

Humber College Institute of Technology & Advanced Learning

MAIDS HOME/BUSINESS INTRUSION DETECTION SYSTEM REPORT

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Report

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# 3.0 Methodology

## 3.1 Required Resources

**The MAIDS project was guided by the following resource management principles: 1. the use of fewer components, parts and materials, as possible, and 2. to use tools, methods and materials to reduce material and energy consumption during the lifecycle of the project and, in particular, to remove, as much as possible, hazardous substances from the production process.**

## 3.1.1 Parts, Components, Materials

### 3.1.1.1 Parts

Parts are the distinct pieces comprising the MAIDS project which are manufactured separately and used to build or repair said project, and when combined with other pieces makes up the whole. This section provides information about the parts that make up the MAIDS assembly. First, it includes multicolored Dupont Wire Female to Female Breadboard Jumper Wires Ribbon Cables Kit for Arduino which serve to internally connect all the various MAIDS components. Second, a 5 volts, 3 ampere power supply version compatible with the Raspberry Pi 4 Model B 2 GB (gigabyte) module with an ON/Off Switch and a USB-C Charger Adapter to provide the power needed for the Pi module. Third, a brushless cup Raspberry Pi 4 Cooling Fan with dimensions of 30 mm x 30 mm x 7 mm, with output voltage of 5 volts DC (direct current) and four rectangular aluminum heatsinks used to dissipate heat from running component (thermal control) and maintain moderate operating temperatures. Fourth, a SanDisk Ultra 32 GB, micro Secure Digital High Capacity (SDHC) flash memory card based on the SDA 2.00 specification, Ultra-High-speed (UHS-I) Card running at approximately 104 Mb/s with Adapter in order to hold Raspbian operating system (OS) and serve as an storage device for produced data. Fifth, a Panel Mount, round, Snap-In, double pole single throw (DPST) (a switch that has 2 inputs and 2 outputs; each input has 1 corresponding output) rocker switch with maximum alternating current (AC) of 16 amperes and maximum operating voltage of 125 volts used to turn MAIDS on or off. Sixth, white acrylic, laser-cut joints used to hold the enclosure together. Seventh, a custom 3-D printed, resin-based camera holder bracket used to attach and hold the MAIDS USB camera in place. Eight, a set of four M2-M3 thread, Male-Female connectors, nylon, hexagonal shapes, standoffs with plastic thread that serve to attach and separate modules, isolate circuit components and prevent short circuits.

### 3.1.1.2 Components

The MAIDS alarm system is comprised of a few components, most modular in nature. Modular components are combined to work together and form a single functioning unit. Since each module is separate, it is often possible to upgrade, change or repair one component while leaving the main system operational. The main components of MAIDS include the following: First, a white acrylic base and laser-cut and etched enclosure used to protect the internal components and designed specifically to provide good aesthetics. Second, a high sensitivity, high reliability, low voltage and low power consumption HC-SR501 Human Sensor Module comprised of a pyroelectric infrared (PIR) Sensor used to detect changing levels in infrared radiation, like the radiation changes of a moving (human) body. Third, a high sensitivity Microphone Audio Amplifier Module with an operating output of 20 decibels (dB) gain, low noise and running at 3.3 volts to 5 volts DC and used to detect sound and changing sound intensities. Fourth, a SunFounder, dual color light emitting diode (LED) sensor module for Arduino and Raspberry Pi used to provides visual intrusion information; green=safe and red=intrusion). Finally, a Raspberry Pi 4 Model B 2019 module, equipped with a Quad-Core, 64 Bit central processing unit (CPU), with WiFi and Bluetooth capabilities and four GB of RAM. The Raspberry Pi module is used to process and control all sensor I/O signals.

### 3.1.1.3 Materials

Proper materials selection insures that the right material is used for the right job. Usually, materials are divided into four key groups: metals, polymers, ceramics, and composites. To complete the MAIDS project, metal and polymer components were the main materials used as inputs to the manufacturing process. First, the project made use of MG Chemicals, 5" x 3" Copper Clad Board, Double Sided (both the top surface and the bottom surface are coated with a conductive material), 1 ounce Copper with a board thickness of 1/16" and FR4 designation (NEMA grade designation for glass-reinforced epoxy laminate material) used in the fabrication of the custom-made project circuit PCB board. Second, Lead Free Solder Wire with a Rosin Core of 0.6 mm in diameter used to provide safe soldering conditions of parts and components. Third, a [Falken Design WT2447-1-8/1212 Acrylic White Sheet with a translucence of 55 percent, board size of 12" x 12", thickness of 1/8"](https://www.amazon.ca/gp/product/B01DYSVPCQ/ref=ppx_od_dt_b_asin_title_s03?ie=UTF8&psc=1) and used as the main material for the enclosure, joints and base plates.

### 3.1.1.4 Bill of Materials (BOM)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Designator | MPN | Qty | Link |
| 1 | HC-SR501 Human Sensor Module Pyroelectric Infrared PIR Sensor Detector PIR Sensor | 4260474030781 | 1 | https://www.amazon.ca/Motion-Detector-Sensor-Switch-Arduino/dp/B075CNDXTB |
| 2 | High Sensitivity Microphone Audio Amplifier Module Output 20dB Gain Low Noise DC 3.3V/5V | STK0114016717 | 1 | https://www.amazon.ca/Microphone-Controller-Detection-Sensor-Arduino/dp/B01DBGZ2K2 |
| 3 | SunFounder Dual Color LED Sensor Module for Arduino and Raspberry Pi | 2SSR | 1 | https://www.amazon.ca/SunFounder-Sensor-Module-Arduino-Raspberry/dp/B014KR6VBA |
| 4 | MG Chemicals 5" x 3" Copper Clad Board, Double Sided, 1 oz Copper, 1/16" Thick, FR4 | 587 | 1 | https://www.amazon.ca/MG-Chemicals-Prototyping-1-Ounce-16-Inch/dp/B008OAFOUO/ref=pd\_sbs\_328\_2/132-5081513-4200133?\_encoding=UTF8&pd\_rd\_i=B008OAFOUO&pd\_rd\_r=95480a50-419b-47d5-91b4-3b88102fc136&pd\_rd\_w=zfGQl&pd\_rd\_wg=FhDkE&pf\_rd\_p=dbebb38c-0e3d-4a67-ac15-432d7c7a2789&pf\_rd\_r=A5QQ0YC5SPEYDWN36ZA7&psc=1&refRID=A5QQ0YC5SPEYDWN36ZA7 |
| 5 | Elegoo 120pcs Multicolored Dupont Wire 40pin Male to Female, 40pin Male to Male, 40pin Female to Female Breadboard Jumper Wires Ribbon Cables Kit for arduino | EL-CP-004 | 1 | https://www.amazon.ca/Elegoo-120pcs-Multicolored-Breadboard-arduino/dp/B01EV70C78/ref=sr\_1\_1\_sspa?keywords=jumper+cables&qid=1579928593&s=industrial&sr=1-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEyVkZXSjU0U1RGSjFQJmVuY3J5cHRlZElkPUEwMDcxMTkxM0tSVVU5WVBKQVhKMiZlbmNyeXB0ZWRBZElkPUEwMzg1ODgyMUwxRTJBRE0zR1dIWCZ3aWRnZXROYW1lPXNwX2F0ZiZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU= |
| 6 | AUSTOR Lead Free Solder Wire with Rosin Core 0.6mm | AMA-17-532 | 1 | https://www.amazon.ca/dp/B071XVPJVX/ref=sspa\_dk\_detail\_0?psc=1&pd\_rd\_i=B071XVPJVX&pd\_rd\_w=apWS0&pf\_rd\_p=4b7c8c1c-293f-4b1e-a49a-8787dff31bcb&pd\_rd\_wg=s5ddm&pf\_rd\_r=Y6RJTAX1MR0X3E50MH9X&pd\_rd\_r=b093f5a4-5e04-4c4a-bf07-683669f8db02&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUExWUMwVUFXVTBTMzUmZW5jcnlwdGVkSWQ9QTA0Nzk5MzAzSENLOTZDTEhKOTBBJmVuY3J5cHRlZEFkSWQ9QTAyMTk5NjJJTDlaVjVBQUtLRksmd2lkZ2V0TmFtZT1zcF9kZXRhaWwmYWN0aW9uPWNsaWNrUmVkaXJlY3QmZG9Ob3RMb2dDbGljaz10cnVl |
| 7 | Rocker Switch DPST 16A (AC) 125V Panel Mount, Snap-In | RR812C1121 | 1 | https://www.digikey.ca/product-detail/en/e-switch/RR812C1121/EG4779-ND/2116258?utm\_adgroup=Rocker%20Switches&utm\_source=google&utm\_medium=cpc&utm\_campaign=Shopping\_Switches\_NEW&utm\_term=&productid=2116258&gclid=Cj0KCQiAsbrxBRDpARIsAAnnz\_MoJhLf6plqc9U7ZpBJv8AWE22h3Xss7RSx12FQA\_XYb0KoUbjW\_LYaAo6NEALw\_wcB |
| 8 | M2 M3 Male-Female Nylon Hex Standoff Plastic Thread Motherboard Spacer | XHHD17041 | 1 | https://www.amazon.ca/Male-Female-Motherboard-Prototyping-Accessories-Quadcopter/dp/B06Y4LNDH9 |
| 9 | Raspberry Pi 4 Model B 2019 Quad Core 64 Bit WiFi Bluetooth (4GB) | 2GB-9003 | 1 | https://www.buyapi.ca/product/raspberry-pi-4-model-b-2gb/ |

## 3.1.2 Manufacturing PCB and Enclosure

### Manufacturing refers to the process (ranger of human activities) for producing products for consumption or sale using machines, materials and tools. In essence, the raw materials are transformed into a finished good. This section of the report will outline the manufacturing process of the MAIDS project.

### 3.1.2.1 PCB Board Manufacturing Process

### The PCB board is first designed using Fritzing software version 6.0.3. Once designed, the PCB board circuit rendition is exported for production as a RS-274X Gerber file and sent to the Humber College Prototyping Lab resulting in a professional quality DIY PCB manufactured board. The MAIDS project PCB board’s design is based on a two-layer approach; separates the input and output (I/O) layer from the ground layer. While the I/O layer is located at on the top surface of the PCB board, the ground layer is located on the bottom layer. It is important to emphasize that Design Rules Check (DRC) tests are performed during the design process to ensure proper board function and reliability before the manufacturing process.

Once the design is received at the Humber College Prototyping Lab, the manufacturing process of the PCB board is subject to a few phases. To begin, the PCB board 274X Extended Gerber format file is loaded into the ProtoMat S103 LPKF plotter and router using LPKF CircuitPro software. The software converts the design from the common layout program into control data for the structuring systems, and allows for the optimization of the layout elements, and verifies design using design verification rules. Once data from the file is imported, the ProtoMat S103 circuit board plotters uses a mechanical fiducial systems (cameras for automatic position detection) (Electronics, Manual Version 0.9, English, 2020) to assist in drilling and milling the double-sided PCB board. In the case of the MAIDS PCB board, it drills four fiducial holes using the Optical Fiducial Recognition Systems (OFRS) on the un-etched sides. This ensures that the structures on both sides of the board are matching so that they remain aligned during transfer between processes. The holes themselves use Through-hole technology; holes that go completely through the boards. In addition, the holes are non-plated (NPTH). With non-plated through holes there is no conductive path from one side of the board to the other. Connections have to be made by applying a thin wire through the hole and soldering it in place to connect the upper and bottom portions of the circuit.

Once positioning holes are drilled, the blank PCB board is transferred to the ProtoLaser S machine. The laser first creates the contours of the circuit and the proceeds to delaminate and evaporate the copper layer. The ProtoLaser S uses a laser low energy source emitting light in the green range (532 nm) (Electronics, ProtoLaser S: Operation manual 2.0, English., 2008) of the visible spectrum, to systematically delaminates and evaporates the conductive copper layer from both sides of the double-sided copper clad PCB board to prevent damage to the substrate. Laser etching makes the process cost effective, fast, and robust. The result is a professional quality PCB circuit board.

Finally, the PCB board is once again transferred to the ProtoMat S103 LPKF plotter and router to cut away the laser etched PCB board from the stock board. The PCB board is then ready for the component placement and the soldering phase.

### 3.1.2.2 Enclosure Manufacturing Process

The enclosure is designed using CorelDraw 2018 for fast and precise laser cutting. CorelDraw 2018 can export either a .svg or .pdf landscape file which are the preferred file formats for laser cutting. The enclosure rendition document ensures that the object size is constrained within the maximum of 12″ by 24″ object size allowed on the laser cutter bed. The laser cutter uses vector lines to cut with the **stroke width set to hairline (0.000 mm wide). Outside laser cuts are colored green while inside cuts are colored red. Etching of words or logos require any other color and** lines thicker than 0.000 mm (hairline) which result in the burning a light layer off of the top of the material.

**Once designed, the .svg or .pdf file is imported into the** Trotec Speedy 100 Laser Engraver which uses JobControl laser software. It is important to emphasize that the .svg file contains not only the designed acrylic walls for the enclosure but also the acrylic joint and base designs; the Speedy 100 cuts and etches the enclosure, as well as, cut the joints to hold it together and the base board on which it rests. The laser cutter and engraver uses a 50 W CO2 laser (Iradion tube) (Trotec, 2020) to cut away the enclosure and joint designs from the acrylic stock material. A fast engraving speed (4.3 m/s) (Trotec, 2020) creates a minimal distortion in the engraving image. Finally, separate parts are then joined together by means of acrylic joints and acrylic glue to produce the final MAIDS project enclosure.

### 3.1.2.3 3-D Printing: Camera Holder Bracket

The camera holder bracket manufacturing process requires 3-D printing. The design requires a SketchUp (software) produced .stl design file. The file is loaded into the Object 30 3-D printer. The Object 30 is a resin-based, ultraviolet light cured, 3-D printer. The 3-D building process begins by depositing a layer of resin 28 microns (0.0011”) thick (Geometries, 2010) and cures it (hardens it) by passing an ultraviolet light over the newly deposited resin. The 3-D printer continues the deposition process in layers with great accuracy (0.1 mm) (Geometries, 2010) to produce the resulting 3-D model of the camera holder bracket.

### 3.1.2.4 Assembly

The MAIDS project is assembled in the following stages: 1. PCB board component placement and soldering, 2. Base plate assembly, 3. Enclosure assembly, and finally, 4. deliverable assembly.

#### 3.1.2.4.1 PCB Board Assembly

The assembly process begins with the PCB board. First, the connecting pins are placed onto and soldered (using safe and lead-free solder) to the laser-etched PCB board taking care that pins connectors are soldered on the appropriate layers. On the one hand, all pins connecting the main components (motion and sound sensors, and dual LED module) are soldered to the top layer of the PCB board. On the other hand, pins connected to the circuit’s ground connection are soldered on the bottom layer of the PCB board. At this point, the MAIDS hardware circuit is complete.

#### 3.1.2.4.2 Base Plate Assembly

Once the circuit is completed, the base assembly process is started. Consequently, the laser-cut base boards are glued together with acrylic glue and left to cure for at least 24 hours to assure maximum the holding power of the glue; the base serves as the physical foundation of the final product.

#### 3.1.2.4.3 Enclosure Assembly

After the MAIDS base is finished, the enclosure assembly is completed. The parts of the enclosure that serve as side walls for the project are placed in a vice-grip for support and correct alignment. Once aligned properly, laser-cut acrylic joint plates are glued onto the walls with acrylic glue; glued walls are set aside for curing for at least 24 hours for maximum hold. After 24 hours, the enclosure is ready for complete assembly of the project.

#### 3.1.2.4.4 Final Deliverable Assembly

To begin, the Raspberry Pi 4 Model B module is fitted, on its underside, with four M3, Male-Female, and Nylon Hex Standoffs to provide short circuit protection and adequate space clearance for the Pi from the base plate. Then, the custom made PCB circuit board is connected to the 40-pin male connector of the Raspberry Pi 4 through its own 40-pin female connector. This stage completes the hardware assembly portion of the process that serves to process signals from and control signals to MAIDS in response to intrusion events.

Once hardware assembly is finished, the assembled enclosure is placed upon the base plate to surround the hardware circuit. When aligned, the enclosure is secured to the base plate by means of two acrylic, laser-cut joint plates and acrylic glue.

Finally, the top acrylic plate of the enclosure is pressure snapped onto the top of the enclosure; the top plate serves to provide accessibility to internal components, in case of needed replacement dues to malfunction.

## 3.1.3 Tools and Facilities

### 3.1.3.1 Fabrication and Research Facilities: Humber College

The MAIDS project design, development, modification and production was possible by the use of the following lab and library facilities located at the North Campus: 1. The Humber prototype lab facilities (Rapid Prototyping lab) located in building J, Room J201 and 2. The Advanced Electronics Lab located in building J, Room J232. The Humber College Library, located on the 4th floor of the Learning Resource Commons was used during the project research phase.

### 3.1.3.2 PCB Board Cutting and Etching

The PCB board design using Fritzing software and produced a 274X Extended Gerber format file employed by the ProtoMat S103 LPKF. The ProtoMat S103 is a circuit board plotter for Contour routing of the circuit board (double layer copper foil) and an Optical fiducial recognition systems for automatic position detection to assist in drilling and milling of double-sided PCBs. It has a spindle speed of 100,000 rpm, a maximum travel speed of 150 mm/s, repeatability of ± 0.001 mm (± 0.04 mil), drilling speed of 120 strokes/min and a resolution of 0.5 μm (0.02 mil). (Electronics, Manual Version 0.9, English, 2020) The lead time for the PCB board is 12 hours.

PCB board etching is accomplished by the ProtoLaser S which etches away the copper from the double-sided copper clad PCB board. The ProtoLaser S has a minimum track/gap of 50 µm/25 µm (2 mil/1 mil), a resolution scan field of 2 µm (0.08 mil), a laser pulse frequency 10 - 100 kHz, continuous wave (CW), and cutting bed dimensions of (12“ x 24“) (Electronics, ProtoLaser S: Operation manual 2.0, English., 2008)

### 3.1.3.3 Laser Engraving

Trotec Speedy 100 Laser Engraver is used for acrylic enclosure cutting and etching. The laser engraver requires a design in .pdf format. The Speedy 100 uses a 50 W CO2 laser (Iradion tube), uses 2 inch lens (standard), a cutting speed of 180 cm/sec speed and its bed size can accommodate objects of up to 12" x 24". (Trotec, 2020)

### 3.1.3.4 3-D Printing

3-D printing requires a SketchUp produced .stl design file which is then created on the Object 30 3-D printer. The Object 30 is a resin-based, ultraviolet light cured, 3-D printer with Support Material SUP705 (WaterJet removable) and SUP706B (soluble), maximum build size of 294 x 192 x 148.6 mm (11.57” x 7.55” x 5.85”), layer thickness of 28 microns (0.0011”) and 16 microns (0.0006”) for VeroClear material, accuracy of 0.1 mm (0.0039”) and employs a fusion deposition system. (Geometries, 2010)

### 3.1.3.5 Soldering

ESD safe, Small footprint (5.9” X 4.5” X 3.6”) Weller WESD51 Soldering Station with power consumption of 50 watts, temperature range 350 ºF – 850 ºF, operating voltage (output) 24 Volts, Temperature Stability +/-10°F (6°C) and Heating Element Type Nichrome Wound; Fiberglass and ceramic insulated. (Elektrotanya, 2020)

## 3.1.4 Shipping, duties and taxes

When shipping finished goods domestically or internationally, it becomes extremely important to consider the effects of shipping charges, duties, and taxes. Shipping internationally can help a business grow financially, in reach and reputation. However, not understanding shipping taxes and duty costs can create massive headaches for the business. Every country has its own laws and rates, and businesses from different sectors face different compliance challenges when shipping internationally or domestically. Depending on the shipment content and the destination, charges could significantly impact the total shipment cost and the products end price. This section presents the shipping, duty and tax charges incurred during the development of the MAIDS system, along with other costs. It is presented in table form for clarity, in explicit order and includes the following sections: Description, quantity, Unit price, Discount, Federal Tax [GST/HST/TPS/TVH], Provincial Tax [PST/RST/QST/TVP/TVD/TVQ], Shipping charges and total cost. The MAIDS shipping, duties and taxes applicable to each component or part are as follows: 1. The High Sensitivity Microphone Audio Amplifier Module Output 20dB Gain Low Noise DC 3.3V/5V ASIN: B07DNWBG1D: 1, $10.30, -$1.10, $0.00, $0.00, $3.99, $13.19, 2. The SunFounder Active Buzzer Sensor Module for Arduino and Raspberry Pi ASIN: B014KQLE8Q: 1, $7.99, -$0.18, $0.00, $0.00, $0.18, $7.99, 3. Aukru 3X HC-SR501 Human Sensor Module Pyroelectric Infrared PIR Sensor Detector ASIN: B019SX6ZR6: 1, $10.99, $0.00, $0.00, $0.00, $0.00, $10.99, 4. Raspberry Pi 4 Fan, GeeekPi Raspberry Pi Cooling Fan 30x30x7mm DC 5V Brushless Cup Cooling Fan with Raspberry Pi 4 Heatsink for Raspberry Pi 4 Model B,3B+, 3B& Retroflag NESPI CASE Plus (1-Pack) ASIN: B07C9C99RM: 1, $9.99, $0.00, $0.00, $0.00, $0.00, $9.99, 5. SunFounder Dual Color LED Sensor Module for Arduino and Raspberry Pi: 1, $12.98, $0.00, $0.00, $0.00, $0.00, $12.98, 6. SanDisk Ultra 32GB micro SDHC UHS-I Card with Adapter, Grey/Red, Standard Packaging (SDSQUNC-032G-GN6MA): 1, $13.99, $0.00, $0.00, $0.00, $0.00, $13.99, 7. Compatible with Raspberry Pi 4 Power Supply with ON/Off Switch, 5V 3A USB-C Charger Adapter for Raspberry Pi 4 Model B 1GB / 2GB / 4GB Version: 1, $13.59, $0.00, -$6.99, $0.00, $6.99, $13.99, 8. Falken Design WT2447-1-8/1212 Acrylic White Sheet, Translucent 55%, 12" x 12", 1/8" Thick: 1, $13.78, $0.00, -$6.99, $0.00, $6.99, $13.78.

## 3.1.5 Working time versus lead time

A better understanding of lead time (LT) can lead to very substantial gains. For example, a company can develop a more profitable scheme that can meet customer requirement more efficiently. In addition, a greater understanding of LT leads to the detection and correction of performance issues that can be corrected quickly. Finally, it leads to the improvement of customer relations by increasing the level of communication. (Rajaniemi, 2012)

It is important to emphasize that there was no stipulated time limits on the number of hours one was required to work on the MAIDS project on the part of Instructors or Humber College, other than, completion of project by the course’s schedule end date. The working time schedule adopted was a voluntarily established and followed project schedule.

The order lead time, the time from order received to customer order delivered was approximately 8 weeks. The order handling time, the time from customer order received to sales order created was less than 12 hours. The manufacturing lead time, Time from sales order created to production finished (ready for delivery) was approximately 2 weeks. The production Lead Time - Time from start of physical production of first submodule/part to production finished (ready for delivery) was approximately 2 weeks. The Delivery Lead Time - Time from production finished to customer order delivered was approximately 1 week due to testing and slight software modifications. (Rajaniemi, 2012)

The working time, time to assemble the complete MAIDS deliverable, was 2.0 hours per work day, five days per week (total of 10 hours per week), for a total of 20 hours, total.

# References

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Electronics, L. L. (2020). *Manual Version 0.9, English.* Germany: LPKF Laser & Electronics AG.

Elektrotanya. (2020, January 12). *Model WES51 Electronic Soldering Station.* Retrieved from Model WES51 Electronic Soldering Station: https://elektrotanya.com/weller\_model\_wes51\_electronic\_soldering\_station.pdf/download.html

Geometries, O. (2010). *Objet30 3-D Printer System: User Guide, English. Page 6.* Germany: Objet Geometries Ltd.

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Trotec. (2020, January 19). *Operation Manual Trotec Job Control. Basic, Advanced, Expert*. Retrieved from Trotec: Operation Manual Trotec Job Control. Basic, Advanced, Expert: https://www.troteclaser.com/fileadmin/content/images/Contact\_Support/Manuals/JobControl-Manual-EN.pdf