

ENGINEERING PROCESS MANUAL





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Purpose, structure and goals

This manual sets out how the fabrication and assembly area works, with clear, safe and repeatable processes for turning CAD designs into a working robot. It follows the real order of robot development, so any team member can understand not only what to do, but how, when and to what quality standard.

The main goal is a reliable process that:

- Minimizes errors and rework
- Reduces wasted material
- Makes the shop safer
- Lets us repeat results from season to season

1.1 Purpose of the area

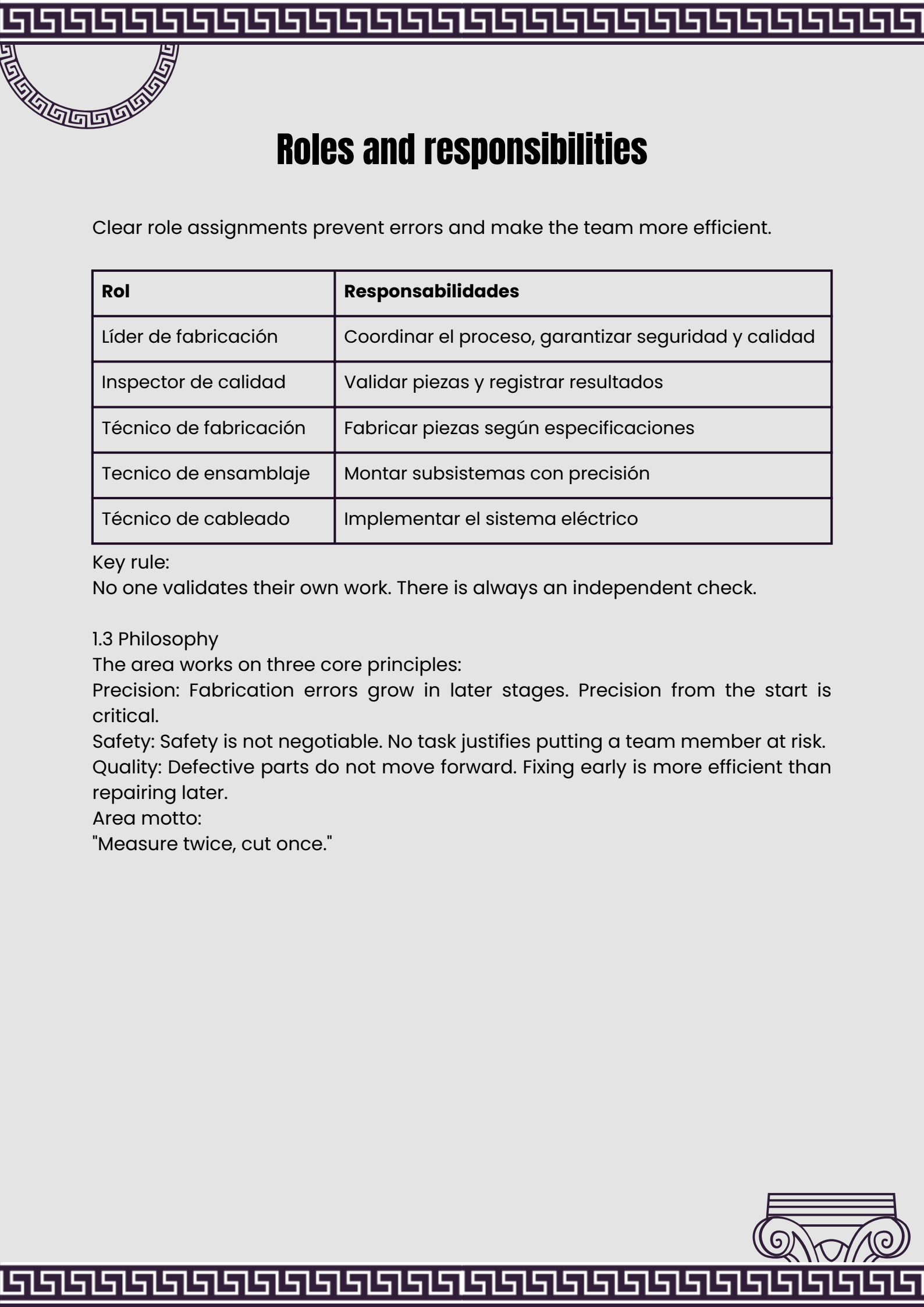
The fabrication and assembly area turns digital designs into working physical systems, with precision, quality and correct integration.

Main functions:

- Fabricating custom parts
- Mechanical assembly of subsystems
- Installing electrical systems
- First physical validation of the robot

It is also the link between design, electronics and programming.





Roles and responsibilities

Clear role assignments prevent errors and make the team more efficient.

Rol	Responsabilidades
Líder de fabricación	Coordinar el proceso, garantizar seguridad y calidad
Inspector de calidad	Validar piezas y registrar resultados
Técnico de fabricación	Fabricar piezas según especificaciones
Tecnico de ensamblaje	Montar subsistemas con precisión
Técnico de cableado	Implementar el sistema eléctrico

Key rule:
No one validates their own work. There is always an independent check.

1.3 Philosophy

The area works on three core principles:

Precision: Fabrication errors grow in later stages. Precision from the start is critical.

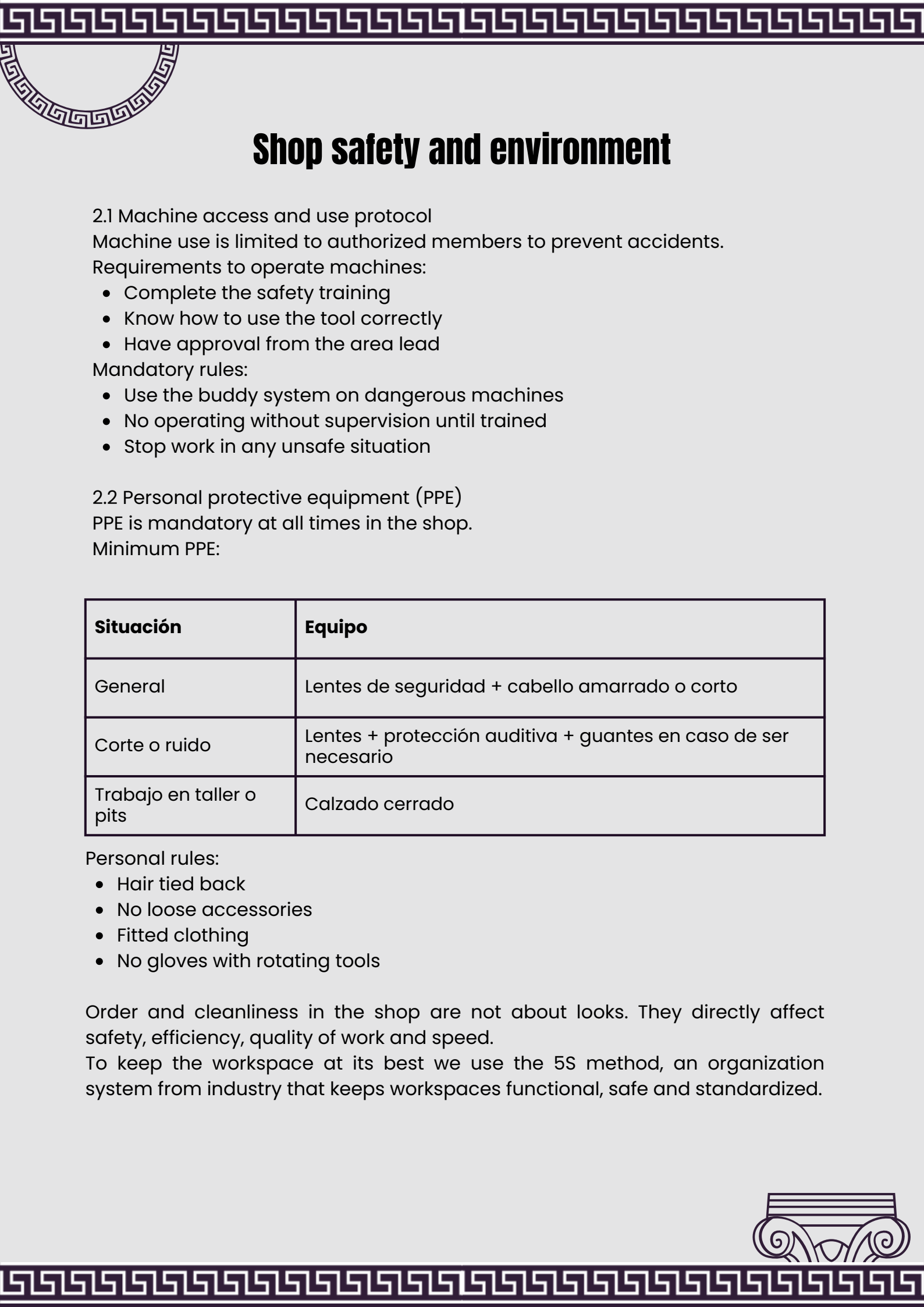
Safety: Safety is not negotiable. No task justifies putting a team member at risk.

Quality: Defective parts do not move forward. Fixing early is more efficient than repairing later.

Area motto:

"Measure twice, cut once."





Shop safety and environment

2.1 Machine access and use protocol

Machine use is limited to authorized members to prevent accidents.

Requirements to operate machines:

- Complete the safety training
- Know how to use the tool correctly
- Have approval from the area lead

Mandatory rules:

- Use the buddy system on dangerous machines
- No operating without supervision until trained
- Stop work in any unsafe situation

2.2 Personal protective equipment (PPE)

PPE is mandatory at all times in the shop.

Minimum PPE:

Situación	Equipo
General	Lentes de seguridad + cabello amarrado o corto
Corte o ruido	Lentes + protección auditiva + guantes en caso de ser necesario
Trabajo en taller o pits	Calzado cerrado

Personal rules:

- Hair tied back
- No loose accessories
- Fitted clothing
- No gloves with rotating tools

Order and cleanliness in the shop are not about looks. They directly affect safety, efficiency, quality of work and speed.

To keep the workspace at its best we use the 5S method, an organization system from industry that keeps workspaces functional, safe and standardized.





What is the 5S method?

5S is a system built on five principles that cut waste, improve organization and keep working conditions consistent.

In the shop it helps us:

- Spend less time looking for tools
- Prevent accidents
- Improve fabrication quality
- Keep the team disciplined

2.3 Applying 5S in the shop

1. Sort (Seiri)

Separate what is needed from what is not.

In the shop:

- Remove damaged or unused tools
- Get rid of leftover material with no planned use
- Flag items that do not belong in the area

Goal:

Reduce clutter and free up space to work efficiently.

2. Set in order (Seiton)

Every item has a specific, defined place.

In the shop:

- Tool shadow boards
- Labeled spaces, racks and bins
- Organized by type: tools, materials, electronics

Goal:

Anyone can find and return a tool in seconds.

3. Shine (Seiso)

Keep the area free of dirt, debris and hazards.

In the shop:

- Clean up chips, dust and debris after working
- Do a basic tool check while cleaning
- Mandatory rule: **the last 15 minutes of every session are for cleanup**

Goal:

Catch problems early and keep the space safe.





4. Standardize (Seiketsu)

Set visual and working standards to keep things in order.

In the shop:

- Cleaning checklists for each station
- Visual marking of work areas
- Colors or labels to sort materials

Goal:

Order should not depend on one person; it is part of the system.

5. Sustain (Shitsuke)

Keep the discipline to follow 5S every day.

In the shop:

- Regular audits of the area
- An owner assigned to each zone
- Fix deviations right away

Goal:

Make order and cleanliness a team habit, not an occasional task.

Shop rules (based on 5S)

- No tool is left out of place at the end of a session
- No station is left dirty or messy
- All material is labeled
- Any problem is fixed on the spot





Workflow: from CAD to fabrication

3.1 Intake and planning

Every fabrication job starts with a structured handoff from the design area. Poor planning here turns directly into errors, rework and lost shop time. This phase makes sure everything needed to fabricate correctly is complete, validated and ready before any cutting or machining starts.

Required documents

Before any part is released for fabrication, we need:

- Final CAD model (RTM: Ready to Manufacture)
- The final version of the design, with no pending changes.
- Bill of materials (BOM)
- Every component needed, separating commercial parts (COTS) from custom parts.
- Drawings or fabrication files
 - Dimensioned 2D drawings
 - DXF, STEP or STL files depending on the process
 - Critical specs (tolerances, finishes, materials)

Intake and release process

The flow follows a clear sequence:

1. Receive the design package
2. The fabrication area receives all the documentation it needs.
3. Validate the information
4. Check that:
 - No critical dimensions are missing
 - Tolerances are defined
 - The material is specified
 - CAD and drawings match
5. Create work orders (WO)
6. Each custom part gets its own WO with:
 - Part name
 - Assigned owner
 - Fabrication process
 - Priority



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- Assign owners
 - Each part or batch has a named owner, so responsibilities are clear.
 - Prepare materials
 - Choose the right material
 - Rough cut if needed
 - Check stock

Material standards

All raw material is labeled to prevent mistakes.

Label format:

- **Project**
- **Material type** (Aluminum, steel, PLA, etc.)
- **Dimensions**

Goal:

Avoid confusion, waste and wrong use of materials during fabrication.

3.2 Fabrication protocol

This protocol defines the right way to turn a design into a physical part, with consistency, quality and repeatability.

Step 1: Review the drawing

Before touching any tool, the person fabricating must fully understand the part.

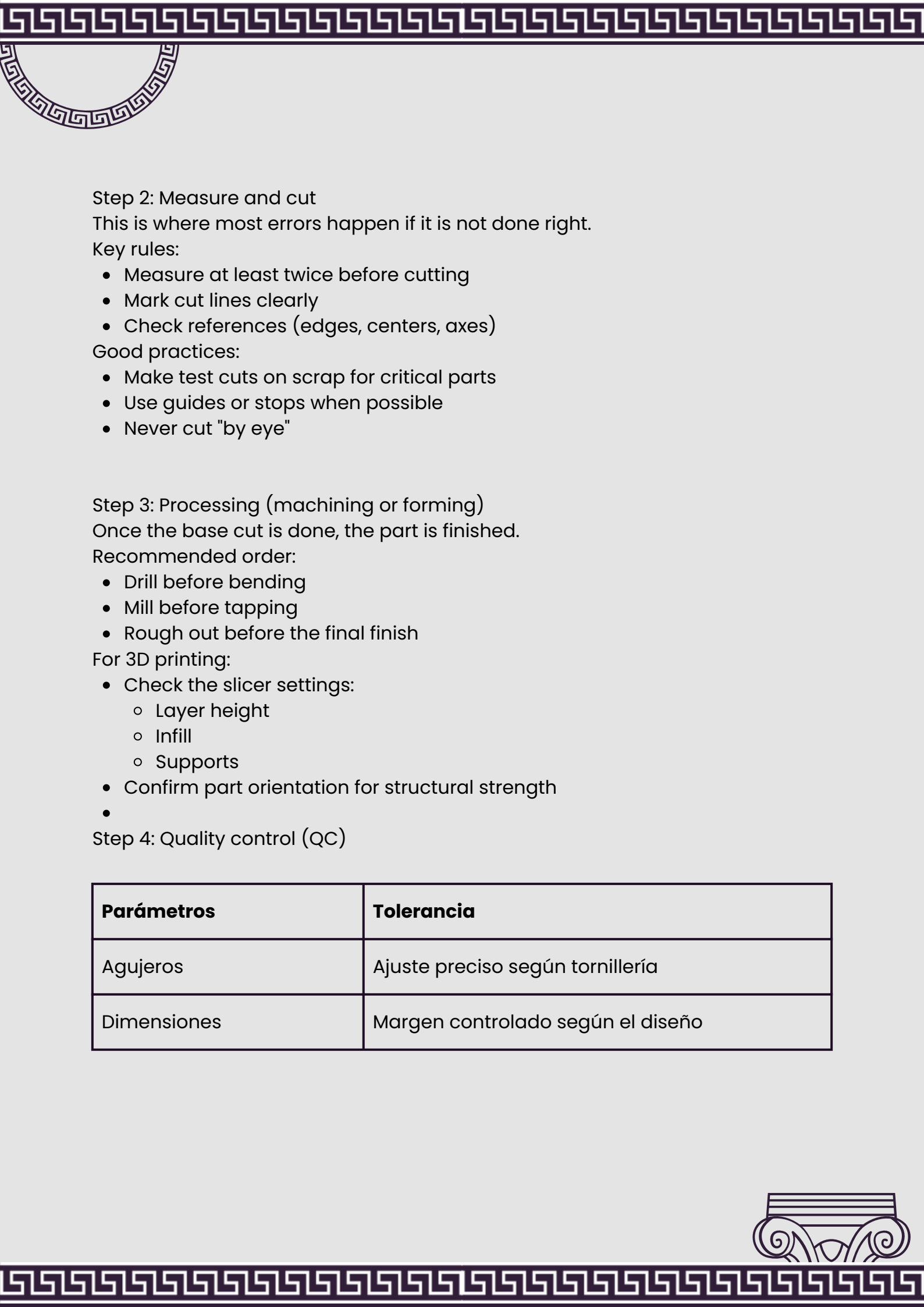
Mandatory checks:

- Critical dimensions
- Tolerances
- Material type
- Overall geometry

Preparation:

- Pick the right tools
- Define the fabrication process
- Identify critical features (holes, cuts, bends)





Step 2: Measure and cut

This is where most errors happen if it is not done right.

Key rules:

- Measure at least twice before cutting
- Mark cut lines clearly
- Check references (edges, centers, axes)

Good practices:

- Make test cuts on scrap for critical parts
- Use guides or stops when possible
- Never cut "by eye"

Step 3: Processing (machining or forming)

Once the base cut is done, the part is finished.

Recommended order:

- Drill before bending
- Mill before tapping
- Rough out before the final finish

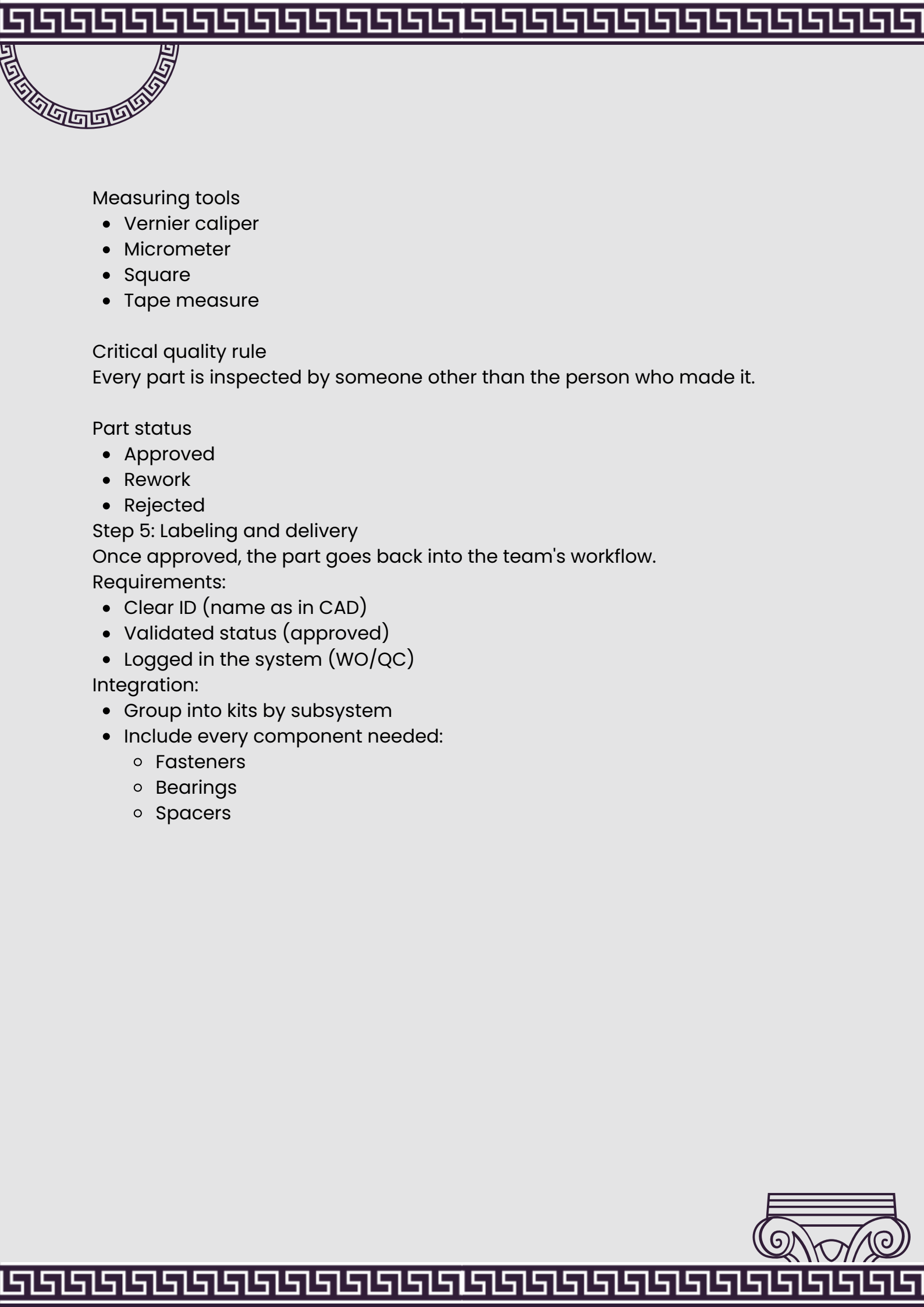
For 3D printing:

- Check the slicer settings:
 - Layer height
 - Infill
 - Supports
- Confirm part orientation for structural strength
-

Step 4: Quality control (QC)

Parámetros	Tolerancia
Agujeros	Ajuste preciso según tornillería
Dimensiones	Margen controlado según el diseño





Measuring tools

- Vernier caliper
- Micrometer
- Square
- Tape measure

Critical quality rule

Every part is inspected by someone other than the person who made it.

Part status

- Approved
- Rework
- Rejected

Step 5: Labeling and delivery

Once approved, the part goes back into the team's workflow.

Requirements:

- Clear ID (name as in CAD)
- Validated status (approved)
- Logged in the system (WO/QC)

Integration:

- Group into kits by subsystem
- Include every component needed:
 - Fasteners
 - Bearings
 - Spacers





Assembly and wiring

4.1 Subsystem assembly

We assemble by independent subsystems (for example drivetrain, intake, arm, shooter) so we can test, isolate errors and iterate quickly without affecting the whole robot.

This lowers risk, improves assembly quality and lets us validate function before full integration.

Assembly method

The process follows a controlled, repeatable sequence:

1. Always refer to CAD

- Use the CAD model as a visual guide through the whole assembly
- Check orientation, position and order of components
- Confirm parts match the latest version of the design

2. Dry fit

- Assemble every component without final torque
- Check that:
 - All parts fit correctly
 - There are no interferences
 - Tolerances are right
- Adjust before fastening permanently

3. Structural fit and alignment

- Align shafts, plates and brackets before tightening
- Keep things parallel and square where needed
- Avoid unnecessary loads on fasteners or bearings

Critical point:

Poor alignment here causes wear, lost efficiency and failures at competition.

4. Controlled final torque

- Tighten progressively (cross pattern where it applies)
- Do not fully tighten one point before the others
- Use the right tool (ideally a torque wrench)

5. Manual mechanical check

- Move the mechanism by hand through its full range
- Look for:
 - Rubbing
 - Binding points
 - Misalignment

Rule:

If it does not move smoothly by hand, it will not work well with a motor.





Subsystem functional check

Before going on the robot, each subsystem passes a basic check:

- Full motion with no interference
- Solid structure (no excess play)
- Components properly fastened
- Easy access for maintenance

Technical recommendations

- Do not overtighten screws, especially in aluminum and plastic
- Use threadlocker on critical joints (vibration)
- Check that bearings spin freely after assembly
- Make sure shafts are not forced or off-center
- Make sure every spacer is in place

Common mistakes to avoid

- Assembling without checking the latest CAD
- Tightening fully before checking fit
- Ignoring small interferences (they become big failures)
- Not checking motion before mounting on the robot
- Mixing up fasteners or using the wrong lengths





Wiring and electronics

The electrical system is one of the most critical parts of the robot. Bad wiring can cause intermittent faults, loss of control or damaged components. The goal is a system that is tidy, safe, accessible and reliable.

Wiring principles

1. Organization

Clean wiring is not about looks; it is about function.

- Group wires by function (power, signal, sensors)
- Secure them with zip ties, velcro or conduit
- Keep routes defined and consistent
- Avoid unnecessary crossings

2. Safety

Wiring must hold up to motion, vibration and continuous use.

- No loose or hanging wires
- Keep clear of moving parts
- Protect wires from sharp edges
- No strain on connectors

3. Controlled slack

- Leave enough slack on moving mechanisms
- Avoid extra wire that can tangle
- Make sure motion never pulls on connectors

4. Connections

- Check every connector is fully seated
- Use latches or retention on critical connections
- No loose or improvised connections
- Label wires when needed

Additional good practices

- Separate high-current wires from signal wires (to avoid electrical noise)
- Keep quick access to key components (PDH, controllers, battery)
- Plan wire routes in CAD
- Keep wiring from blocking maintenance or part swaps
- Use colors or labels to speed up troubleshooting





Electrical system check

Before power-on, confirm:

- Every device is connected to the correct port
- Wiring matches the electrical diagram
- No wires are reversed or crossed

Pre power-on check

Before powering the robot, do a full review of the electrical system. This step is mandatory and critical.

Checklist

1. Short check

- Use a multimeter in continuity mode
- Confirm there is no connection between V+ and GND

2. Polarity

- Check motor connections
- Confirm polarity on sensors and modules

3. Connections

- Check every connector is secure
- Confirm there are no loose wires

4. Wiring integrity

- Check insulation
- Confirm there is no physical damage

Critical rule

The first battery connection is made only by:

- The area lead
- An authorized mentor
- The electronics lead

Safety conditions for the first power-on

- Robot raised or wheels off the ground
- Area fully clear
- One person dedicated only to cutting power in an emergency
- Clear communication among team members





Handoff to testing

5.1 Formal handoff to software and testing

Moving from fabrication to testing is not just a change of area; it is a critical checkpoint. The robot is not handed over when it is "finished," but when it is ready to test without basic problems.

The goal is clear: let the software team work on control, optimization and strategy, not on fixing hardware errors.

Minimum handoff criteria

Before moving to testing, the robot must have:

- The mechanical system fully assembled
- The electrical system installed and secured
- Sensors connected correctly
- Wiring tidy, fixed and safe

Quality conditions for handoff

Beyond the minimum, confirm that:

- Every motor is connected to the correct controller
- The robot can be powered safely
- There are no mechanical interferences
- Wiring does not get in the way of motion
- Electrical components are accessible

Key principle

We do not hand over an assembled robot; we hand over a robot ready to test.

Fabrication area responsibilities

Fabrication makes sure to:

- Not pass basic problems on to software
- Deliver complete systems, not partial ones
- Meet agreed deadlines

Why delivery time matters

The time software gets defines the robot's final performance:

- More time: better control, better accuracy, better strategy
- Less time: a working robot, but not a competitive one

A robot finished late limits everything that comes after.





5.2 Startup protocol (first power-on)

The first power-on is a controlled check of the complete robot.

It is not a performance test; it is a safety and basic function test.

First power-on goals

- Check electrical integrity
- Confirm actuators work at a basic level
- Check sensor readings
- Catch faults before real testing

Sequence

1. Load the base program
2. Simple code to drive motors and read sensors
3. Enable by subsystem
 - Test one at a time
 - Never enable everything at once
4. Recommended order
 - Drivetrain
 - Main mechanisms
 - Secondary subsystems
5. Progressive tests
 - Start at low power
 - Increase only if there are no faults

Validation checklist

During power-on, confirm:

- Motors spin in the right direction
- Sensors return sensible data
- Encoders count correctly
- No noises, smoke or abnormal behavior

Safety conditions

- Robot raised or wheels off the ground
- Area clear
- One person ready to cut power
- Clear communication across the team





Software integration (key)

After the first power-on, the robot goes to software.

That time is used for:

- Controller tuning
- Fine adjustment
- Autonomous testing
- Fast iterations

Documentation

6.1 Documentation templates and examples

Documentation is a core part of the engineering process. It keeps traceability, justifies decisions, supports iteration and passes knowledge from one season and generation of the team to the next.

A good documentation system turns hands-on experience into a reusable asset.

Required documents

Every process in the area produces documented evidence. At a minimum we keep these records:

Documento	Propósito
Certificaciones	Validar qué miembros están autorizados para operar maquinaria
Órdenes de trabajo (OT)	Controlar la fabricación de piezas y asignación de responsabilidades
Registro de Calidad (QC)	Documentar inspecciones, tolerancias y resultados
Documento As-Built	Registrar cualquier desviación respecto al diseño original
Checklist de Power-On	Validar condiciones seguras antes del primer encendido





What each document is for

Certifications

An up-to-date record of which members can operate tools and machines, with date, type of certification and who validated it.

Work orders (WO)

Goes with every part or batch. It includes:

- Part name
- Owner
- Material
- Required process
- Status (in progress, done, rejected)

Quality record (QC)

Records:

- Critical measurements
- Tools used
- Inspection result
- Inspector's signature

As-built document

A record of changes from the original CAD. It includes:

- What changed
- Why it changed
- Impact on the system

Power-on checklist

A structured list to confirm the robot is ready to be powered safely.

Documentation quality requirements

All documentation meets these standards:

- Clarity: anyone on the team can understand it
- Accuracy: correct, verifiable data
- Traceability: decisions and changes can be traced
- Kept current: written during the process, not at the end
- Evidence: photos, diagrams or screenshots when needed

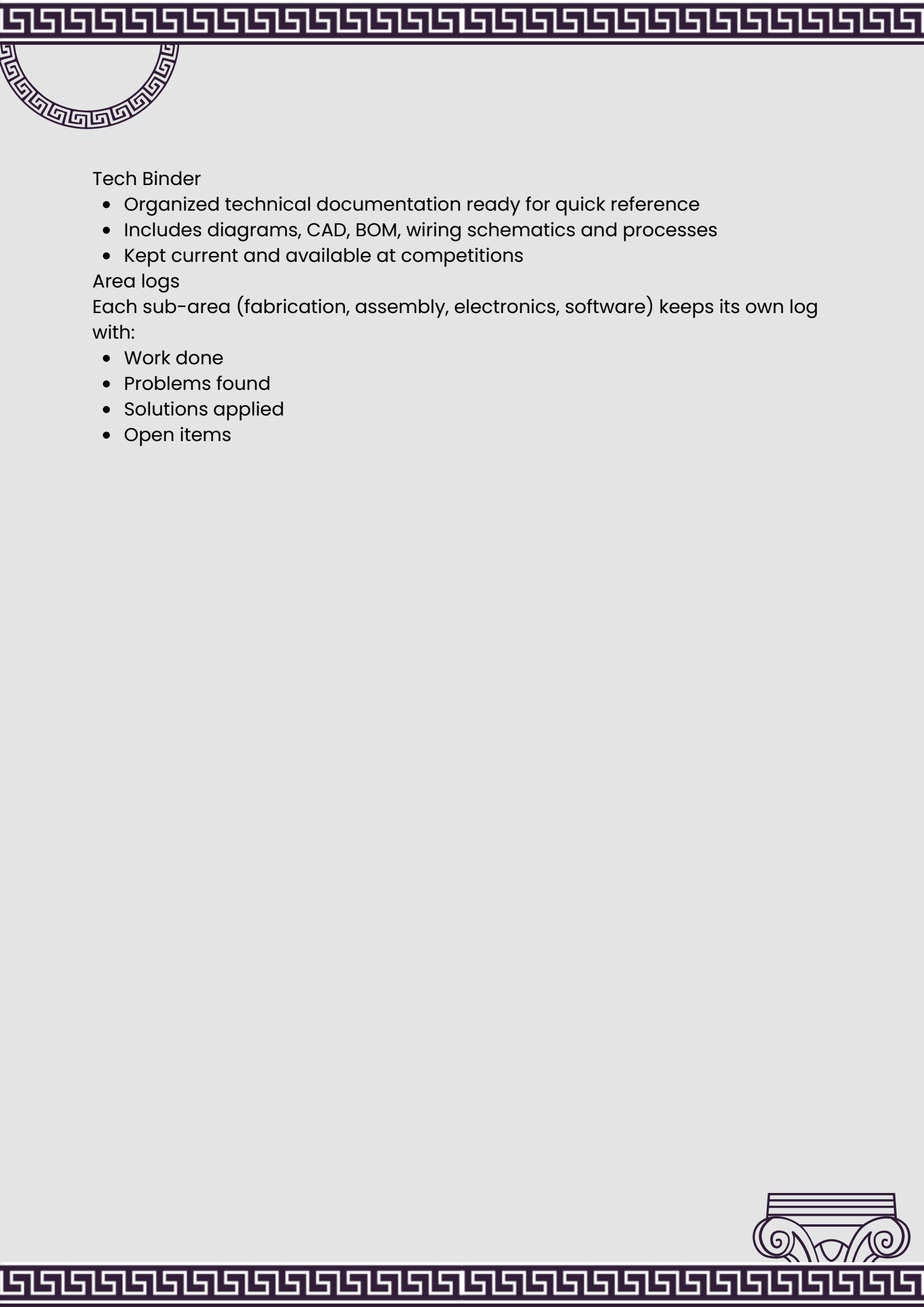
Where documentation goes

Everything the area produces is added in a structured way to the team's official systems:

Engineering Notebook

- Formal record of design, fabrication and decisions
- Includes iterations, mistakes, solutions and lessons learned
- Key for judging, awards and technical follow-up





Tech Binder

- Organized technical documentation ready for quick reference
- Includes diagrams, CAD, BOM, wiring schematics and processes
- Kept current and available at competitions

Area logs

Each sub-area (fabrication, assembly, electronics, software) keeps its own log with:

- Work done
- Problems found
- Solutions applied
- Open items