Industrialization and mass production challenges

Industrialization; Manufacturing; Mass production; Quality assurance; Hardware; Crisis

White paper

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Introduction

Industrialization is transforming a prototype into a product that can be manufactured and the subsequent training to manufacture it competitively: cost, time, reliability.

This article aims to provide an integrated view of all the industrialization process, from development to product delivery, summarizing the manufacturing process and quality aspects while also analyzing the importance of its resilience to risks and adversities, such as the COVID-19 pandemic crisis that we are facing.

Industrialization

Industrialization as a process (see **Figure 1**) starts with defining the product's requirements for hardware, software, mechanical and other factors, which will have to consider all client and industry needs.

The next stage is to develop all the elements necessary to build the first prototypes, which include schematics, printed circuit board (PCB) layout, bill of materials (BoM), 2D and 3D models of all modules, enclosures, labeling, gift box, flyers, packaging, among other details. The right choice of materials is essential since it dramatically impacts cost, reliability, repair, and maintenance.

In parallel, embedded software starts to be developed, and unitary tested to ensure that as soon as the first units come out from prototyping manufacturing, the combination of the hardware and the software bring-up is performed. At this time, all main tests start, including but not limited to the streams described in **Figure 2**.

Part of the software includes the internal requirements to support the manufacturing tests, providing tools for the programming and test of all the hardware functions and interfaces. These tools will ensure the maximum test coverage either at the mass production stage or at the return merchandise authorization (RMA) process (refurbishing).

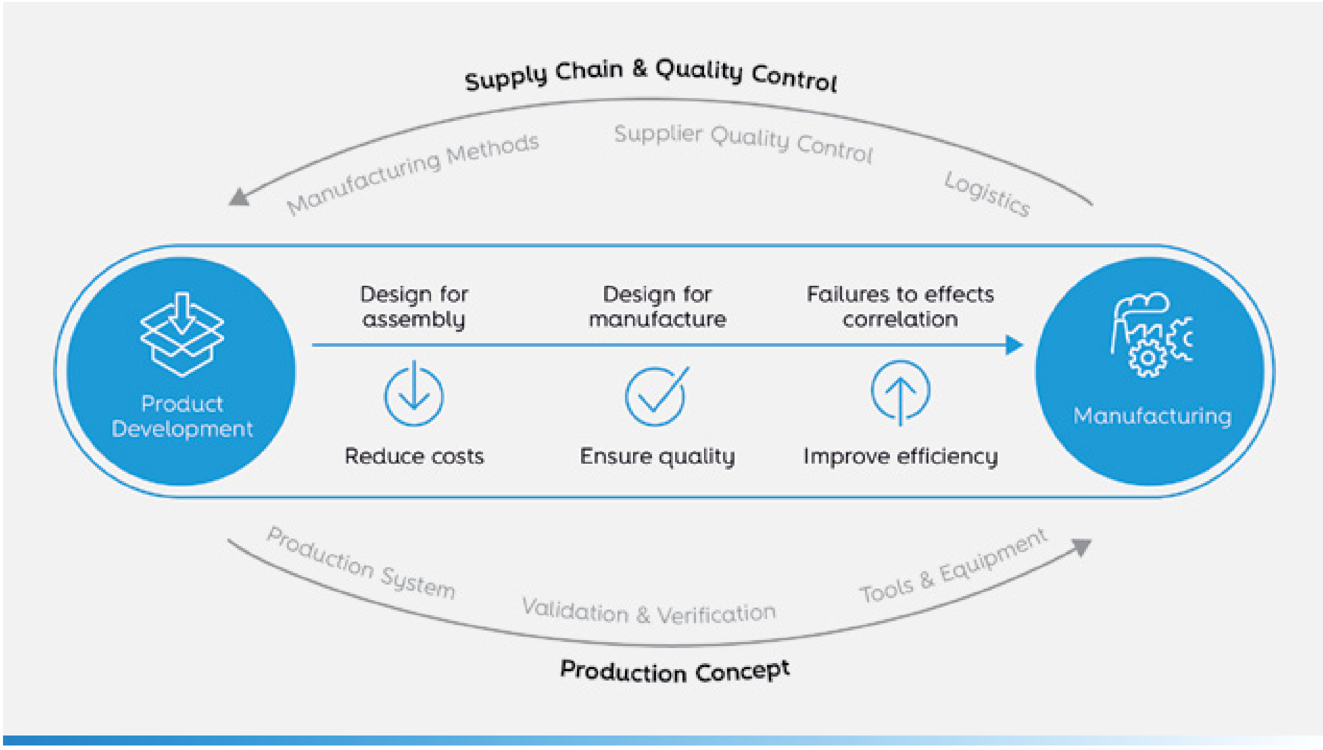


Figure 1 – Industrialization & Design for Manufacturing

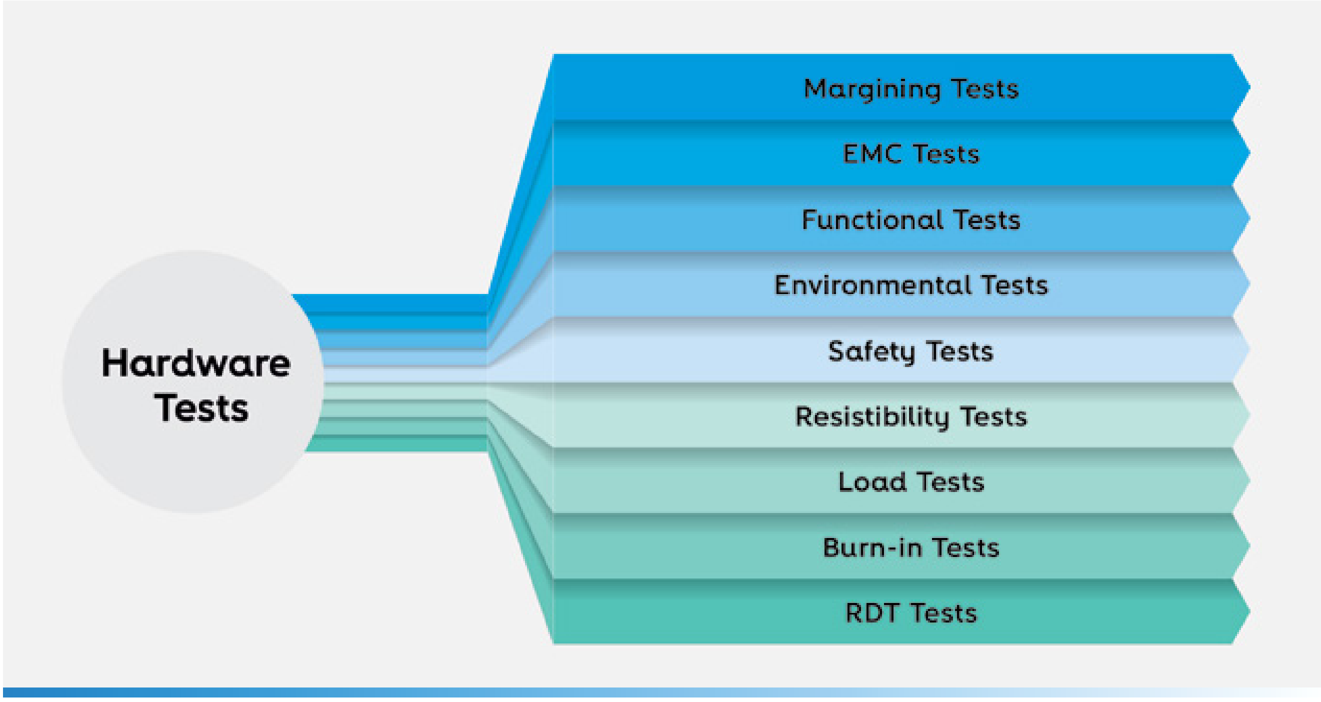


Figure 2 – Main hardware test streams

All the information required for industrialization and manufacturing is collected to create the specific product technical database during each stage. In other words, industrialization starts when the product is conceived and, along the way, a collection of all the technical data needed for the manufacturing process is gathered. The industrialization process's quality will impact the manufacturing process, contributing to achieving cost and time reduction while improving margins.

Manufacturing is the final stage of the industrialization process, defining workflows and procedures to manufacture a product with the suitable components in the shortest period while guaranteeing quality by performing a full test coverage.

Although during the current pandemic crisis, with imposed travel restrictions, the maturity of Altice Labs' industrialization process enabled the manufacturing of new products, with new technical specifications, in factories located abroad, without the need to perform on-site inspections, we continuously work to improve all the methodologies and tools to go even further.

Mass production

The mass production goal is to reproduce many samples of a given product with quality, in the shortest time and at the lowest price, in a business where the margins are small and very dependent on the overall process quality (see a factory ground floor example in **Figure 3**).

The more the manufacturing process is automated, the greater will be the repeatability with less likelihood of errors. In mass production, the operator should not need to make any decisions, limiting himself to comply with the work instructions set for his station.

Figure 3 – Factory ground floor for mass production of hardware

Process smoothness relies upon the design for manufacturing (DFM), starting with the product's requirements fine-tuned in the prototype production, which is the perfect time to validate and correct all the negative aspects that may impact mass production. Sometimes, however, a short time to market (TTM) leads to a lack of time to incorporate the changes requested by the DFM. In this case, a rigorous risk analysis must be observed and weighted to decide whether to bear the costs of delaying the product's availability or, instead, move forward, compromising the DFM's perfection.

Although there are duly standardized and transversal processes and instructions regarding production and inspection, all tasks must be adapted to the assembly line, whether in the context of facilities, equipment, tools, and human resources.

Besides the DFM process, it is highly recommended to implement a new product introduction (NPI) phase, with a smaller production, to validate and adapt the entire line setup process, production tools, and procedures according to the manufactured products. A good analysis of the whole production dossier carried out in the pre-setup phase allows predicting process times and production rates. However, only the NPI phase will allow getting close to reality, having already implemented all the optimization possibilities either in terms of:

- Automatic assembly equipment;
- Sequencing of tasks based on operators;
- Definition and adoption of line layouts.

Manufacturing tests are part of the mass production, from the raw material inspection to the final quality control analysis. Before the first delivery of a new product to any Customer, it is necessary to demonstrate the product's mean time between failures (MTBF) goal through live cycle acceleration, in a process called reliability demonstrations test (RDT). With RDT, a predefined set of product samples is exposed to the aging caused by multiple temperature cycles inside a climatic chamber while running a set of functional tests. Newer products can only be delivered after having completed the first customer shipment (FCS) without failures. This step is essential to commit to an annualized failure rate (AFR) of less than 2%, required for all Altice Labs hardware products.

Manufacturing tests and quality assurance

Quality is the most crucial factor in mass production. The goal is to find the best balance between production costs and times while improving the quality, resulting in better reliability.

Control points start very early in the manufacturing process (see example in **Figure 4**), beginning with the selection and inspection of the raw materials, and including steps to ensure the product's integrity throughout the production phase until it reaches the tests. Solder paste inspection (SPI) and automatic optical inspection (AOI) pre-flow and post-flow are examples of the steps mentioned above. These checkpoints allow the immediate identification and correction of errors during the process, avoiding the recurrence of issues.

Figure 4 – Automatic optical inspection

Complementary, all the preventive maintenance based on manufacturing equipment calibrations and correct verification of their configuration guarantees the proper operation, resulting in flawless manufactured products.

Concerning quality assurance in mass production, Altice Labs tests all the manufactured units instead of sampling, performing electrical and functional tests. Test plans are designed to maximize hardware test coverage, widen the automated tests that decrease testing time and costs, and improve the final quality and business margins. All test scenarios are built taking into account portability, scalability, reliability and high availability, including equipment backups.

Another concern is related to the documentation that must be complete, structured, and easily understandable to communicate the essential knowledge to the workers involved. Training is also a critical point in the knowledge transfer process. Altice Labs usually provides on-job training for its products in the production lines and ensures test setup validation on site. During manufacture, production partners perform regular testware verification and calibration in the manufacturing test lines, retesting their golden samples, a set of products previously produced that conform to all the requirements and can be used for comparison later in the process.

The availability of the appropriate information systems and the effective management of the teams that integrate the entire process are the basis of the business's support and resilience.

Likewise, ensuring traceability by keeping per device records of the machinery used in the production, the lots of the raw material assembled, and the testing pass/fail complete results is a crucial step to understand and close the quality loop.

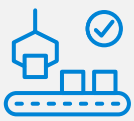
It is not possible to ensure both quality and competitive prices in the products without high 1st pass yields (number of good vs. defective units produced without rework). Therefore, maximizing results and other key performance indicators (KPI) is a permanent priority. Manufacturing partners are committed to providing periodic reports about the entire manufacturing processes, including direct visibility about testing yields and live analysis. Regarding test criteria, initial thresholds are defined according to each product's complexity and historic and afterward adjusted as production evolves.

Whenever the yield is less than 100%, even the smallest failure entails understanding the cause and its immediate correction since it is in the efficiency of the business margin. In addition to an increase in costs, rework requires a second intervention subjecting the affected components to complementary thermal stress that may not benefit the product.

Recurrent failures should be given the maximum attention, as they may indicate a systemic problem (manufacturing, design, or other) that is only perceived in the presence of a larger number of samples during the manufacturing process than the prototyping phase.

During the pre-industrialization phase, prototypes are verified, and in-circuit tests (ICT) project specifications are prepared, when required, by verifying, analyzing, and maximizing coverage and placement/distribution of test points. Boundary-scan can also be used in compatible boards to increase test coverage with a very accurate diagnosis in case of failure. Finally, it is essential to perform BoM analysis to optimize it to mass production and remove unnecessary components, sometimes used only for development or validation purposes, and not need in the final BoM.

Test applications used in the manufacturing of Altice Labs' products can either be designed and developed by Altice Labs or specified by Altice Labs and developed by the manufacturing partner with Altice Labs validation. The advantage is taken on the knowledge and experience acquired during the validation tests and re-use in manufacturing test lines (know-how, test scripts, scenario designs, auxiliary test equipment integration like traffic generators, spectrum analyzers, power meters, for example).



Altice Labs develops specific test applications for each product, ensuring maximum coverage and minimum test duration, helping to decrease test costs. These applications must allow full control of manufacturing test line parameters like thresholds and provide all required information like results, cadence, yields, KPI.

The next phase is to deploy and follow-up. When a new product comes to the manufacturing test line, a functional test application is deployed, and pass/fail thresholds are adjusted if needed, considering the test results with new units from the production line. Altice Labs usually has a close follow-up on the manufacturing test line, on-site, monitoring all the test stations using golden samples as reference. Remote monitoring takes place as soon as a high confidence level in the process is reached.

Finally, it is time for the NPI production itself. Using a control run with a smaller quantity of units, Altice Labs can validate product quality and evaluate its stability. Besides, by analyzing data collected during the control run, both product and manufacturing tests can be improved to prepare mass production with the highest efficiency.

Upon the manufacturing process's conclusion, a set of random samples of finished products are collected for the out of box analysis (OBA) - see **Figure 5** - in a quantity that depends on the lot size. This last test phase will verify all product stages, from the visual inspection of the external packaging and labels (gift box) to the product's internal arrangement and its accessories and user guides. It will also verify the performance of a set of functional tests to ensure that all the products are effectively working as required.

Figure 5 – Random selection of products for the out-of-the-box analysis

In parallel, additional tests are performed in other product samples to ensure the products' continued reliability. The ongoing reliability test (ORT) phase is designed to capture defects that are not necessarily detectable by the standard manufacturing tests or OBA. This phase includes a set of non-functional tests, namely thermal shock, high temperature and humidity storage, burn-in, vibration, and drop test.

In these last stages, no failures are allowed. If any occurs, Altice Labs must be immediately notified by the manufacturer, and the production line must be stopped until the failure root cause is found, and preventive measures are adopted to prevent it from happening again.

The manufacturing process is not static and is usually fed with information from the after-sales service to ensure the constant improvement in the performance and quality of Altice Labs products.

Challenges, risks, and threats

Cutting edge technology companies such as Altice Labs face several challenges:

Shorter innovation lead-times	**Time to market competitiveness**	**Cost reduction**	**Mass customization demands**
Increasingly complex products	**Geographical dispersion**	**Inventories subject to rapid depreciation**	**Immediate fulfillment needs**

The COVID-19 pandemic increased these challenges, bringing new risks and threats with substantial impact on businesses. Transport freight costs increased the logistic costs and the delivery time, thus affecting major products and services. Manufacturers of electronic components that depend on raw materials also felt the pandemic effects and, consequently, have higher lead times and suffer temporary supply chain disruptions.

Resiliency must be grounded on contingency plans to overcome the significant risks with high impact, identifying the actions to be taken if an unexpected event or situation occurs to recover normal business operations. These plans exist either for negative or positive events, such as many purchase orders that overload business delivering capacity and may lead to a decrease in quality or increase in delivery times that may damage the company's image.

Typical major risks include fire, flood, earthquakes, main power failures, loss of big clients to competitors, data loss/hacking/theft, and critical employees leaving to competitors, to name a few. In the manufacturing industry and mass production, additional risks must be considered (see **Figure 6**), such as the inflation of raw materials or labor prices, high lead times for raw materials delivery, product demand variations, and geopolitical constraints in accepting hardware manufactured from specific countries.

Figure 6 – Major risks associated to the manufacturing industry and mass production

How to be resilient in the face of these significant risks?

In the case of raw materials, the DFM must include, whenever possible, at least three alternative options for the components of the BoM to ensure negotiating capacity as well as to mitigate longer delivery times. Other options may include using alternative distribution channels, having short/mid time forecasts from the clients, and as a last resource, stocking, with the inherent risks and costs.

To overcome any geopolitical constraints, it is vital to completely systematize and organize the whole industrialization process. It will ensure that the manufacturing process is as portable and adaptable as possible to enable the manufacturing site's change whenever and when circumstances require, even without a local presence at the factories, as has been the case during the current pandemic crisis.

Although the strategies adopted to mitigate these risks are regularly evaluated and updated, we are continually challenged with new variables and threats that have to be considered in the business strategy, contributing to improving the companies' success in this area.

Acronyms

2D/3D	Two/Three-dimensional
AFR	Annualized Failure Rate
AOI	Automatic Optical Inspection
BoM	Bill of Materials
COVID-19	Coronavirus disease 2019
DFM	Design For Manufacturing
EMC	Electromagnetic Compatibility
FCS	First Customer Shipment
ICT	In-Circuit-Test
KPI	Key Performance Indicators
MTBF	Mean Time Between Failures
NPI	New Product Introduction
OBA	Out of Box Analysis
ORT	Ongoing Reliability Test
PCB	Printed Circuit Board
RDT	Reliability Demonstrations Test
RMA	Return Merchandise Authorization
SPI	Solder Paste Inspection
TTM	Time to Market

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