United Tooling Coalition
General Approach to Functional Build

DEFINITION OF FUNCTIONAL EVALUATION

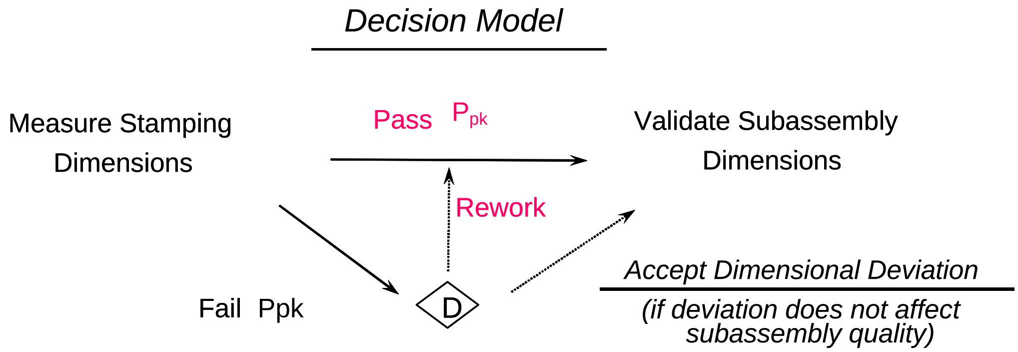
There are several definitions for functional build. The following is one version:

> *An iterative analysis and decision making process that provides a means of adjusting engineering specifications, as required, determined through the Engineering Process. It utilizes the construction of components, assemblies, and/or complete vehicles to evaluate their acceptability based on visual and functional performance. Appropriate stakeholders make the best business decisions to change product, process or specifications in order to achieve customer satisfaction.*

Strategy

Striving for parts that meet original design intent (dimensions and tolerances) with compliant parts (sheet metal or molded parts) follows the law of diminishing returns. A significant percentage of dimensions can be attained readily, but achieving dimensional conformance on the remaining points is often tedious, time consuming, and of questionable value. For this reason, traditional buyoff requirements that place a disproportionate importance on achieving C_{pk} on all dimensions result in a large number of tools becoming accepted only when time runs out. The perceived quality of the tool (% of points meeting C_{pk}) is governed by the time available. This results in tools being shipped to the home production line that still have significant dimensional concerns, resulting in build problems late in the program. Consequently, UTC supports the ***Event-Based Functional Build*** process that combines both timing and dimensional conformance for tooling buyoff. UTC begins all major tooling programs with our customers by co-developing the timing and quality gates associated with event-based functional build.

Generally, the entire launch process is more efficient when parts meet their initial dimensional requirements, and some simple tools will produce 100% of these requirements. These tools then proceed through the quality gates (ship tools to plant, home line tryout, PPAP, etc.) as "problem-free" tools. However, the tools that do not meet dimensional objectives need to be evaluated **before time expires.** See Decision Model diagram.



Since the event-based functional build process is governed primarily by event timing, rather than by satisfying dimensional requirements, the program timing is not allowed to be violated, and the degree-of-freedom becomes component dimensional quality. The functional evaluation team generally assumes (and may even mandate) that panels not submitted on-time to functional evaluation must meet 100% of the design requirements. With the focus on component quality, the priorities become:

1. Achieve 100% part stability (e.g., $C_p > 1.0$ or 1.33 as desired). This first requirement must be met prior to moving to the second requirement.
2. Achieve a "window" of dimensional conformance (a distribution of part dimensions must fall within nominal targets). The dimensional conformance requirement increases along the timeline, ultimately reaching 100% at PPAP.
3. Satisfy functional performance as evaluated through the match metal process.
4. Achieve final production part approval (PPAP).

The event-based functional build approach quickly attains stable metal before evaluating the need for nominal shifts and tooling rework. Since part quality is "never perfect", this strategy allows for prioritizing where to make nominal shifts, which is critically important in the event that timing lapses later in the program. Evidence has shown that this approach results in better quality than allowing all nominal shifts to be given equal consideration under the conventional buyoff approach. Further, because of shortcomings in design, this evaluation process also helps identify problems not tied to dimensional data sooner in the buyoff process.

The strategic, up-front definition of the quality gates, passing criteria, and timing events is crucial to successfully executing functional build.

Submittal Criteria & Quality Gates

Once the timing and quality gates are set, the criteria for progressing through them is critical. The first use of submittal criteria occurs when the press tools are tried out at the tooling production source. Different, more stringent submittal criteria issues pertain to how closure panels will be evaluated. Since closure panels are significantly affected by hemming, there are alternative approaches to buying off closures. The specific criteria depend on several factors, including:

- How aggressive the timing objectives are (program timing)
- The detail GD&T (tolerances), use of slip planes, how constrained the measurement and assembly processes are, etc.
- The costs associated with identifying tooling rework decisions "downstream," such as at the home line (i.e., shipping a tool to the home line that still requires rework). If the costs are high, then a more conservative buyoff approach would use more stringent criteria.

Some companies also apply different submittal criteria to thin and thick steel panels. One U.S. OEM decided to identify three levels of buyoff criteria, and then assign each part to one of the three levels. Another simpler approach based on steel gauge is shown in the following table.

Type of Dimension	Criteria	Non-Rigid Part Thickness < 1.5	Rigid Parts Thickness > 1.5
Cut Lines Exterior Panels (Hemmed Asm)	Profile & Parallelism* (form and attitude)	within tolerance	
SPC Points	Variation	Range < 1mm (range= max - min)	Range < 1mm (range= max - min)
SPC Points	Mean	- 80% of means within tolerance; - if mean out-of-tol, mean < tol + 0.75	All means Within spec
Other DBO Points	sample of one (1pc full dimensional)	all others < tol + 1mm	All means Within spec

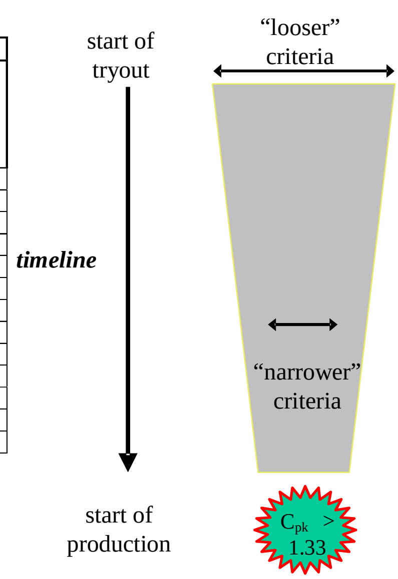
A minimum of three panels are needed to determine process capability (estimated using range or C_p), but UTC recommends five panels, even though some OEMs still require ten or more panels. The number of checkpoints measured on a panel is also important, but a sample of 15-20 is usually sufficient for a door inner panel, and about 75 checkpoints on a body side inner, for example. Additional measurement points are often made using CMM equipment, but these are for reference and problem solving should a build problem be identified.

There are three principal quality gates:

1. When to submit panels from the tooling tryout source for the first build evaluation. (Note: die work that could affect part geometry is generally halted once a panel is submitted for functional evaluation.).
2. Criteria to meet before the tool can be shipped to the home production line.
3. Final production approval (PPAP: production part approval process).

The recognized quality level of the tool continues to increase as it progresses through these gates. Early on (first quality gate), the looser criteria are applied in order to readily get feedback on prioritizing necessary rework. Later, when striving for PPAP, the criteria become stringent (if desired, C_{pk} can be used).

Process Validation Stage	**Panel Examples**	**Details** HSS Panels A piller B/S inner Dash Plenum Etc.
Construction Source- Submittal Requirements for Functional Build (Required)	Cp	1.00
	%	100%
	Cpk	> 0.00
	%	80%
	Max. mean	3t
Approval to Ship to Home Line (Goal)	Cp	1.00
	%	100%
	Cpk	0.50
	%	80%
Home Line (Requirement)	Cp	1.33
	%	100%
Production Approval (Requirement)	Cpk	1.00
	%	100%



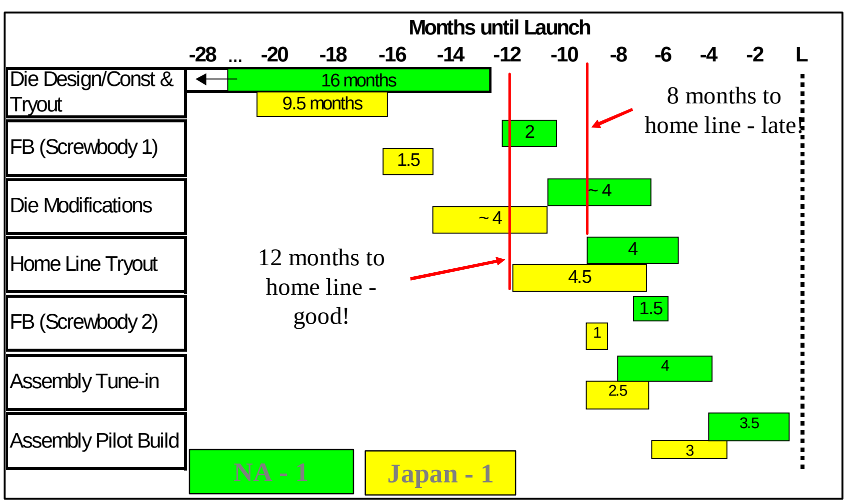
It is important to recognize that this strategy of increasingly stringent criteria to progress through the quality gates is possible because tolerances are adjusted to match the component as long as those dimensions are producing a good build. The assembly build (using the match metal process) is the key process identifying tooling rework decisions.

UTC recommends not making final tolerance revisions until the tools are operating on the home production line. Even when dimensions are tentatively approved to ship to the home line, small changes will occur when the tools are run in the production press. Hence, final disposition should wait until these changes are evaluated with match metal, and the tools are proven capable. When match metal accepts these deviations, the tolerances can either:

1. Be left alone if the tool is producing an acceptable PPAP requirement (e.g., $C_{pk} > 1.33$).
2. Be given a unilateral or bilateral tolerance expansion (depending on customer preferences), provided the expansion is not "too large" (Increasing the tolerance band should generally be limited to 50%.).
3. Shift the nominal dimension because of the amount of the deviation from specification nominal is large (e.g., greater than 50% or 0.5mm).
4. Combination of 2 and 3 above. Ironically, it is likely that when the tolerance shift is made that the bilateral tolerances can often be <u>reduced</u>, which is indicative of the improved quality that functional build produces.

<u>Match Metal</u>

The match metal process is a manual build event usually conducted with part coordination fixtures (PCF). Typically, match metal begins at around 12 months before SOP with tryout source panels, and 9-10 months SOP on home line, and runs through PPAP (ideally about 1 month SOP). See generic timing chart where Toyota conducts these events sooner than in the U.S.:



Characteristics of the PCF process are:

- The match metal decision team includes as a minimum representatives from: product, process (welding and press tools), manufacturing, quality, and functional evaluation (build supervisor).

- Assembly of a "sub-sub" (first level subassembly) to ascertain fit-up of adjacent panels and to evaluate if the sub-sub meets dimensional requirements. Most companies seek 100% dimensional conformance for the sub-sub, and continue this expectation through the build up of the body-in-white, although exceptions can be made if the higher level of sub-assembly conforms to design. A scribed panel is often used to help support the PCF assembly process and identify matching problems (submitting a scribed panel to functional build may be a requirement).

- Manual assembly of panels in the PCF using a process/sequence that emulates the assembly weld tools, usually beginning with the sub-sub "master" datum panel. This implies a consistent sequencing of adding sub-sub panels, clamping, and joining with the production assembly process. Joining is typically done with screws in the spot-weld locations, which allows for substitution of future generation panels. (At this point, some companies "experiment" with the build process to identify build issues that can be remedied with the assembly process, such as changing build sequence, modifying datums and changing weld locations, etc.)

- A disposition report is used to document all significant observations, dispositions, and to track assigned actions. A build disposition report can include tooling rework for any of the submitted panels, recommendations for assembly tooling, or tentative acceptance (pending evaluation with other panels or tentative approval to see how the panel looks when produced on the home line). Tentative approvals may also be assigned if any of the mating panels in the sub-sub involve non-production processes (prototype parts, laser trimmed parts, etc.) Any panel given a tentative approval that has key dimensions out of print requires the approval of the match metal team.

- The match metal team decides on problem solutions based on timing, cost and quality. Quality is based on fit, function and appearance, and not on conformance to design specifications. The team may require that another panel be resubmitted for evaluation if die rework is performed, or if the rework is minor they can request the rework, and bypass the need for another evaluation. The evaluation team is responsible for any risks (such as the need for tooling rework) associated with shipping the die to the home production line.

- A build up of the sub-subs, leading to the body-in-white is performed. This activity supports assembly tool tune-in and evaluates general assembly (trim, hinges, etc.). In some cases where the sub-subs are still not very rigid, feedback may still be important for the press tooling evaluation, which is going on in parallel.

There are several approaches for performing the match metal process. The PCF cost is significant and the fixtures are not used much after launch. One OEM has developed an approach that allows re-use of the PCF either a checking fixture for assemblies or individual parts. Another OEM avoids the use of PCFs by designing the geometry stations in the weld line to be used for matching metal prior to setting up the welding process. Theoretically, the ideal approach according to a UM study, would use the assembly fixture (geometry station) and weld the panels instead of using screws.

Factor	Variable		Significance	Comments
Assembly	Assembly Tool	Match Check	Yes	0.5 - 1.0mm
Joining	Screw	Weld	Yes	Yes in Assembly, No in Match Check (# clamps)
Panel Selection	Representative	Random	No	Small panel variation

The second match metal event occurs at the body shop (or sometimes at the press shop) using panels off the home production line. Criteria are developed for sample size, process capability (C_p), and press repeatability (across die sets). The final outcome of the final match metal event is production approval, or PPAP.

Production Approval

The UTC commitment that is **no tool is completely "bought off" until it passes PPAP**. Furthermore, UTC supports that no tool can pass PPAP until the part's assembly passes PPAP. This functional build philosophy is based on the concept that achieving a functional assembly (leading to the body-in-white) is the ultimate goal of functional build. If an assembly cannot achieve PPAP and if the limiting factor relates to panel dimensions, than either specifications need to be revised (on the part or subassembly) or the panel needs to be changed through tooling rework. If the customer supports this concept, then the match metal decision team should be empowered through the press tooling tryout and body shop PPAP phase.

Frequently Asked Questions

1. Who should be on the functional build evaluation team?
   This team should include representation from: die engineering, weld engineering, product design, stamping, assembly, and functional evaluation. Other interested individuals may also be involved.

2. When do you change component tolerances?
   If tolerances require revision in order for the component to "be in specification," they should wait until the tools are on the home production presses and automation has been added. Prior to this, any revisions should be considered tentative. An agreed upon process (and formula) should be developed to identify when to expand and when to shift a tolerance.

3. When are tools officially approved?
   The tools cannot be approved until the sub-assembly processes achieve PPAP. The functional build process is not sequential, requiring parts to achieve PPAP before the assemblies.

4. Do all parts have to achieve the same level of dimensional quality before functional evaluation?
   No. Larger and less-rigid components will have looser dimensional requirement for submission to functional evaluation. The goal for all submitted parts is 100% dimensional capability. Small, rigid components may also require 100% design capability (Cpk) even with functional build.

5. Does functional build obviate the need for the witness panel process (or other assembly tool tune-in process)?
   No. The assembly tune-in process is separate from functional build and still required.

6. Is one functional build evaluation event performed?
   Usually two are performed: one with dies at the tryout source (tryout presses), and a second one when the dies are run on the home line. As soon as the weld line geometry stations are available, the functional evaluation process can switch to using the production assembly tools.

7. When are engineering changes implemented to stamping tools?
   Functional build does not necessarily affect when changes should be implemented. However, if engineering changes are being batched for implementation (in order to expedite the first tool evaluation), then implementation after the first evaluation is typical. A second submittal of the part to functional evaluation may be required before the tool can ship.

8. Does functional build reduce die design and construction costs?
   No, these costs are unaffected. It does reduce tooling tryout and validation costs.

9. What documentation is used to record changes in tools at functional evaluation?
   The functional evaluation report documents changes in tools and dies as agreed upon by the evaluation team. The tool's disposition is recorded and the information is sent to the tool source. Required part changes are identified on the report.