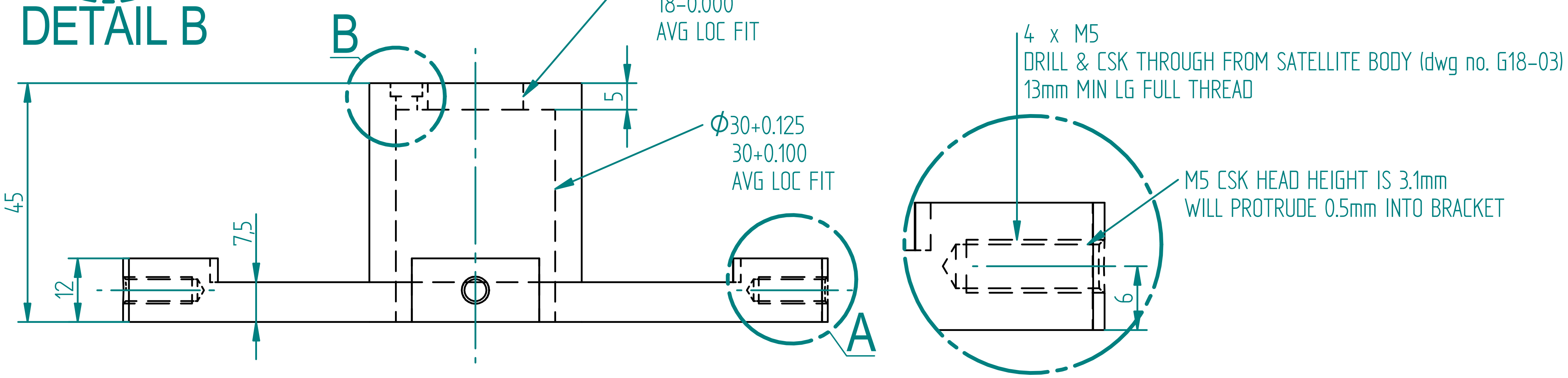
SCALE - 1:1	
THIRD ANGLE PROJECTION	
DRAWN: DAVID B	02-04-2011
APPROVED: t.b.a	dd-mm-yy

	SIZE	SHEET
dwg no. G18-01	A3	1 OF 15



DETAIL B





DETAIL A

QTY: 1

MATERIAL: 45mm ALUMINIUM PLATE
MAX DIM. 45 x 132.76 x 132.76

SURFACE FINISH: AS PROCESSED,
UNLESS OTHERWISE SHOWN.

CONDITION: AS SUPPLIED.

FASTENERS USED FOR ASSEMBLY:
4 X M5x12 CSK
4 x M3x10 PAN

dwg G18-02

NOTES:
ALL DIMENSIONS IN MILLIMETRES

TOLERANCES :
GENERAL TOLERANCE: +/- 0.1

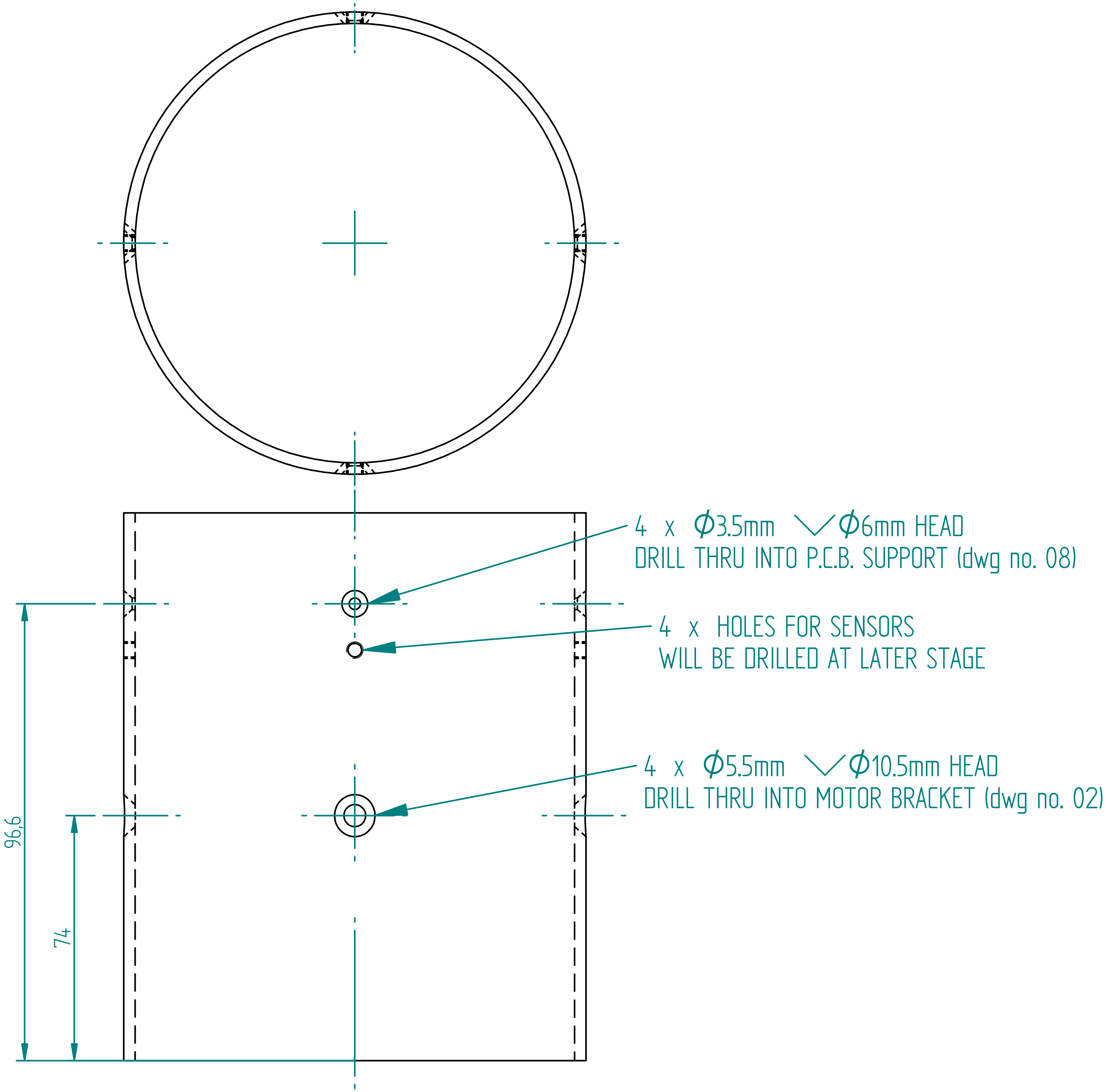
METR2800: GROUP 18

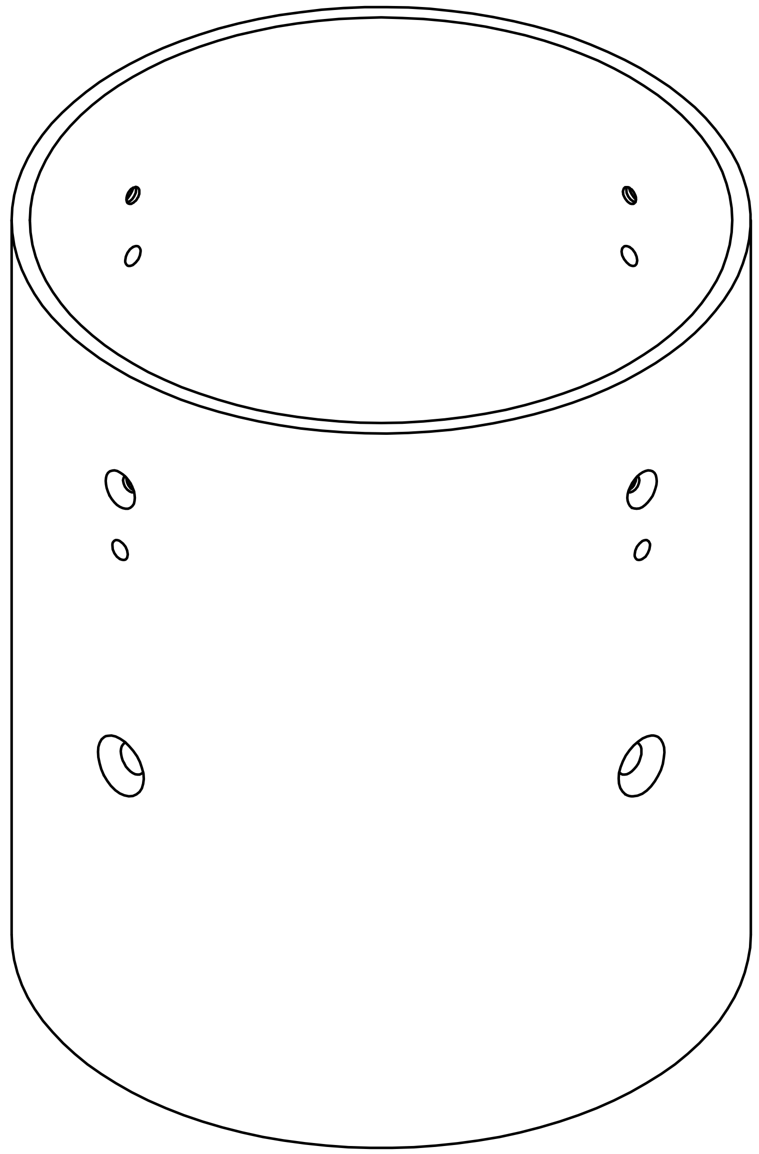
MOTOR BRACKET

SATELLITE PROJECT

SCALE - 1:1	
THIRD ANGLE PROJECTION	
DRAWN: DAVID B	02-04-2011
APPROVED: t.b.a	dd-mm-yy

	SIZE	SHEET
dwg no. G18-02	A3	2 OF 15





MACHINE ONLY
DO NOT FABRICATE

MATERIAL: ALUMINIUM TUBE

FASTENERS USED FOR ASSEMBLY:
4 x M3x6 CSK
4 x M5x12 CSK

dwg G18-03

NOTES:
ALL DIMENSIONS IN MILLIMETRES

TOLERANCES :
GENERAL TOLERANCE: FINE OR MEDIUM (CONFIRM??)
OR AS SHOWN.

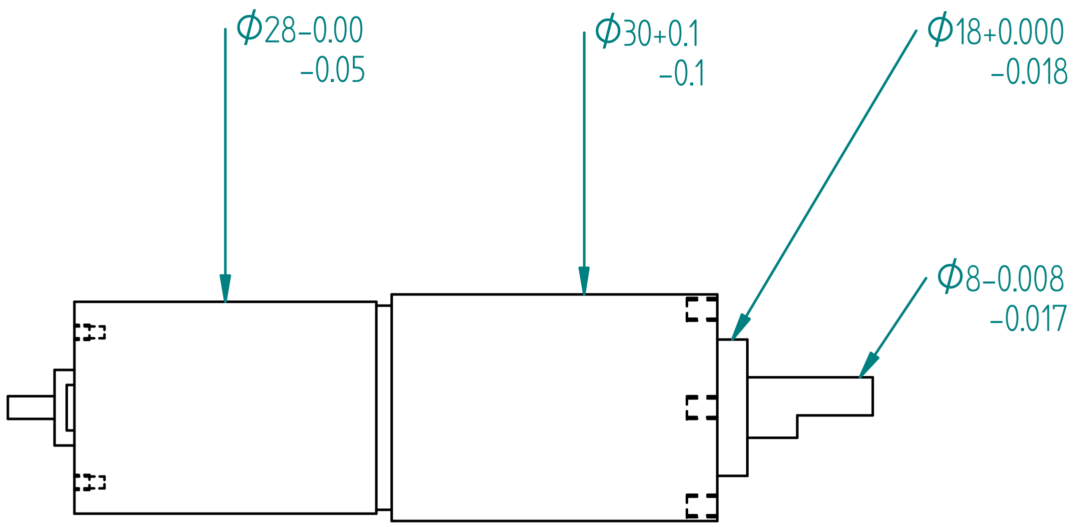
METR2800: GROUP 18

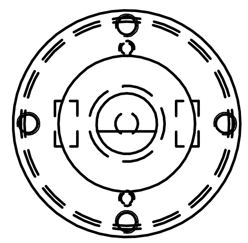
SATELLITE BODY

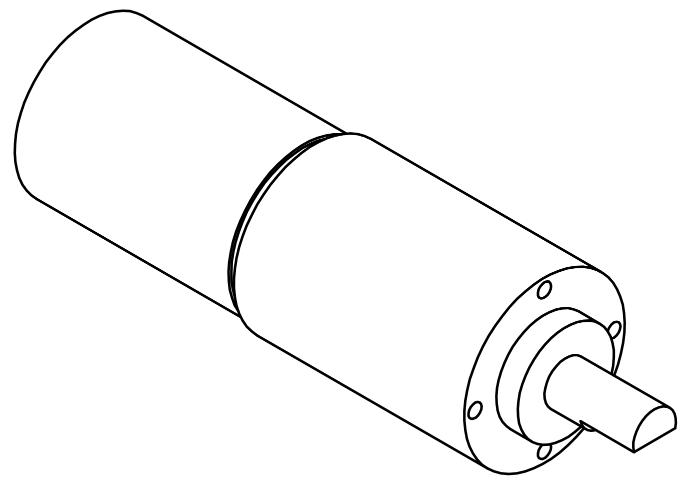
SATELLITE PROJECT

SCALE - 0.7:1
THIRD ANGLE PROJECTION
DRAWN: DAVID B — 02-04-2011
APPROVED: t.b.a — dd-mm-yy

dwg no. G18-03	SIZE	SHEET
	A3	3 OF 15







MOTOR USED FOR ASSEMBLY.

TOLERANCES AS SUPPLIED BY MANUFACTURER.

ONLY THOSE DIMENSIONS REQUIRED FOR MANUFACTURING OTHER PARTS ARE SHOWN.

FASTENERS USED FOR ASSEMBLY:
4 x M3x10 PAN
4 x M2x12 PAN
1 x M3x30 PAN (GRUBSCREW)

dwg G18-04

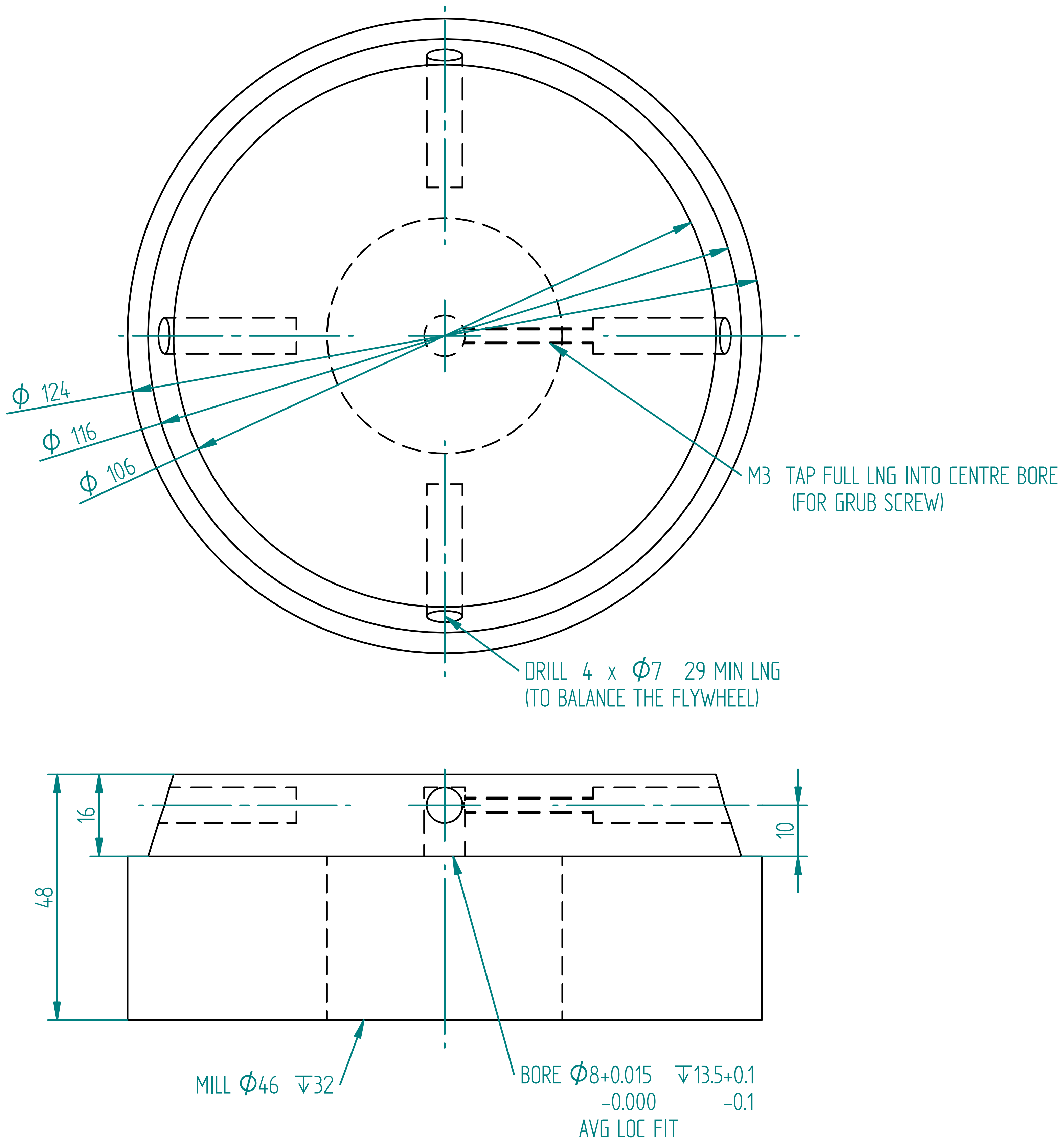
NOTES:
ALL DIMENSIONS IN MILLIMETRES

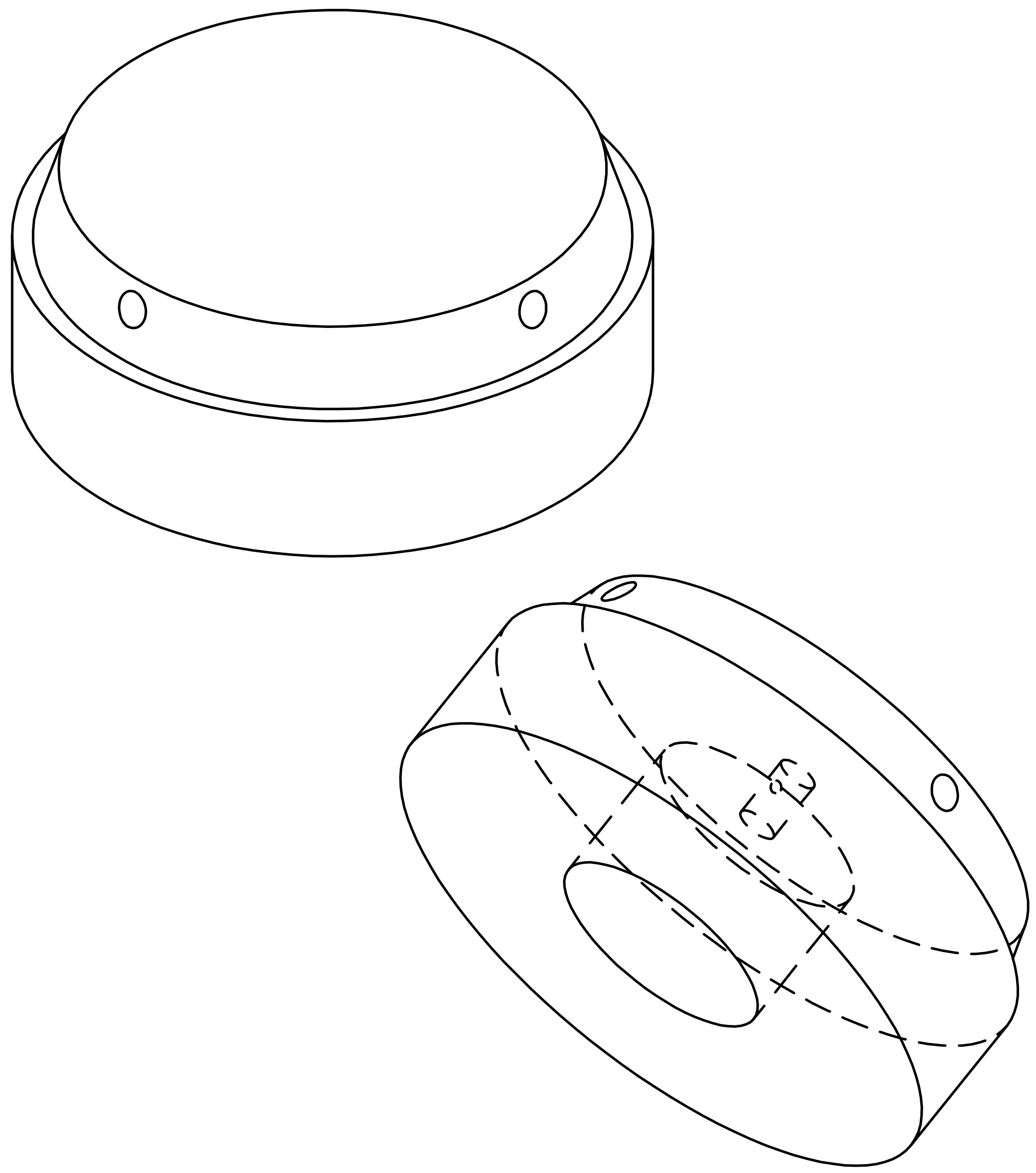
METR2800: GROUP 18

MOTOR

SATELLITE PROJECT

SCALE - 1:1	
THIRD ANGLE PROJECTION	
DRAWN: DAVID B	02-04-2011
APPROVED: t.b.a	dd-mm-yy
dwg no. G18-04	SIZE: A3 / SHEET: 4 OF 15





QTY: 1

MATERIAL: 48mm STEEL PLATE
MAX DIM. 48 x diam124

SURFACE FINISH: AS PROCESSED,

CONDITION: AS SUPPLIED.

FASTENERS USED FOR ASSEMBLY:
1 x M3x30 PAN (GRUBSCREW)

dwg G18-05

NOTES:
ALL DIMENSIONS IN MILLIMETRES

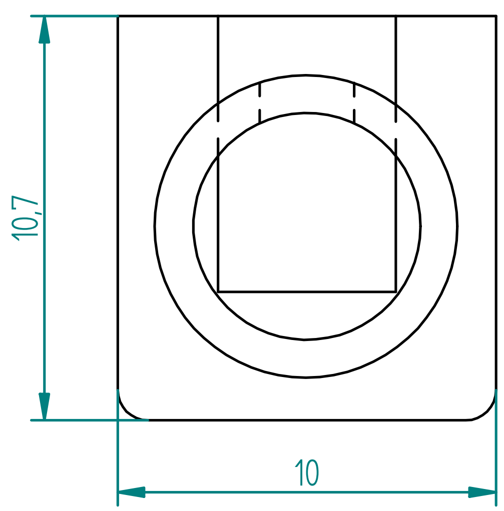
TOLERANCES :
GENERAL TOLERANCE: +/-0.1

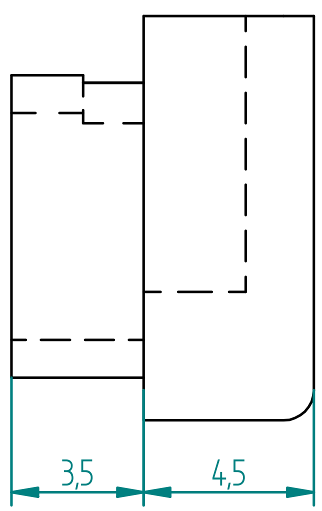
METR2800: GROUP 18

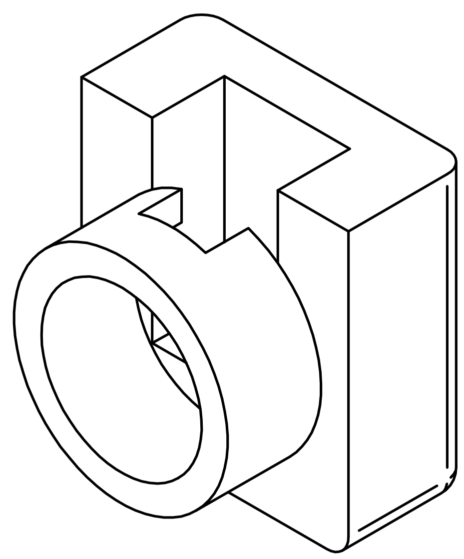
REACTION WHEEL

SATELLITE PROJECT

SCALE - 1:1		
THIRD ANGLE PROJECTION		
DRAWN: DAVID B		02-04-2011
APPROVED: t.b.a		dd-mm-yy
dwg no. G18-05	SIZE	SHEET
	A3	5 OF 15







ONLY BASIC DIMENSIONS SHOWN.
TO BE MANUFACTURED BY PLASTIC PRINTER.

QTY: 6

MATERIAL: PLASTIC

SURFACE FINISH: AS PROCESSED

dwg G18-06

NOTES:
ALL DIMENSIONS IN MILLIMETRES

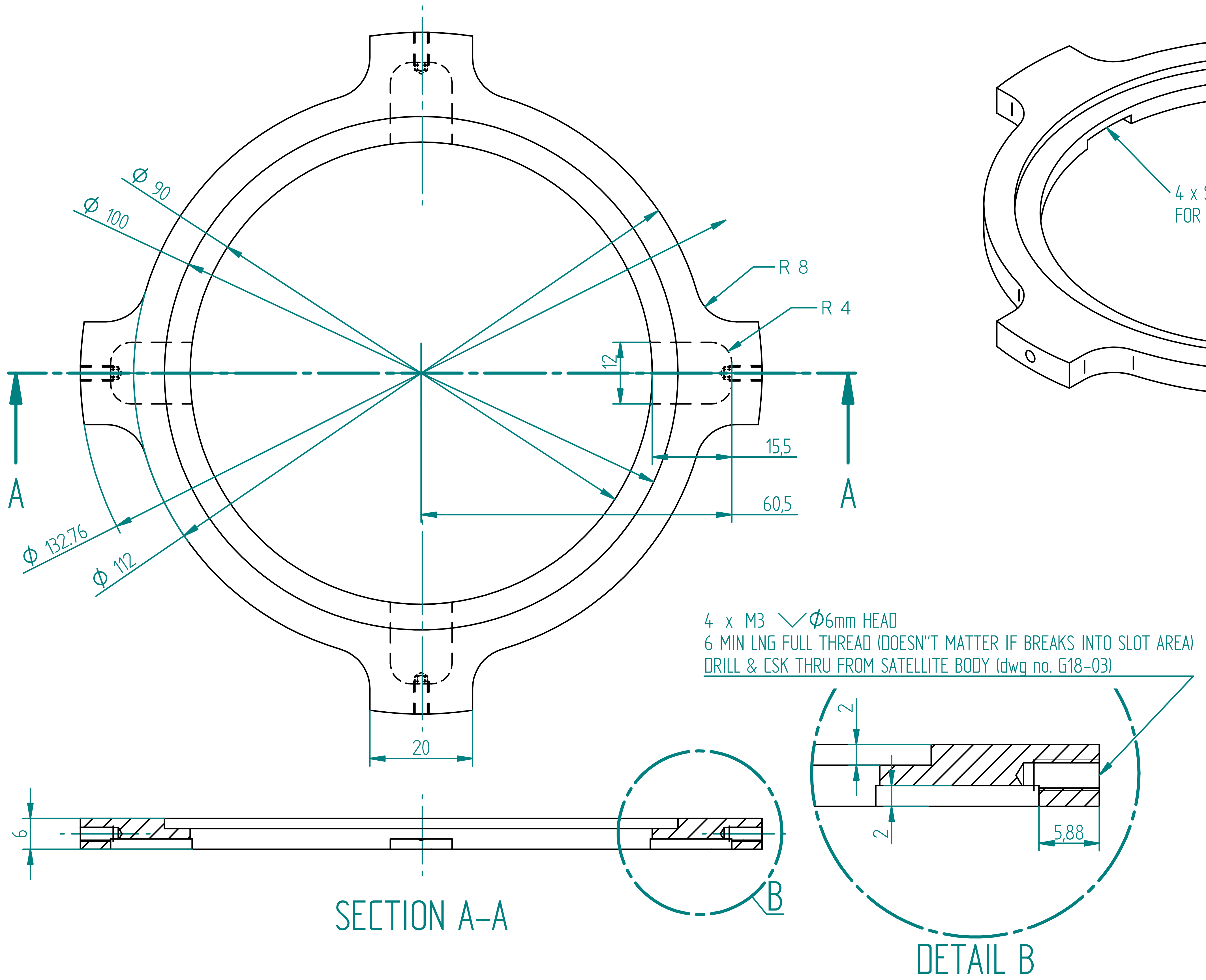
METR2800: GROUP 18

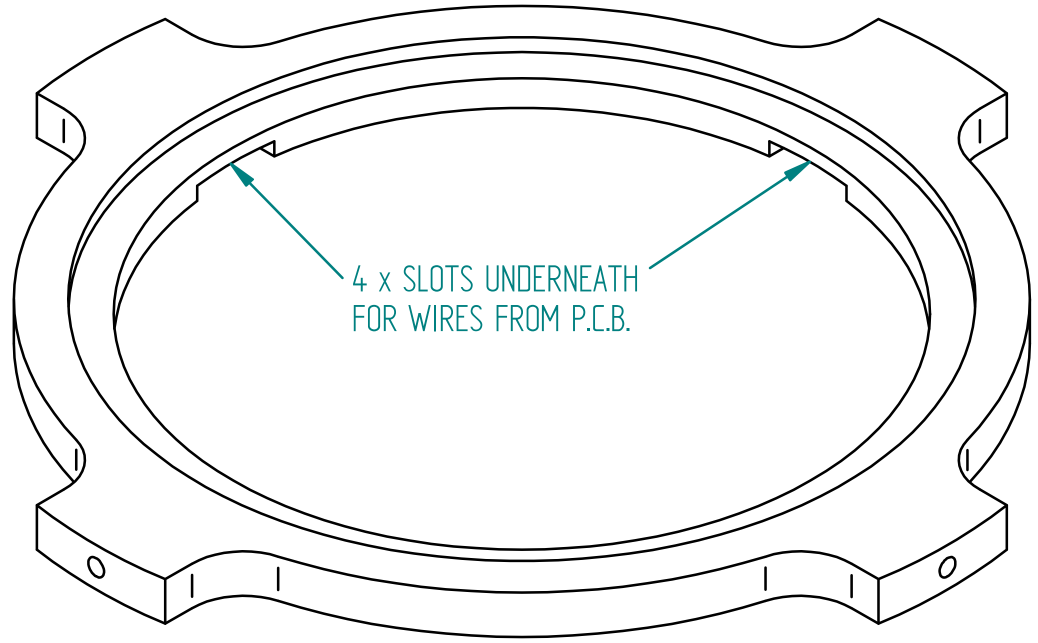
SENSOR HOLDER (qty. 6)

SATELLITE PROJECT

SCALE - 5:1	
THIRD ANGLE PROJECTION	
DRAWN: DAVID B	20-5-2011
APPROVED: t.b.a.	

dwg no.	SIZE	SHEET
dwg no. G18-06	A3	6 OF 15





QTY: 1

MATERIAL: PLASTIC
MAX DIM. 6 x 132.76 x 132.76

SURFACE FINISH: AS PROCESSED,

CONDITION: AS SUPPLIED.

FASTENERS USED FOR ASSEMBLY:
4 x M3x6 CSK

dwg G18-07

NOTES:
ALL DIMENSIONS IN MILLIMETRES

TOLERANCES :
GENERAL TOLERANCE: +/- 0.1

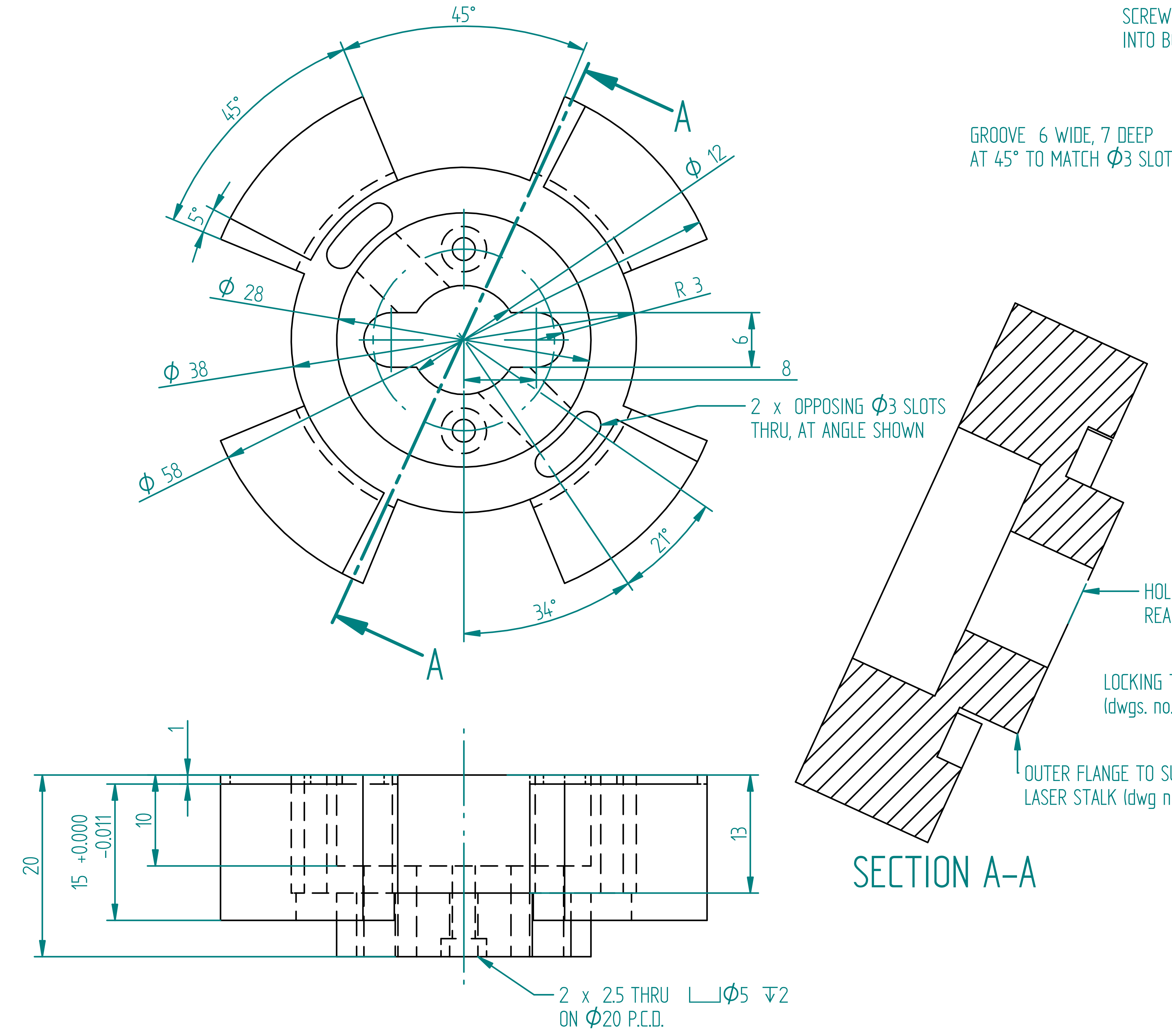
METR2800: GROUP 18

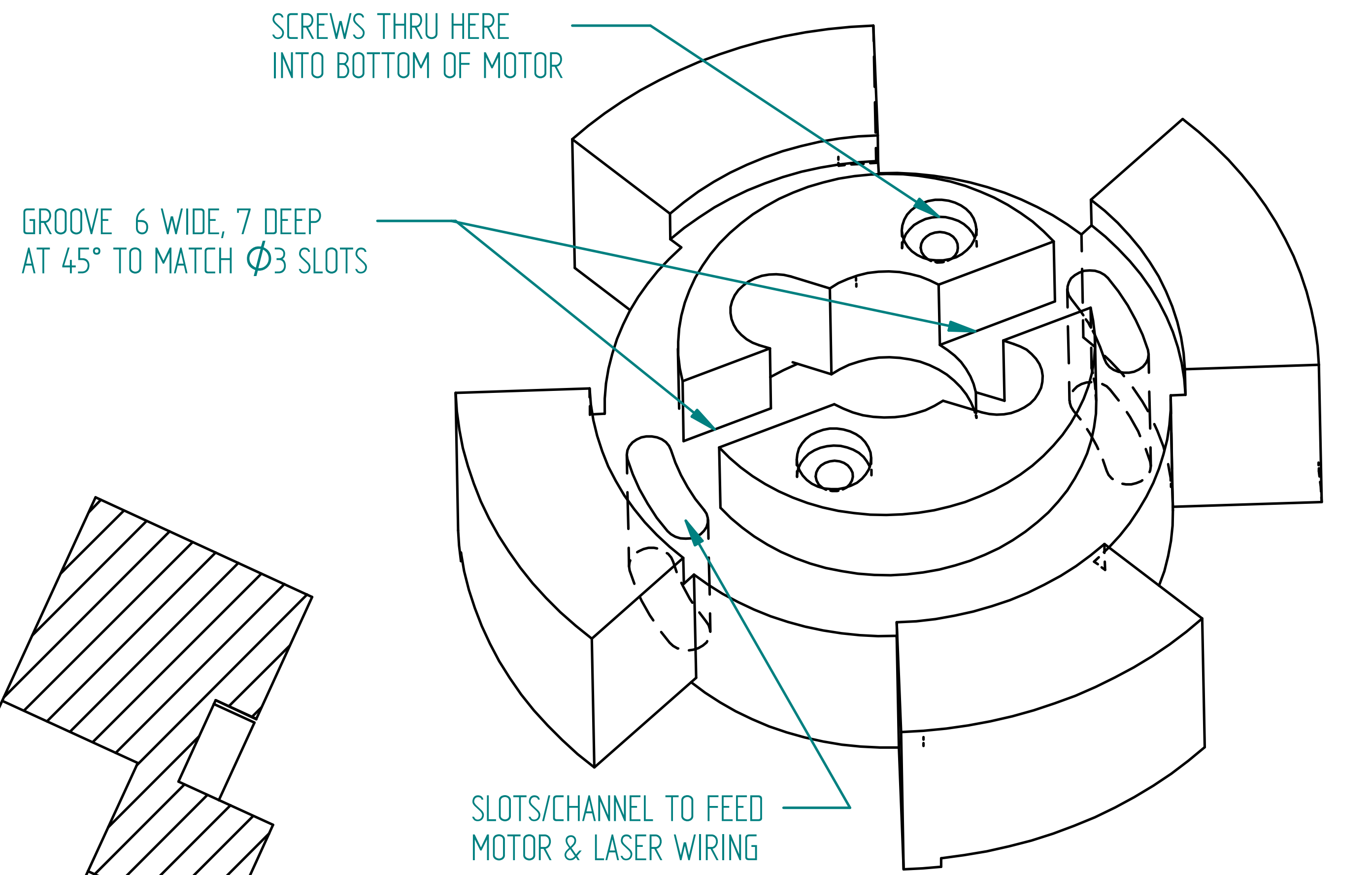
P.C.B. SUPPORT

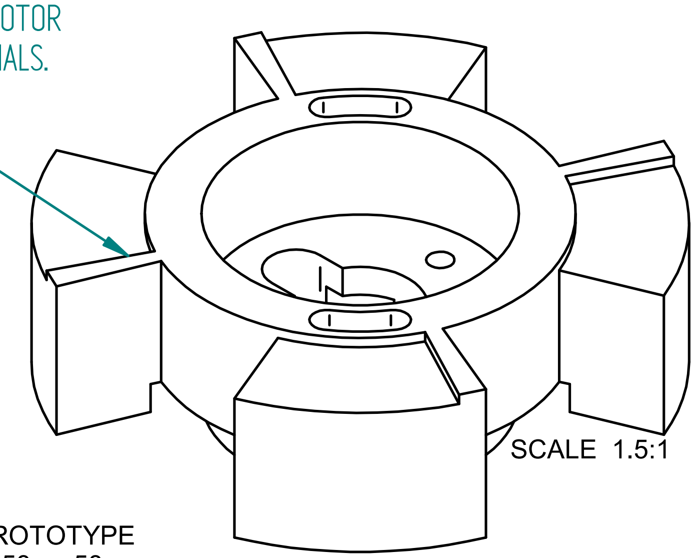
SATELLITE PROJECT

SCALE - 1.2:1	
THIRD ANGLE PROJECTION	
DRAWN: DAVID B	02-04-2011
APPROVED: t.b.a	dd-mm-yy

	SIZE	SHEET
dwg no. G18-07	A3	7 OF 15







QTY: 1

MATERIAL: PLASTIC PROTOTYPE
MAX DIM. 20 x 58 x 58

SURFACE FINISH: AS PROCESSED,
CONDITION: AS SUPPLIED.

FASTENERS USED FOR ASSEMBLY:
2 x M2x12 PAN

dwg G18-08

NOTES:
ALL DIMENSIONS IN MILLIMETRES

TOLERANCES :
GENERAL TOLERANCE: +/- 0.1

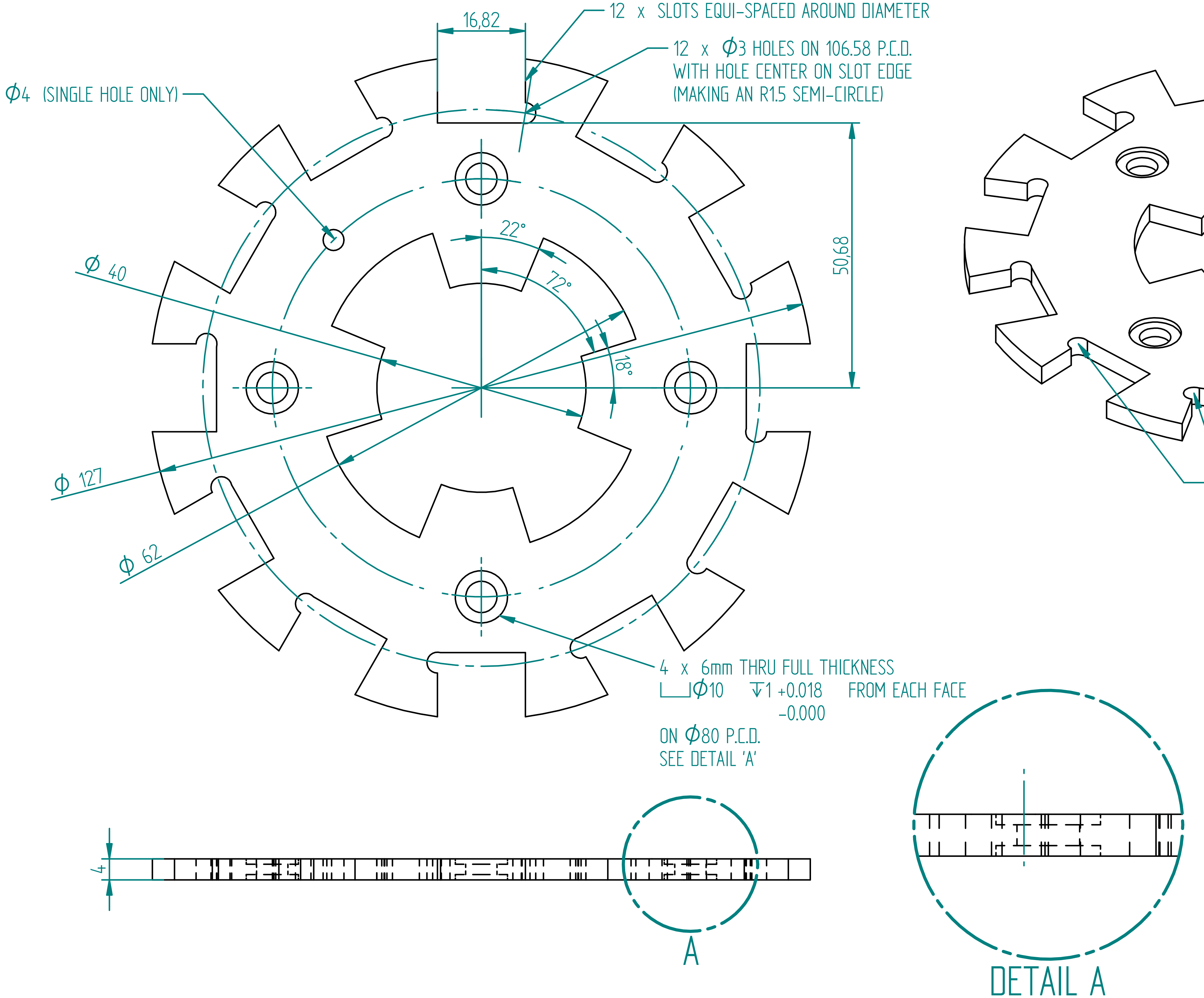
METR2800: GROUP 18

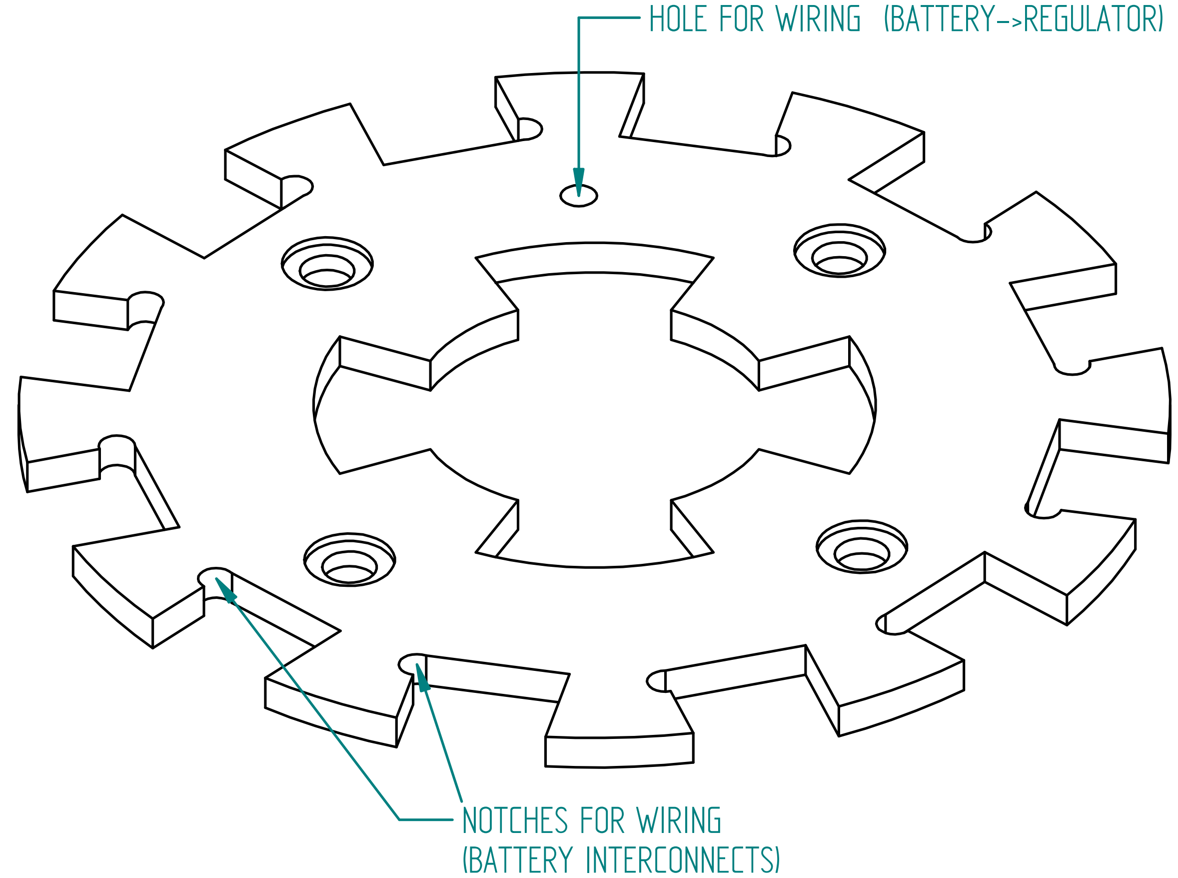
BATTERY MODULE - BRACKET

SATELLITE PROJECT

SCALE - 2:1
THIRD ANGLE PROJECTION
DRAWN: DAVID B 02-04-2011
APPROVED: t.b.a dd-mm-yy

dwg no. G18-08	SIZE: A3	SHEET: 8 OF 15





QTY: 1

MATERIAL: PLASTIC PROTOTYPE
MAX DIM. 4 x 127 x 127

SURFACE FINISH: AS PROCESSED

CONDITION: AS SUPPLIED.

FASTENERS USED FOR ASSEMBLY:
4 x M5x10 PAN

dwg G18-09

NOTES:
ALL DIMENSIONS IN MILLIMETRES

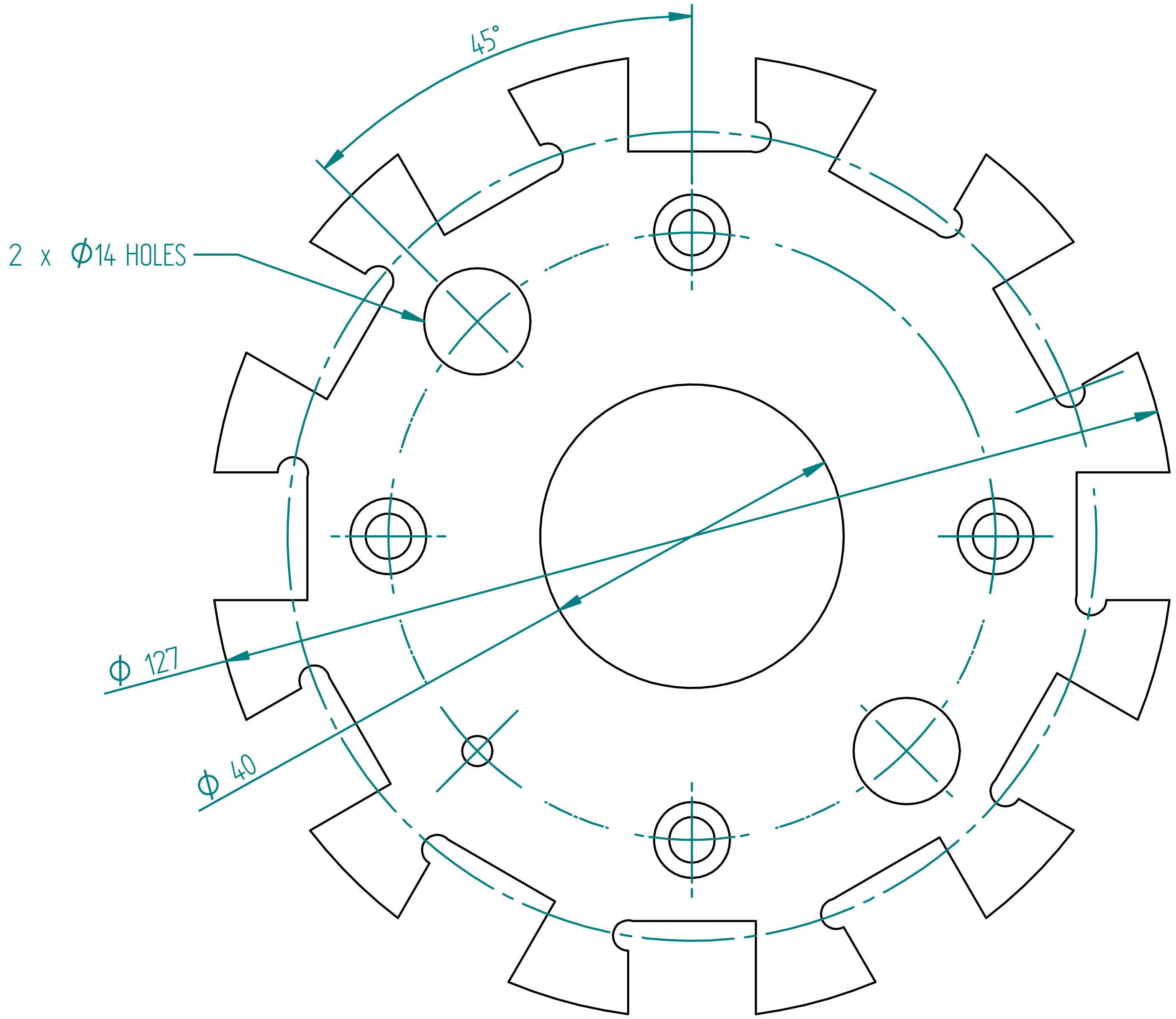
TOLERANCES :
GENERAL TOLERANCE: +/- 0.1

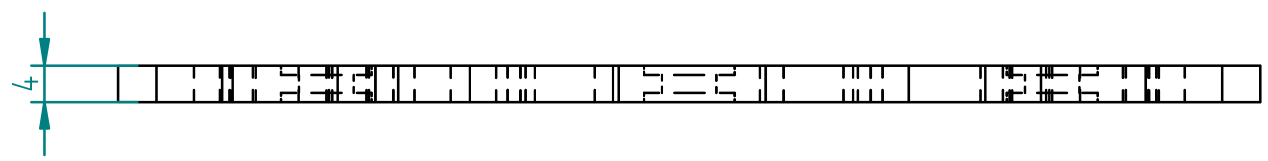
METR2800: GROUP 18

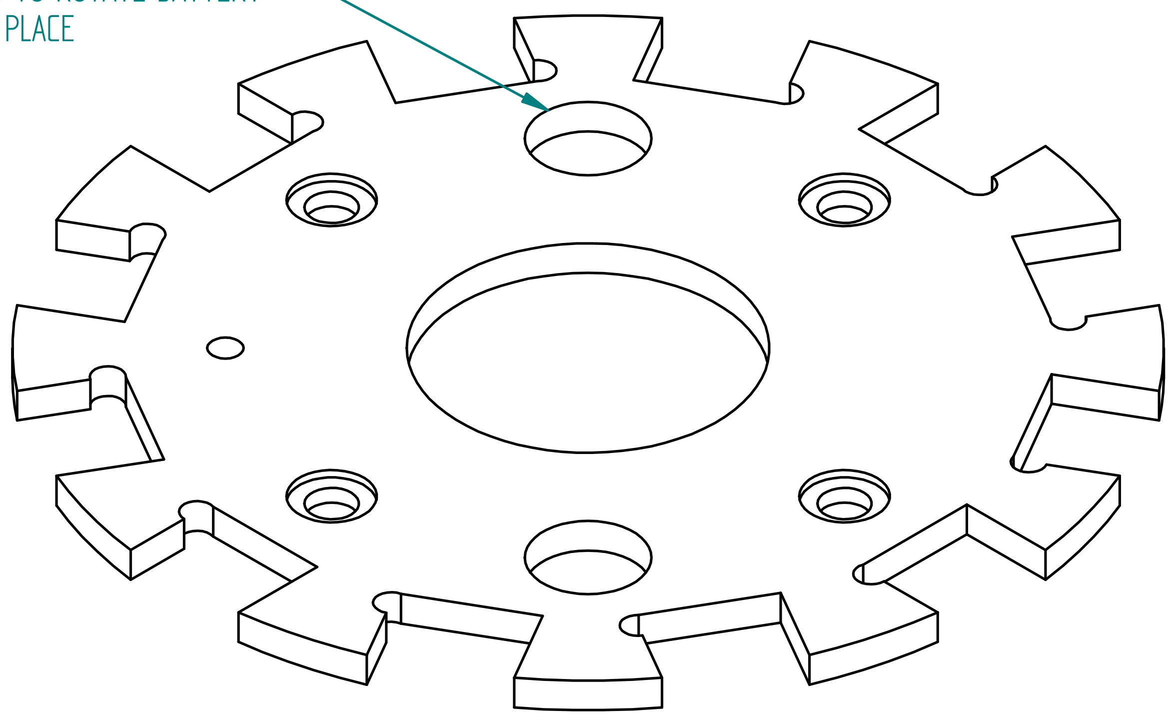
BATTERY MODULE - TOP

SATELLITE PROJECT

SCALE - 1.2:1	
THIRD ANGLE PROJECTION	
DRAWN: DAVID B	02-04-2011
APPROVED: t.b.a	dd-mm-yy
dwg no. G18-09	SIZE: A3 / SHEET: 9 OF 15







QTY: 1

MATERIAL: PLASTIC PROTOTYPE
MAX DIM. 4 x 127 x 127

SURFACE FINISH: AS PROCESSED

CONDITION: AS SUPPLIED.

FASTENERS USED FOR ASSEMBLY:
4 x M5x10 PAN

dwg G18-10

NOTES:
ALL DIMENSIONS IN MILLIMETRES

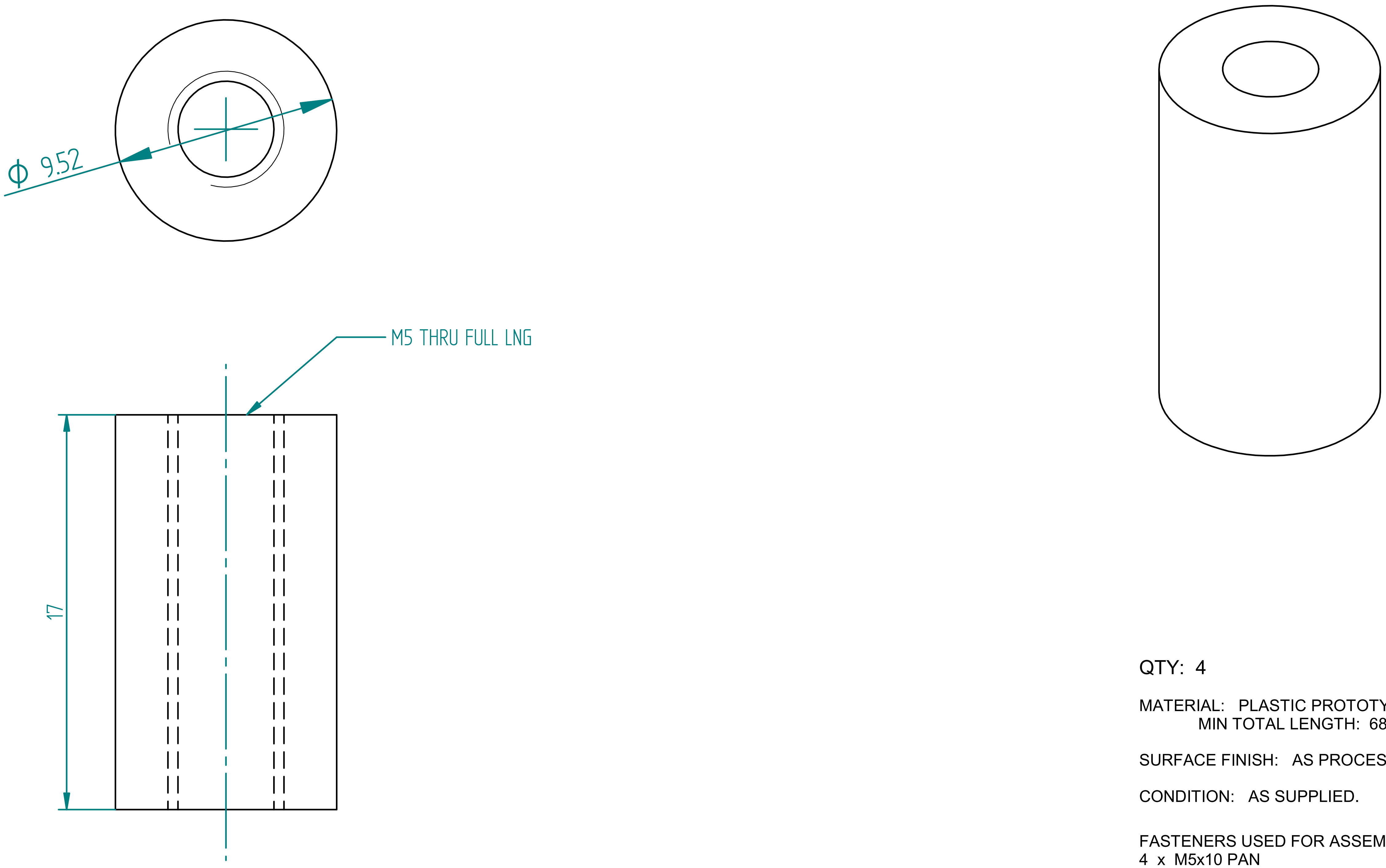
TOLERANCES :
GENERAL TOLERANCE: +/- 0.1

METR2800: GROUP 18

BATTERY MODULE - BOTTOM

SATELLITE PROJECT

SCALE - 1.2:1	
THIRD ANGLE PROJECTION	
DRAWN: DAVID B	02-04-2011
APPROVED: t.b.a	dd-mm-yy
dwg no. G18-10	SIZE: A3 / SHEET: 10 OF 15



QTY: 4

MATERIAL: PLASTIC PROTOTYPE
MIN TOTAL LENGTH: 68

SURFACE FINISH: AS PROCESSED

CONDITION: AS SUPPLIED.

FASTENERS USED FOR ASSEMBLY:
4 x M5x10 PAN

dwg G18-11

NOTES:
ALL DIMENSIONS IN MILLIMETRES

TOLERANCES :
GENERAL TOLERANCE: +/- 0.1

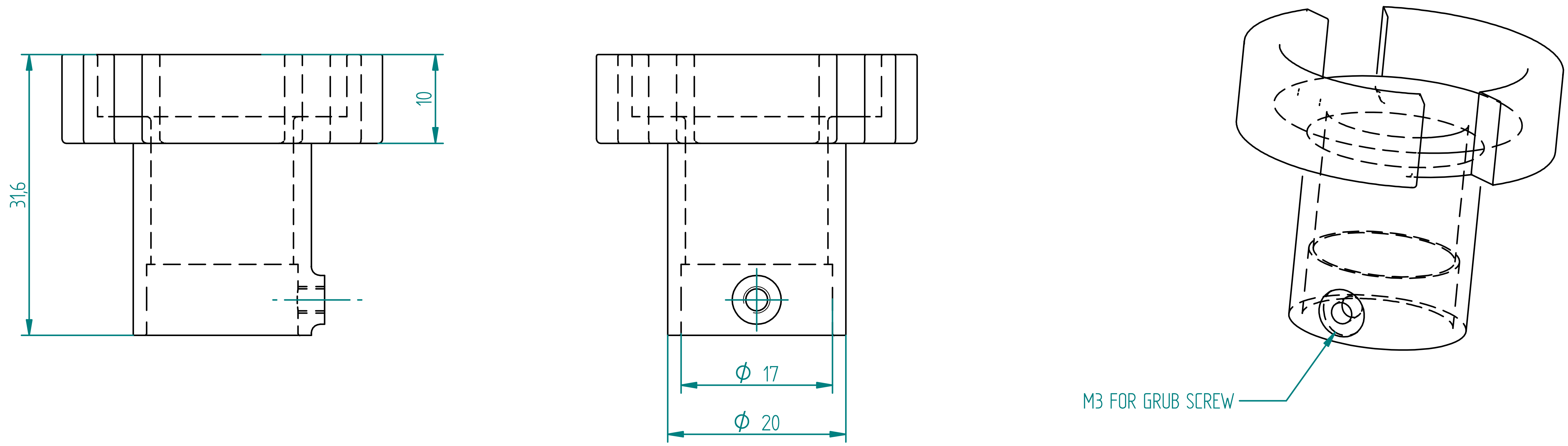
METR2800: GROUP 18

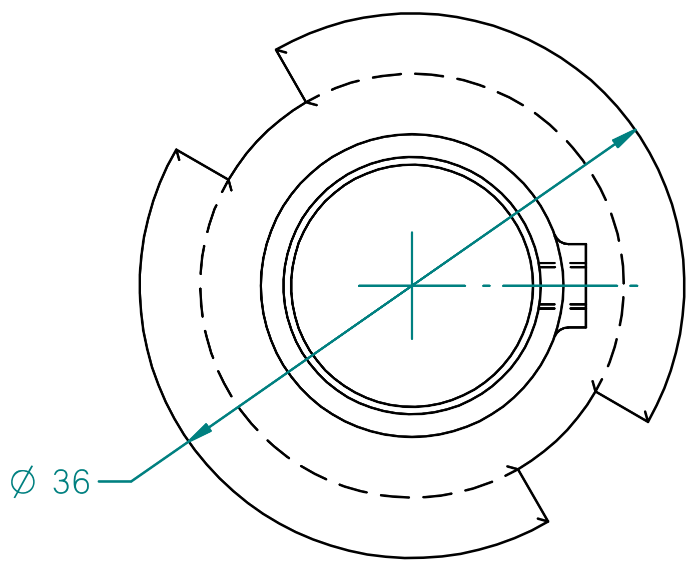
BATTERY MODULE - RODS (qty. 4)

SATELLITE PROJECT

SCALE - 5:1	
THIRD ANGLE PROJECTION	
DRAWN: DAVID B	02-04-2011
APPROVED: t.b.a	dd-mm-yy

	SIZE	SHEET
dwg no. G18-11	A3	11 OF 15





ONLY BASIC DIMS. SHOWN.
TO BE MANUFACTURED BY RAPID PROTOTYPE PRINTER.

QTY: 1

MATERIAL: PLASTIC PROTOTYPE
MAX DIM. 31.6 x 36 x 36

SURFACE FINISH: AS PROCESSED,
UNLESS OTHERWISE SHOWN.

CONDITION: AS SUPPLIED.

FASTENERS USED FOR ASSEMBLY:
1 x M3x6 NYLON CHEESE (GRUB SCREW)
ADHESIVE

dwg G18-12

NOTES:
ALL DIMENSIONS IN MILLIMETRES

TOLERANCES :
GENERAL TOLERANCE: +/- 0.1

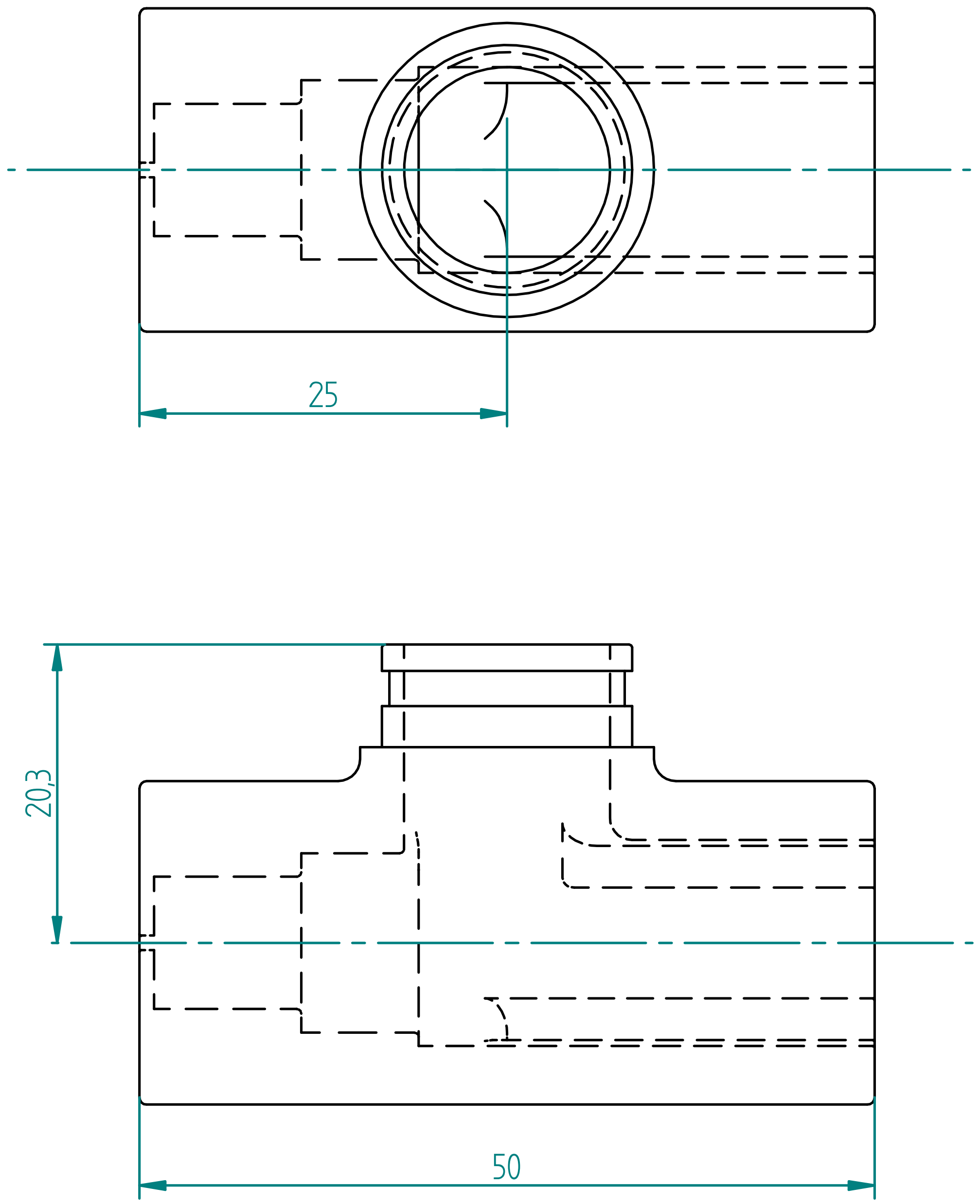
METR2800: GROUP 18

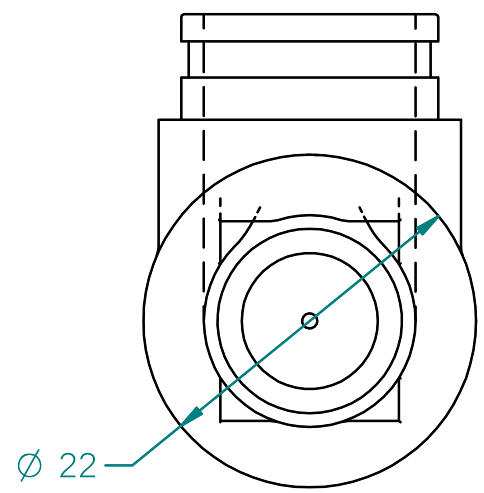
LASER - STALK

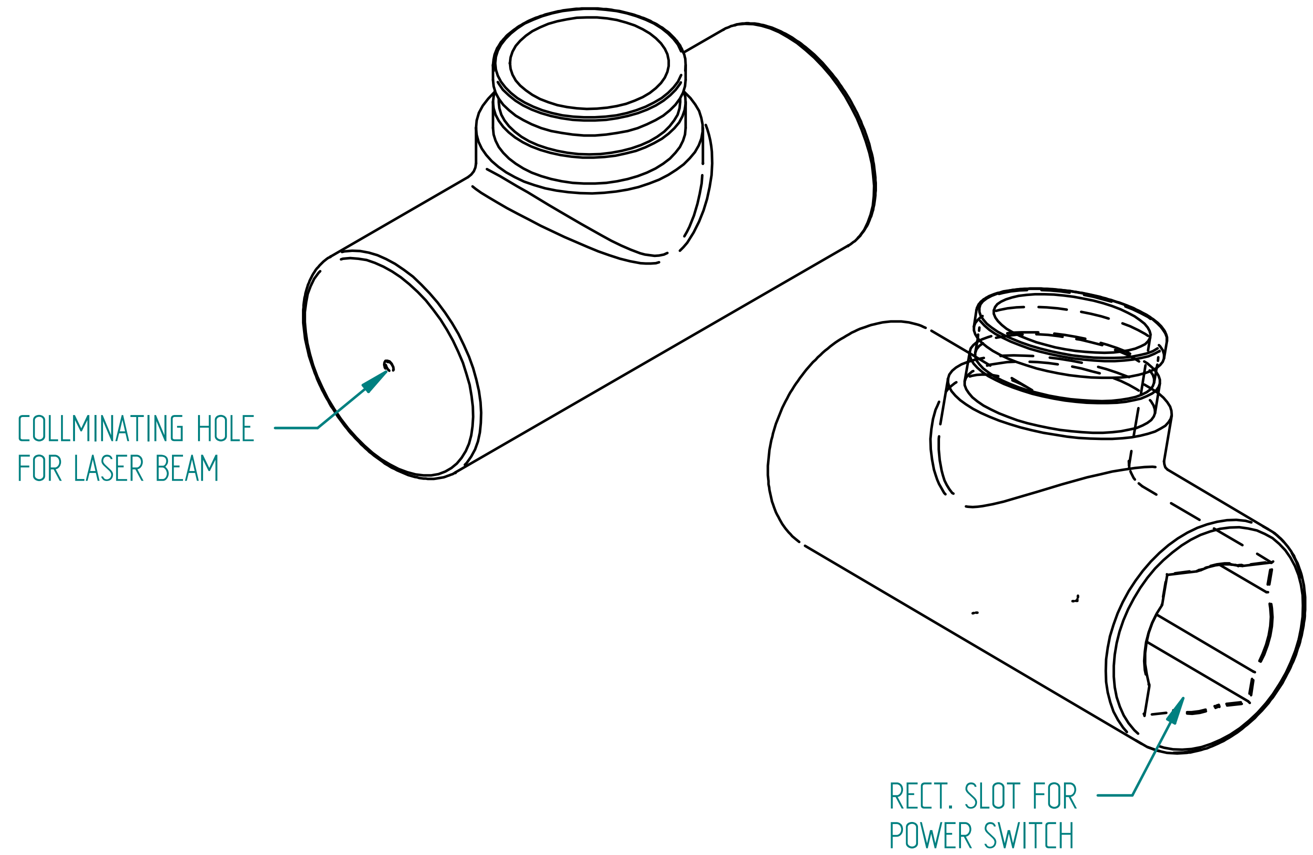
SATELLITE PROJECT

SCALE - 2:1
THIRD ANGLE PROJECTION
DRAWN: DAVID B 02-04-2011
APPROVED: t.b.a dd-mm-yy

dwg no. G18-12	SIZE	SHEET
	A3	12 OF 15







ONLY BASIC DIMS. SHOWN.
TO BE MANUFACTURED BY RAPID PROTOTYPE PRINTER.

QTY: 1

MATERIAL: PLASTIC PROTOTYPE
MAX DIM. 45 x 20 x 20

SURFACE FINISH: AS PROCESSED,
UNLESS OTHERWISE SHOWN.

CONDITION: AS SUPPLIED.

FASTENERS USED FOR ASSEMBLY:
ADHESIVE

dwg G18-13

NOTES:
ALL DIMENSIONS IN MILLIMETRES

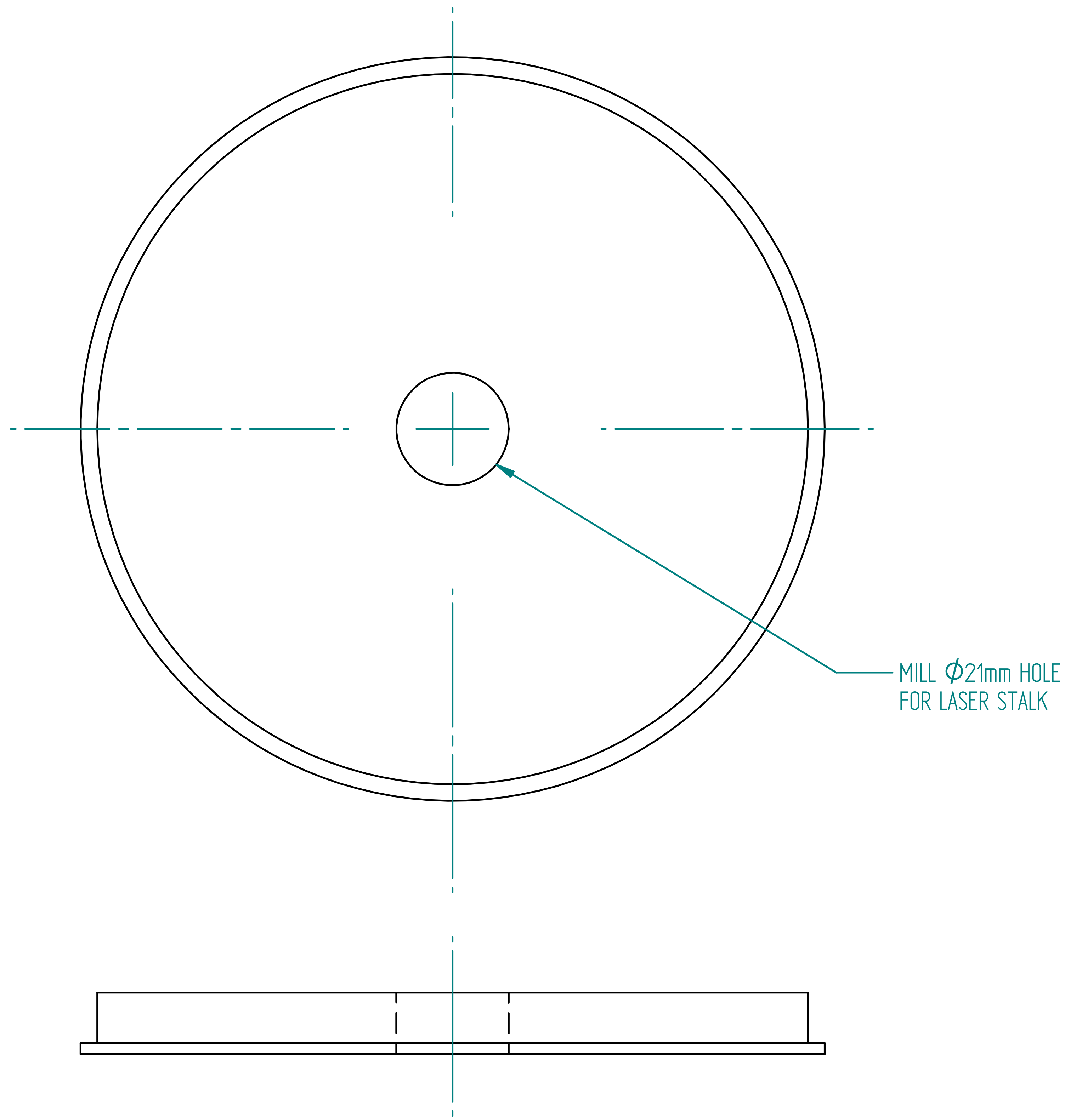
TOLERANCES :
GENERAL TOLERANCE: FINE OR MEDIUM (CONFIRM??)
OR AS SHOWN.

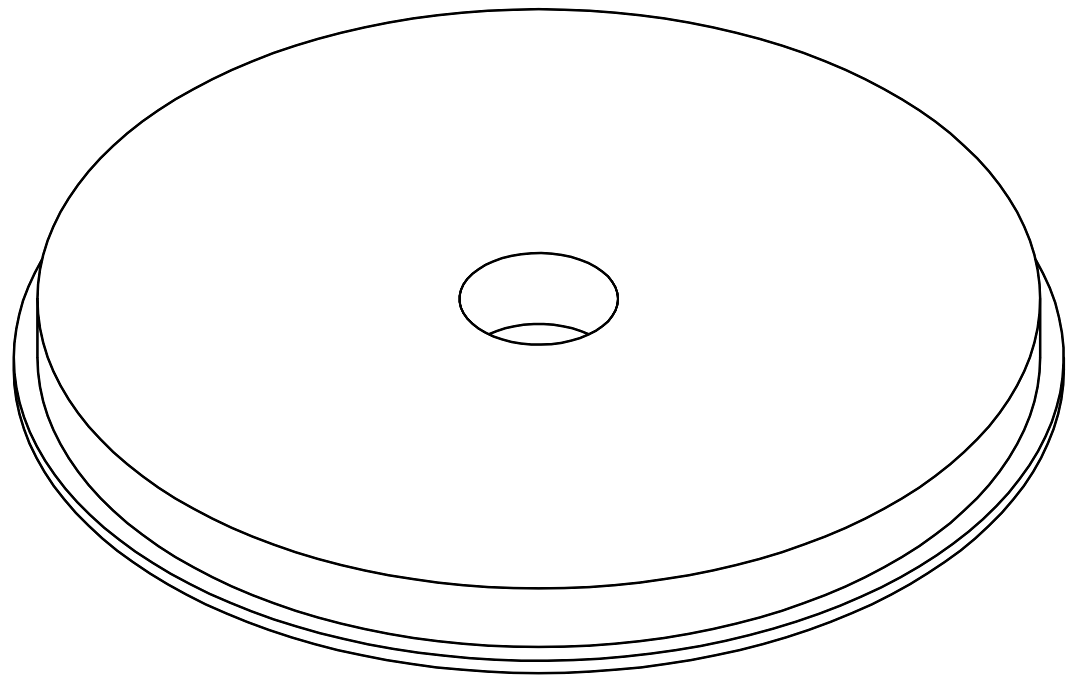
METR2800: GROUP 18

LASER - CASE

SATELLITE PROJECT

SCALE - 2:1			
THIRD ANGLE PROJECTION			
DRAWN: DAVID B			02-04-2011
APPROVED: t.b.a			dd-mm-yy
dwg no. G18-13		SIZE A3	SHEET 13 OF 15





MACHINE ONLY
DO NOT FABRICATE

MATERIAL: PLASTIC PERSPEX

dwg G18-14

NOTES:
ALL DIMENSIONS IN MILLIMETRES

TOLERANCES :
GENERAL TOLERANCE: FINE OR MEDIUM (CONFIRM??)
OR AS SHOWN.

METR2800: GROUP 18

BOTTOM CAP

SATELLITE PROJECT

SCALE - 1:1

THIRD ANGLE PROJECTION

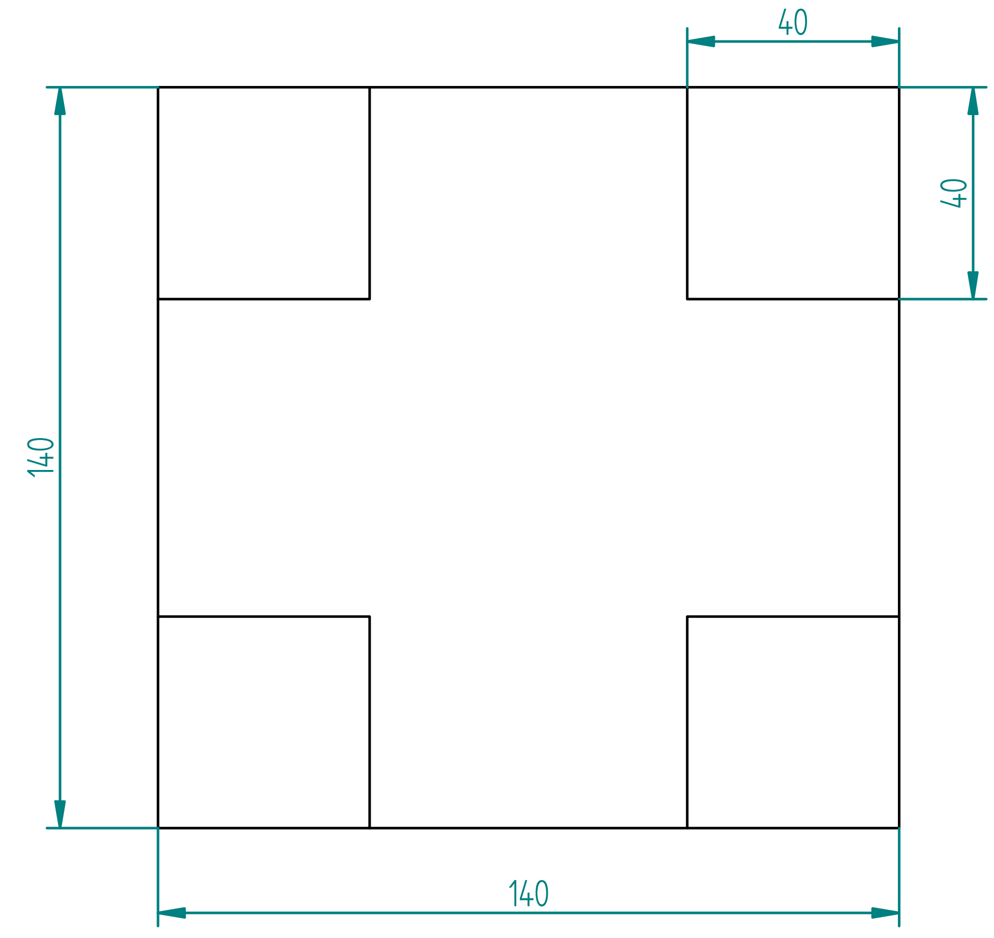
DRAWN: DAVID B — 02-04-2011

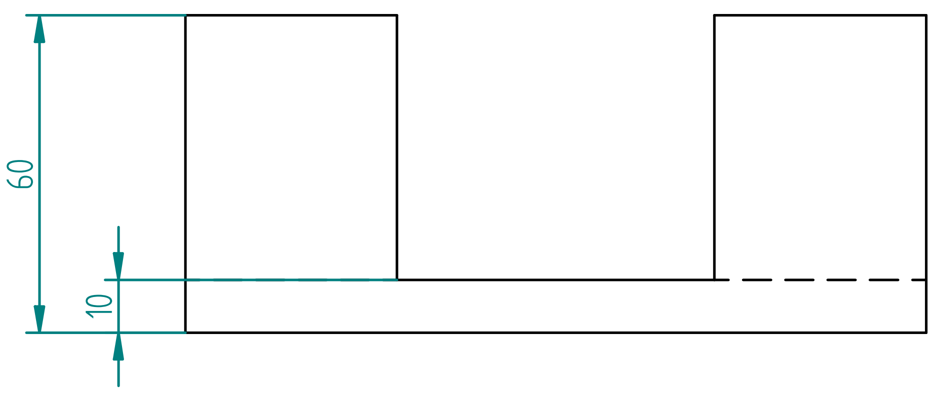
APPROVED: t.b.a — dd-mm-yy

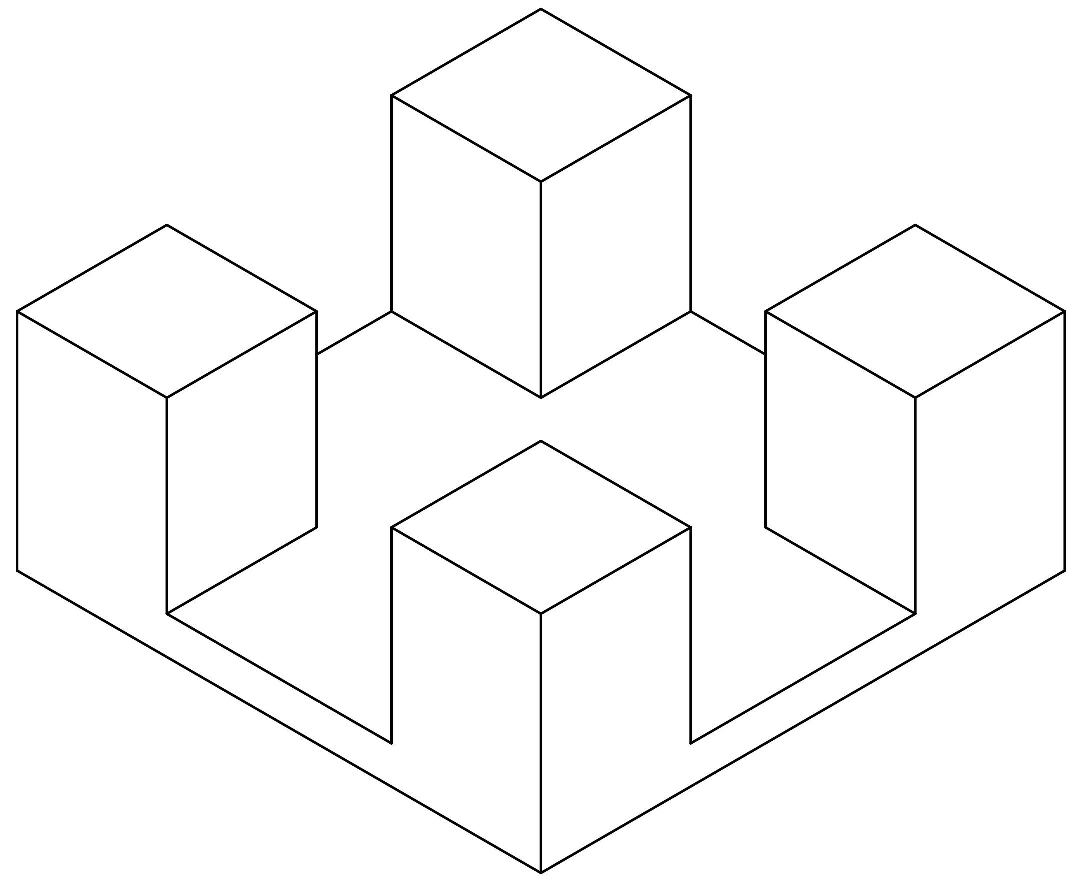
dwg no. G18-14

SIZE: A3

SHEET: 14 OF 15







THIS IS A TESTING BASE TO SIT THE SATELLITE ON.

CAN USE 40-60 MM SQUARE BLOCK, DEPENDING ON AVAILABILITY.

TIMBER BASE CAN BE 8, 10, or 12mm THICK.

ATTACH BLOCKS WITH SCREW OR NAILS.
GROUP 18 CAN ASSEMBLE IF REQ'D.

QTY: 1

MATERIAL: TIMBER (MDF or Plywood)

SURFACE FINISH: AS PROCESSED, UNLESS OTHERWISE SHOWN.

CONDITION: AS SUPPLIED.

FASTENERS USED FOR ASSEMBLY:

dwg G18-15

NOTES:
ALL DIMENSIONS IN MILLIMETRES

TOLERANCES :
GENERAL TOLERANCE: FINE OR MEDIUM (CONFIRM??)
OR AS SHOWN.

METR2800: GROUP 18

TESTING BASE

SATELLITE PROJECT

SCALE - 1:1	
THIRD ANGLE PROJECTION	
DRAWN: DAVID B	02-04-2011
APPROVED: t.b.a	dd-mm-yy

	SIZE	SHEET
dwg no. G18-15	A3	15 OF 15

This page is intentionally blank

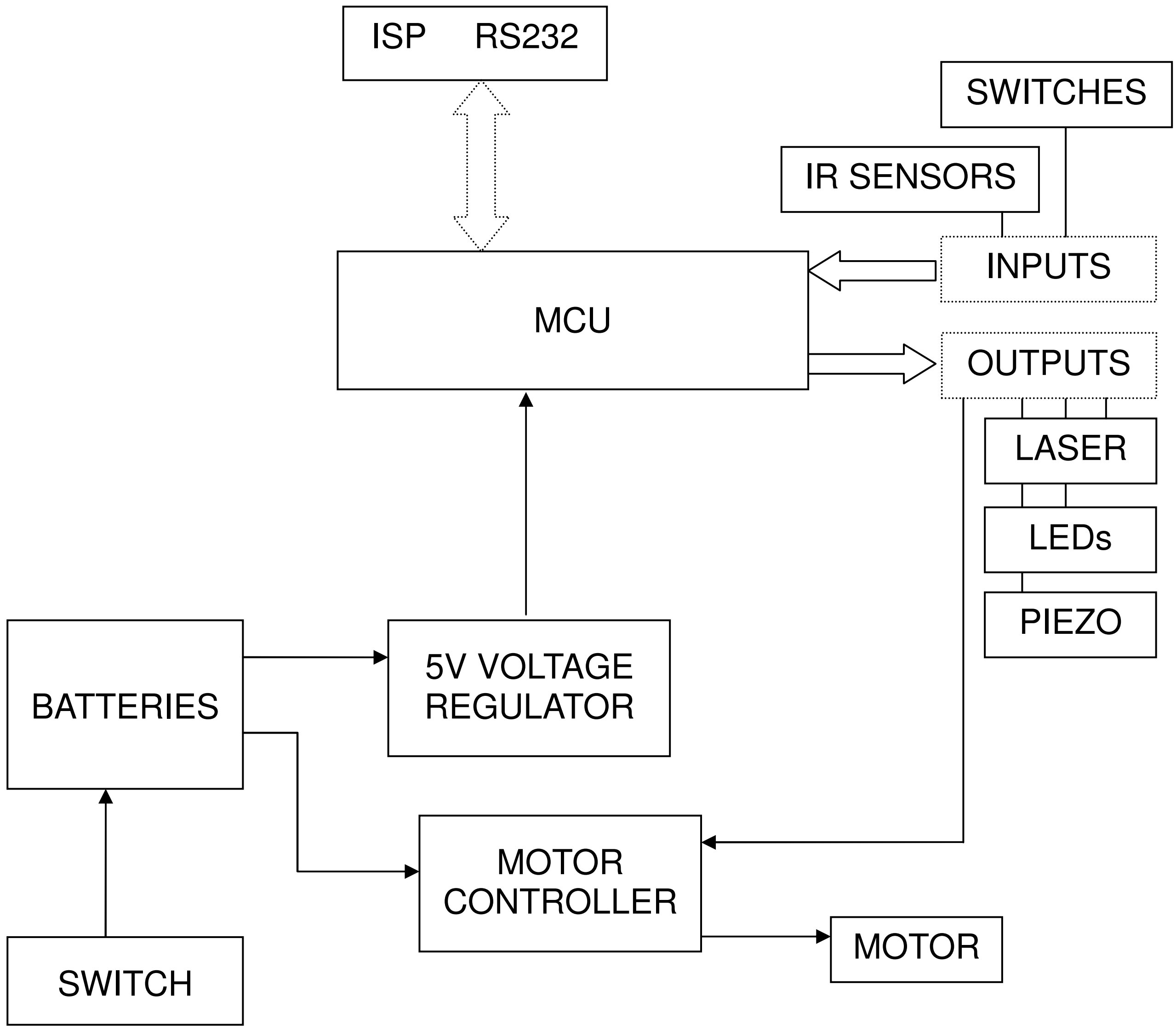
This page is intentionally blank

This page is intentionally blank

This page is intentionally blank

Appendix G

Block diagram of electronic modules



Appendix H

Exerts from ATmega32 datasheet

8-bit AVR® Microcontroller with 32KBytes In-System Programmable Flash

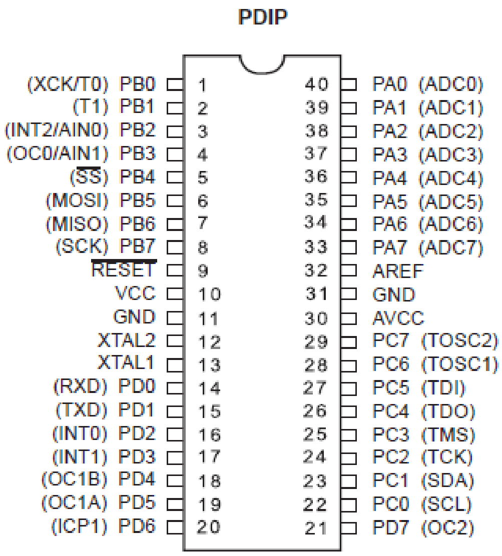
ATmega32
ATmega32L

Features

- High-performance, Low-power Atmel®AVR® 8-bit Microcontroller
- Advanced RISC Architecture
  - 131 Powerful Instructions – Most Single-clock Cycle Execution
  - 32 × 8 General Purpose Working Registers
  - Fully Static Operation
  - Up to 16 MIPS Throughput at 16MHz
  - On-chip 2-cycle Multiplier
- High Endurance Non-volatile Memory segments
  - 32Kbytes of In-System Self-programmable Flash program memory
  - 1024Bytes EEPROM
  - 2Kbytes Internal SRAM
  - Write/Erase Cycles: 10,000 Flash/100,000 EEPROM
  - Data retention: 20 years at 85°C/100 years at 25°C[1]
  - Optional Boot Code Section with Independent Lock Bits
    In-System Programming by On-chip Boot Program
    True Read-While-Write Operation
  - Programming Lock for Software Security
- JTAG (IEEE std. 1149.1 Compliant) Interface
  - Boundary-scan Capabilities According to the JTAG Standard
  - Extensive On-chip Debug Support
  - Programming of Flash, EEPROM, Fuses, and Lock Bits through the JTAG Interface
- Peripheral Features
  - Two 8-bit Timer/Counters with Separate Prescalers and Compare Modes
  - One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode
  - Real Time Counter with Separate Oscillator
  - Four PWM Channels
  - 8-channel, 10-bit ADC
    8 Single-ended Channels
    7 Differential Channels in TQFP Package Only
    2 Differential Channels with Programmable Gain at 1x, 10x, or 200x
  - Byte-oriented Two-wire Serial Interface
  - Programmable Serial USART
  - Master/Slave SPI Serial Interface
  - Programmable Watchdog Timer with Separate On-chip Oscillator
  - On-chip Analog Comparator
- Special Microcontroller Features
  - Power-on Reset and Programmable Brown-out Detection
  - Internal Calibrated RC Oscillator
  - External and Internal Interrupt Sources
  - Six Sleep Modes: Idle, ADC Noise Reduction, Power-save, Power-down, Standby and Extended Standby
- I/O and Packages
  - 32 Programmable I/O Lines
  - 40-pin PDIP, 44-lead TQFP, and 44-pad QFN/MLF
- Operating Voltages
  - 2.7V - 5.5V for ATmega32L
  - 4.5V - 5.5V for ATmega32
- Speed Grades
  - 0 - 8MHz for ATmega32L
  - 0 - 16MHz for ATmega32
- Power Consumption at 1MHz, 3V, 25°C
  - Active: 1.1mA
  - Idle Mode: 0.35mA
  - Power-down Mode: < 1µA

Pin Configurations

Figure 1. Pinout ATmega32



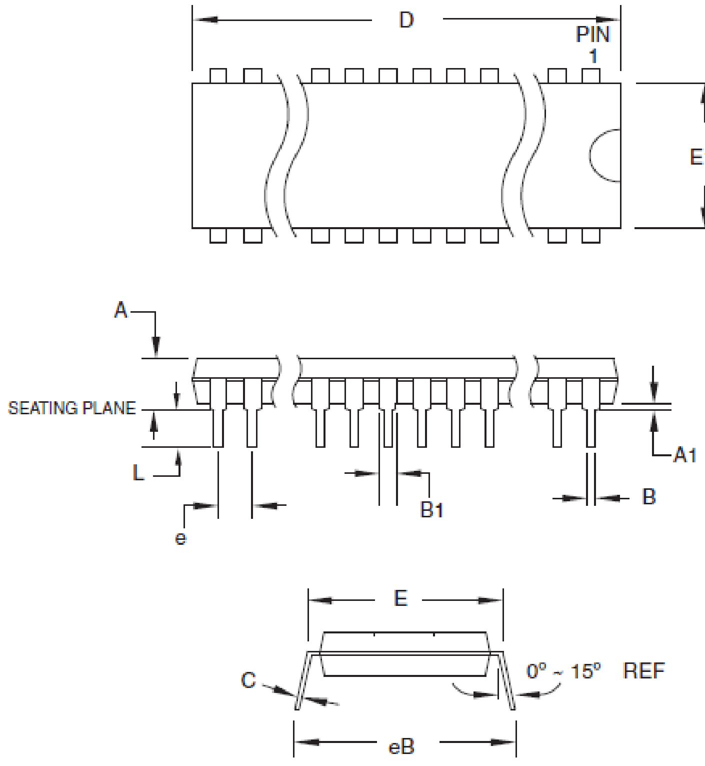
Calibrated Internal RC Oscillator

The Calibrated Internal RC Oscillator provides a fixed 1.0, 2.0, 4.0, or 8.0MHz clock. All frequencies are nominal values at 5V and 25°C. This clock may be selected as the system clock by programming the CKSEL fuses as shown in Table 9. If selected, it will operate with no external components. The CKOPT Fuse should always be unprogrammed when using this clock option. During Reset, hardware loads the calibration byte for the 1MHz into the OSCCAL Register and thereby automatically calibrates the RC Oscillator. At 5V, 25°C and 1.0MHz Oscillator frequency selected, this calibration gives a frequency within ±3% of the nominal frequency. Using calibration methods as described in application notes available at www.atmel.com/avr it is possible to achieve ±1% accuracy at any given V_{CC} and Temperature. When this Oscillator is used as the Chip Clock, the Watchdog Oscillator will still be used for the Watchdog Timer and for the reset time-out. For more information on the pre-programmed calibration value, see the section "Calibration Byte" on page 258.

Table 9. Internal Calibrated RC Oscillator Operating Modes

CKSEL3..0	Nominal Frequency (MHz)
0001(1)	1.0
0010	2.0
0011	4.0
0100	8.0

Note: 1. The device is shipped with this option selected.



COMMON DIMENSIONS
(Unit of Measure = mm)

SYMBOL	MIN	NOM	MAX	NOTE
A	–	–	4.826	
A1	0.381	–	–	
D	52.070	–	52.578	Note 2
E	15.240	–	15.875	
E1	13.462	–	13.970	Note 2
B	0.356	–	0.559	
B1	1.041	–	1.651	
L	3.048	–	3.556	
C	0.203	–	0.381	
eB	15.494	–	17.526	
e	2.540 TYP			

Notes:
1. This package conforms to JEDEC reference MS-011, Variation AC.
2. Dimensions D and E1 do not include mold Flash or Protrusion. Mold Flash or Protrusion shall not exceed 0.25 mm (0.010").

09/28/01

	TITLE	DRAWING NO.	REV.
2325 Orchard Parkway San Jose, CA 95131	**40P6**, 40-lead (0.600"/15.24 mm Wide) Plastic Dual Inline Package (PDIP)	40P6	B

Appendix I

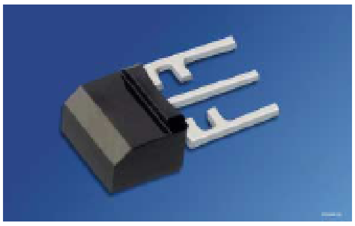
Datasheet for IR sensors

OSRAM

Dual Silicon NPN Phototransistor with Daylight-Cutoff Filter

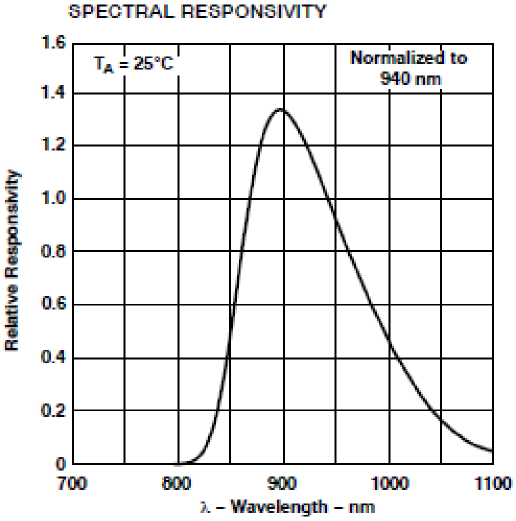
Lead (Pb) Free Product - RoHS Compliant

SFH 3160 F



Features

- Daylight Filter
- Dual Phototransistor positioned one on top of each other
- Dual Phototransistor with common Collector
- Ideal combination with SFH4111 (vertical encoder)



Applications

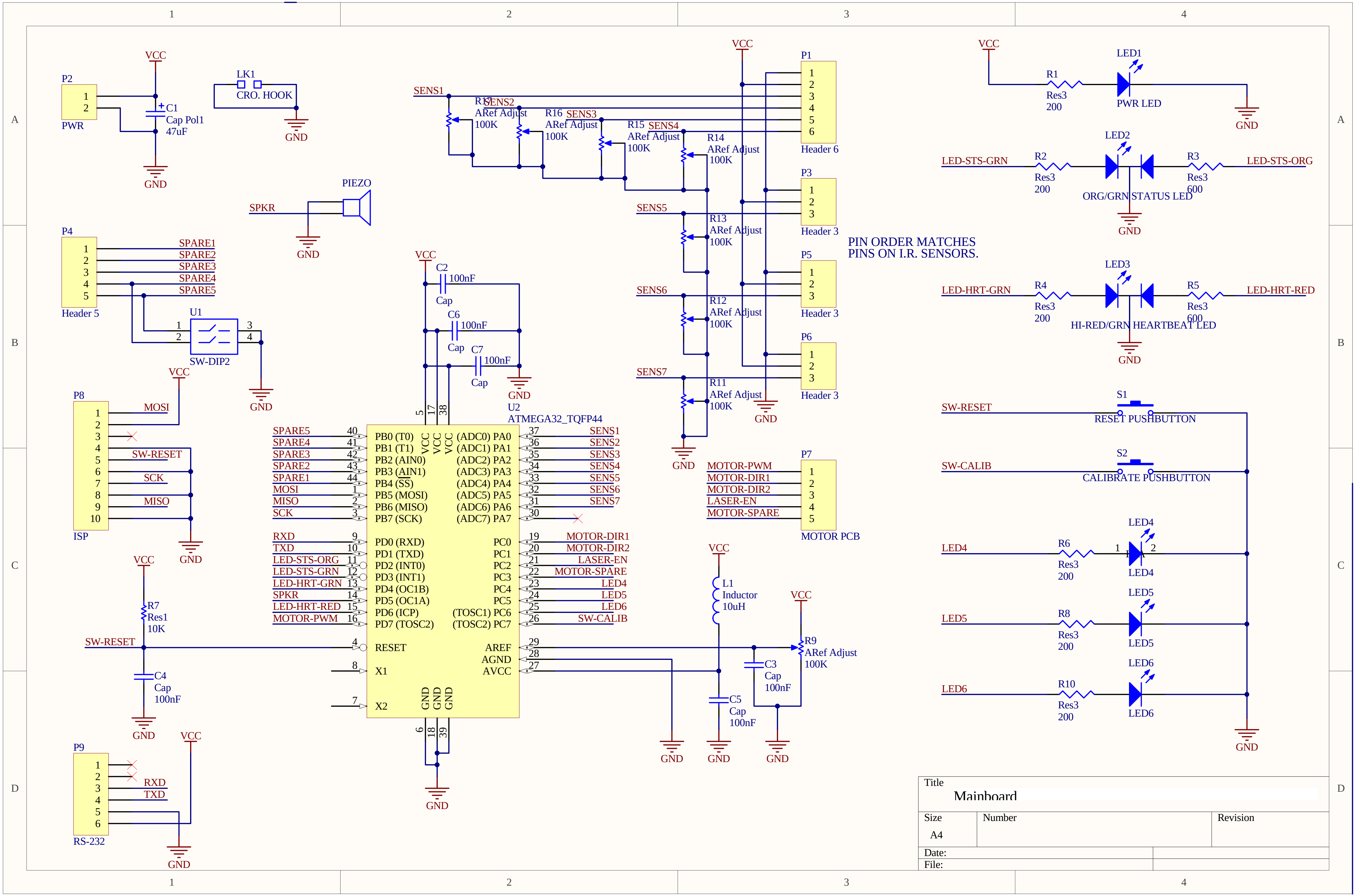
- Direction detection
- Detector in photointerrupters
- Tape end detection
- Position sensing
- Barcode reader
- For control and drive circuits
- Coin counters

Typ Type	Bestellnummer Ordering Code	$I_{ce(on)}$ [µA] (V_{ce}=3.5V, 950nm, E_e=0.34mW/cm²)
SFH 3160 F	Q62702P5296	90 ... 290

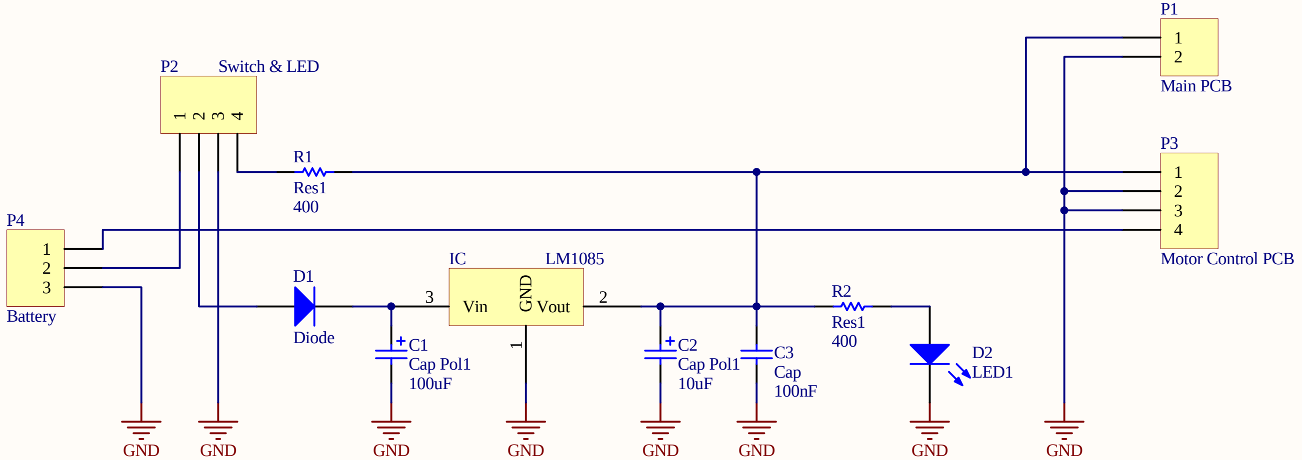
This page is intentionally blank

Appendix K

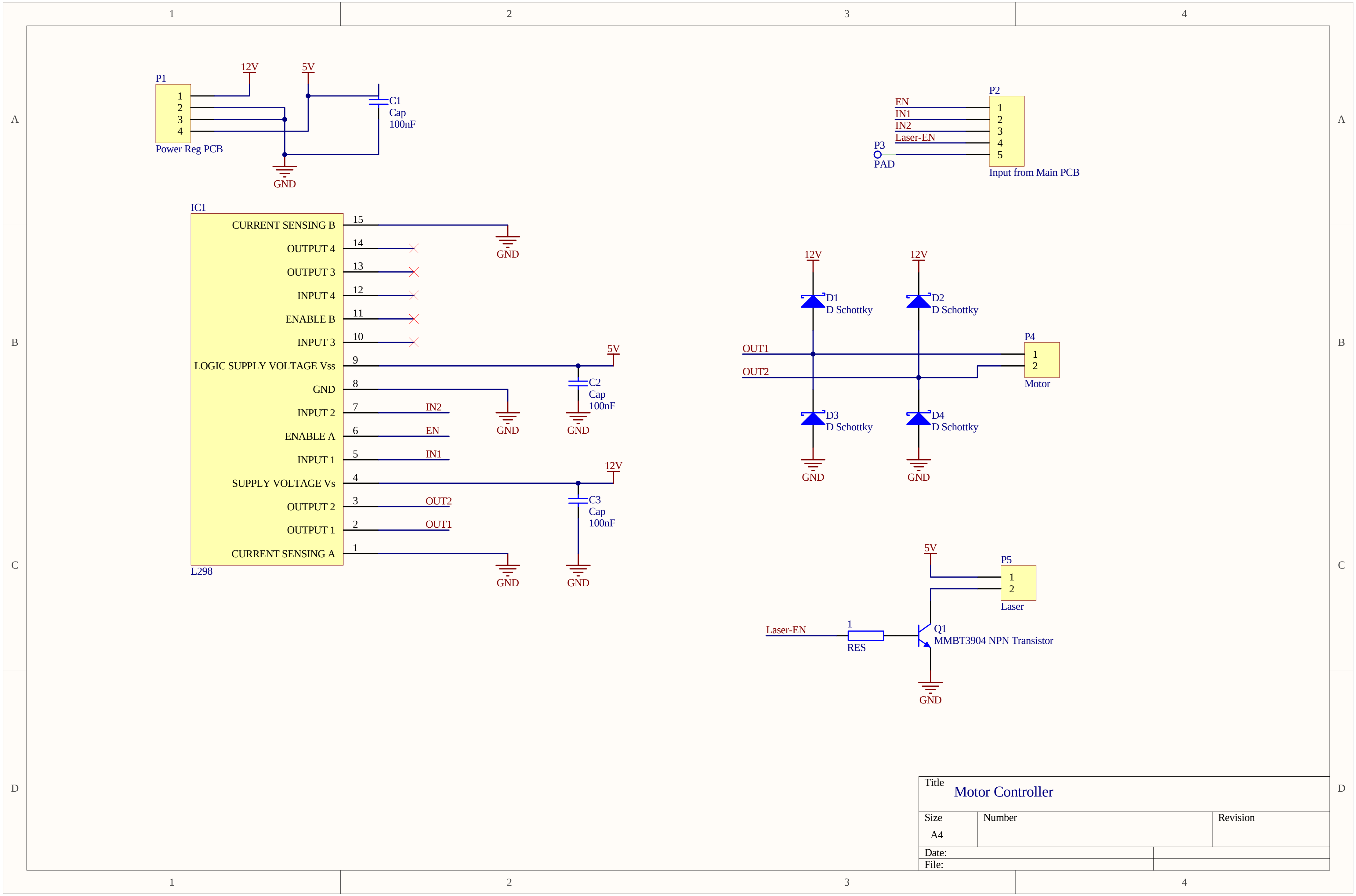
Electrical schematics for proposed design



PIN ORDER MATCHES
PINS ON I.R. SENSORS.
PWR
Cap Pol1
47uF
CRO. HOOK
PIEZO
SPKR
Header 5
SW-DIP2
ISP
RS-232
ATMEGA32_TQFP44
Header 6
Header 3
MOTOR PCB
PWR LED
ORG/GRN STATUS LED
HI-RED/GRN HEARTBEAT LED
RESET PUSHBUTTON
CALIBRATE PUSHBUTTON
Inductor
10uH
AREF
AGND
AVCC
RESET
VCC
GND
Title
Mainboard
Size
A4
Number
Revision
Date:
File:



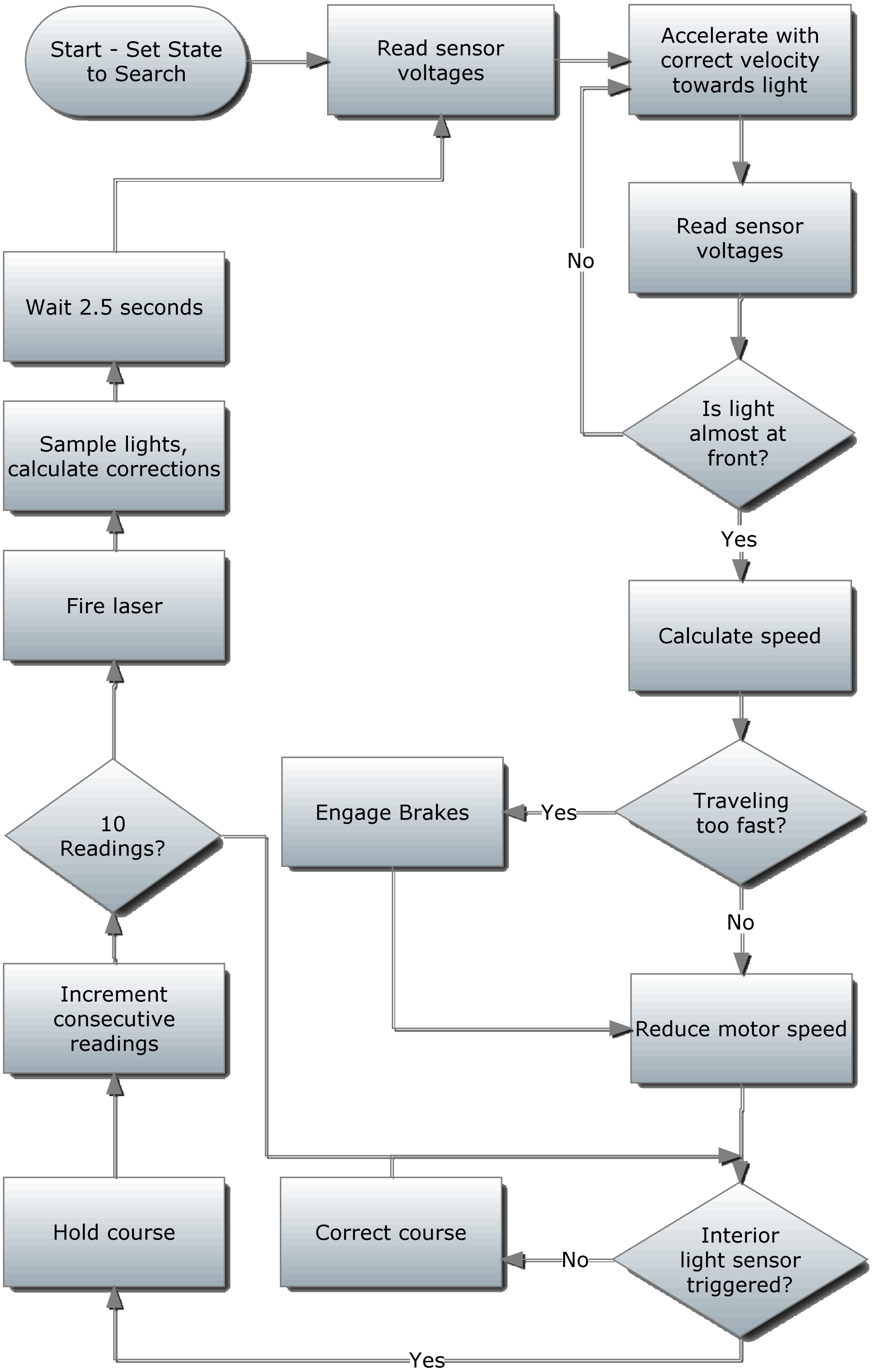
Title	Power Regulator	
Size A4	Number	Revision
Date:		
File:		



P1
1
2
3
4
Power Reg PCB
12V
5V
C1
Cap
100nF
GND
P2
EN
IN1
IN2
Laser-EN
1
2
3
4
5
P3
PAD
Input from Main PCB
IC1
CURRENT SENSING B
OUTPUT 4
OUTPUT 3
INPUT 4
ENABLE B
INPUT 3
LOGIC SUPPLY VOLTAGE Vss
GND
INPUT 2
ENABLE A
INPUT 1
SUPPLY VOLTAGE Vs
OUTPUT 2
OUTPUT 1
CURRENT SENSING A
L298
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
IN2
EN
IN1
OUT2
OUT1
C2
Cap
100nF
C3
Cap
100nF
12V
D1
D Schottky
D2
D Schottky
D3
D Schottky
D4
D Schottky
OUT1
OUT2
P4
1
2
Motor
5V
P5
1
2
Laser
Laser-EN
1
RES
Q1
MMBT3904 NPN Transistor
GND
Title
Motor Controller
Size
A4
Number
Revision
Date:
File:

Appendix L

Block diagram of software



Appendix M

Mass and moment calculations

Info:

- Basics: flywheels are a common device used to store rotational energy in the form of kinetic energy, utilising momentum.
- Density of steel is about 7.833g/cm^3
- Density of aluminium 6061-T6 is 2.712g/cm^3

Useful Formulae:

$$E = \frac{I\omega^2}{2}$$

E is the kinetic energy stored in the flywheel

$$I_{holcyl.} = \frac{m({r_{outer}}^2 + {r_{inner}}^2)}{2}$$

I is the moment of inertia for a hollow cylinder

Calculations:

Aluminium case:

$$m_{estimate} = \rho V$$
$$= 2.712 \times \left(16.546\pi\left(\left(\frac{13.967}{2}\right)^2 - \left(\frac{13.32}{2}\right)^2\right) - 4\left(0.647\left(\pi\left(\frac{0.35+0.6}{4}\right)^2 + \pi\left(\frac{0.55+1.05}{4}\right)^2\right)\right)\right)$$
$$= 617.43\,\text{g}$$

$$I = \frac{m({r_{outer}}^2 + {r_{inner}}^2)}{2} = \frac{617.43\left(\left(\frac{13.967}{2}\right)^2 + \left(\frac{13.32}{2}\right)^2\right)}{2}$$
$$= 28749.04\,\text{g}\cdot\text{cm}^2 = 0.003\text{kg}\cdot\text{m}^2$$

Perspex cap (*2):

$$m_{estimate} = \rho V$$
$$= 1.19 \times (\pi(\left(\frac{13.896}{2}\right)^2 \cdot 0.2 + \left(\frac{13.27}{2}\right)^2 \cdot 0.95)$$
$$= 161.72\text{g}\ (30.33\text{g} + 138.39\text{g})$$

$$I = \frac{m_1 {r_1}^2}{2} + \frac{m_2 {r_2}^2}{2} = \frac{30.33 \cdot \left(\frac{13.896}{2}\right)^2}{2} + \frac{138.39 \cdot \left(\frac{13.37}{2}\right)^2}{2}$$
$$= 3824.36\,\text{g}\cdot\text{cm}^2 = 0.00038\,\text{kg}\cdot\text{m}^2$$

Motor: (will consider gearbox as part of non-moving since internal movement is hard to calculate)

$m = 132\text{g}$ (From datasheet)

$I = 130\,\text{g}\cdot\text{cm}^2 = 1.3\times10^{-5}\,\text{kg}\cdot\text{m}^2$ (Using SolidEdge)

Gearbox:
$m = 171g$ (From datasheet)
$I = 190\ g \cdot cm^2 = 0.000019\ kg \cdot m^2$ (Using SolidEdge)

Laser mount and laser:
Considering the value of I of the motor, the I for these two components is most likely negligible due to its light mass and small radius.

Using metals:
Motor Bracket (Aluminium):
$m = 176\ g$ (Using SolidEdge)
$I = 2570\ g \cdot cm^2 = 0.000257\ kg \cdot m^2$ (Using SolidEdge)

Battery Bracket (Aluminium): *Note: is from old ver. so actual values will be lower*
$m = 94\ g$
$I = 450\ g \cdot cm^2 = 0.000045\ kg \cdot m^2$

Battery Module (Aluminium)*2 with 12 alkaline batteries attached:
$$m = 2 \cdot 90g + 12 \cdot 23g$$
$$= 456\ g$$
$I = 13360\ g \cdot cm^2 = 0.001336\ kg \cdot m^2$ (Using SolidEdge)

PCB Support (Al.), base and board:
$$m = 58 + 57$$
$$= 115\ g$$
$I = 2330\ g \cdot cm^2 = 0.000233\ kg \cdot m^2$ (Using SolidEdge)

Total I of turning parts:
$$I = 28749.04 + 2 \cdot 3824.36 + 130 + 2570 + 450 + 13360 + 2330 - 190$$
$$= 55047.76\ g \cdot cm^2 = 0.0055048\ kg \cdot m^2$$

The minimum height of the flywheel:
$$55047.76 = \frac{m_{flywheel}(r_{outer}{}^2 + r_{inner}{}^2)}{2}$$
$$55047.76 = \frac{m(6.2^2 + 2.3^2)}{2}$$
$$m_{flywheel} = 2517.62\ g$$
$$h_{min} = \frac{m}{\rho\pi(r_{outer}{}^2 - r_{inner}{}^2)}$$
$$= \frac{2517.62}{7.833\pi(6.2^2 - 2.3^2)}$$
$$= 3.086\ cm = 30.86\ mm$$
This is assuming the flywheel is a simple cylinder with an outer radius of 62mm and an inner radius of 23mm

Using plastics:
Motor Bracket (ABS Plastic):
$m = 66\ g$ (Using SolidEdge)
$I = 970\ g \cdot cm^2 = 0.000097\ kg \cdot m^2$ (Using SolidEdge)

Battery Bracket (ABS Plastic): *Note: is from old ver. so actual values will be lower*
$m = 36\ g$
$I = 170\ g \cdot cm^2 = 0.000017\ kg \cdot m^2$

<u>Battery Module (ABS Plastic)*2 with 12 alkaline batteries attached:</u>

$$m = 2 \cdot 34g + 12 \cdot 23g$$
$$= 346\ g$$

$I = 10880\ g \cdot cm^2 = 0.001088\ kg \cdot m^2$ (Using SolidEdge)

<u>PCB Support (ABS Pl.), base and board:</u>

$$m = 22 + 57$$
$$= 79\ g$$

$I = 1290\ g \cdot cm^2 = 0.000129\ kg \cdot m^2$ (Using SolidEdge)

<u>Total I of turning parts:</u>

$$I = 28749.04 + 2 \cdot 3824.36 + 130 + 970 + 170 + 10880 + 1290 - 190$$
$$= 49647.76\ g \cdot cm^2 = 0.0049648\ kg \cdot m^2$$

<u>The minimum height of the flywheel:</u>

$$49647.76 = \frac{m_{flywheel}({r_{outer}}^2 + {r_{inner}}^2)}{2}$$
$$49647.76 = \frac{m(6.2^2 + 2.3^2)}{2}$$
$$m_{flywheel} = 2270.65g$$
$$h_{min} = \frac{m}{\rho\pi({r_{outer}}^2 - {r_{inner}}^2)}$$
$$= \frac{2270.65}{7.833\pi(6.2^2 - 2.3^2)}$$
$$= 2.783\ cm = 27.83\ mm$$

This is assuming the flywheel is a simple cylinder with an outer radius of 62mm and an inner radius of 23mm

Appendix N

Materials analysis

A part of this project is to choose the right material, which means a material that is adequate for the job and within our budget consideration. This rules out extreme materials such as Gold, Carbon Fibre and Titanium. This appendix will analyse which material is most suitable for the internal frame work, flywheel, mounts and fasteners. The primary materials that will be evaluated are common metals and plastic.

Flywheel

The fly wheel needs to be fairly heavy so that the effective rotational inertia is greater at lower speeds. To achieve this, plastics have to be ruled out as their density is not high enough.
It is most suitable to use a metal as it is easy to machine and easy to obtain. The options for metal are Lead, due its high density, and relatively low cost, but an important consideration is its toxicity . Another option is Cast Iron, this metal has a relatively high density, however it is hard to cast as the administrative process of receiving clearance and casting the fly wheel would take too long, resulting in little or no testing time. The most suitable material was found to be steel, it also has a relatively high density and it is cheaper to manufacture and obtain. We also have the administration clearance to work on steel in the workshop.

Internal framework

The internal frame work for this project has to be able to be machined easily as well as be light and inexpensive.
The most suitable materials are plastic and metals. Plastics are quite cheap and relatively easy to manufacture a complex shape with the use of a plastic prototype printer. From the metals we can rule out Iron, Steel and lead as they are too heavy. We can also rule out Nickel, Copper and Gold as they are too expensive. The most suitable metal is Aluminium, a relatively inexpensive material with good machining properties and strength. It can easily be machined into complex structures that may be required.

Mounts and Fasteners

Mounts and Fasteners encompass a whole range of structures, including PCB mounts, Laser mounts, Battery fasteners, connection fasteners. Metal is easy to work with, however the best option is plastic printing; it’s relatively cheap and allows room for creative design and easy design-to-product translation.