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TECHNICAL NOTE 111: TESTING & INSPECTION THROUGHOUT A FIREARM'S LIFE CYCLE

I. BACKGROUND:

Few folks outside of the firearms engineering/quality community have a full understanding and appreciation of the testing and inspection that are involved in the lifecycle of a firearm. Some aspects of this subject have been lightly touched upon in previous Technical Notes (e.g. Tech Notes 89, 96, 106). This Technical Note will delve into the subject much more deeply. The topics that we'll address herein include:

The Life Cycle of a Firearm
Conflicts Among User (Customer) Requirements
Tradeoffs In Weapons System Design
Sources of Requirements (User vs Prototype Performance)
Engineering Tests vs User Tests
R&D Testing vs Production Testing
Performance Spec vs Fully Disclosed Technical Data Package
First Article Testing vs Lot Acceptance Testing
Sampling versus 100% Testing/Inspection During Production
Military Testing versus Commercial Testing
Customers as "Beta testers"

In reality, each of these topics could fill an entire book. There is no way that I can discuss them in depth in a Technical Note. But, perhaps I can give you a short overview that will provide you a basis for further study of any topics you deem interesting. And, of course, you can always contact the Program Management Office at ArmaLite if you have specific questions.

Military test and inspection requirements are usually much more stringent than those of law enforcement and commercial customers. So, I'll discuss the military requirements, recognizing that law enforcement and commercial customers' requirements are usually only a subset of military requirements.

Typically, "testing" is defined as some physical action with the firearm (e.g. firing, dropping, subjecting the firearm to heat, cold or chemicals.). And, "inspection" is defined as some measurement of the firearm or its components. For our purposes in this

Tech Note, we'll probably lump "testing" and "inspection" together and just call it all "testing".

II. THE LIFE CYCLE OF A FIREARM:

The "life cycle" of a firearm spans the timeframe from its first concept until it is retired from service, no longer being logistically supported.

From a testing standpoint, for our purposes, the life cycle of a firearm can be divided into two primary phases. Those phases are the Research & Development (R&D) phase and the Production phase (which includes the operational/deployment phase).

During the R&D phase, every conceivable test is conducted. Those tests are intended to assure that the firearm's design is adequate in every possible climate and scenario. Once the sufficiency of the design is confirmed, the firearm can be put into full scale production and sent to users. The design is traditionally captured (defined) in a technical data package consisting of drawings and specifications that define the physical and functional characteristics of the firearm. However, throughout production, testing and inspection are required to assure continued conformance to that physical/functional baseline thereby assuring the performance defined during R&D is continued throughout production.

Note that the testing during R&D has a different purpose than the testing during Production. So, the specific tests employed during R&D differ from the tests employed during Production.

III. CONFLICTS AMONG USER/CUSTOMER REQUIREMENTS:

In the military, new firearms are typically developed in response to a "User Requirement Document". In other words, one or more branches of the service must formally state that they have a need for the new firearm. (And they must convince Congress to fund the firearm's development, production and fielding.)

The User Requirement Document is a listing of all of the performance requirements of the firearm. The document is generally prepared by a team composed of representatives of the actual users and representatives of the engineering organizations who will be responsible for development and production of the firearm.

Within that team, the "users" put forth a "wish list" of all the features and performance characteristics that they desire. Then the engineers recommend modifications to the wish list to assure that the firearm can actually be developed. (The initial wish list may not be achievable. In fact, some of the wishes on the list may contradict other wishes. And some of the wishes may even violate basic principles of physics.)

In other words, the users tell the developers what they want. The engineers tell the users what they believe they can provide. Hopefully, discussions between members of the group will evolve a practical Requirements Document toward which engineers can design to provide users with a firearm that gives them an enhanced capability against all anticipated foes. Put simply, the engineering development community's responsibility is to translate the user's wishes into a technical description of reality.

IV. TRADEOFFS IN WEAPON SYSTEM DESIGN:

A Harley-riding friend of mine often wore a t-shirt that said (in part) "THERE AIN'T NO FREE RIDES". That statement is true in nearly all facets of life. It's particularly true in firearms design. To put it in other words, nearly everything in firearms design is a tradeoff.

Let me explain.

Key user requirements for a firearm typically include requirements for:

--Reliability (in both normal and adverse environmental conditions)
--Durability
--Interchangeability
--Portability (weight, size, etc.)
--Rate of Fire
--Ammo Capacity
--Controllability
--Safety
--Accuracy and/or Hit Probability
--Terminal Ballistics
--Muzzle Flash
--Ergonomics (useable by 5% size woman to 95% size man)
--Other Features (e.g. trigger pull weight)

What the user "wants" is a firearm that never malfunctions, never wears out, weighs less than a pound, has an adjustable rate of fire up to 10,000 rounds per minute, never runs out of ammo, has no recoil, is completely safe, always hits the target, destroys anything its projectile hits, can be used effectively by any soldier regardless of size or skill, and has no muzzle flash or sound signature. Unfortunately any one of these "wants" is unrealistic. So engineers provide realistic guidance and counsel to users. But, even when each requirement, taken individually, seems reasonable, it must be understood that those requirements interact. So, the establishment or change of any one requirement necessarily impacts other requirements.

Let's look at a few examples. For those examples, let's assume that users have specified reasonable individual requirements.

TRADEOFF EXAMPLE # 1: The user typically specifies Portability requirements in terms of weight and overall dimensions, particularly overall length. But, Portability may interact with Controllability, Rate of Fire and/or Ammo Capacity. If the user wants improved Portability in terms of lighter firearm weight, he may be required to sacrifice some Controllability. If the firearm itself cannot be made lighter, the engineers might lighten the entire system by reducing the firearm's Ammo Capacity. If he wants to improve Portability without sacrificing Controllability or Ammo Capacity, the engineers might reduce the Rate of Fire. If the user requires improved Portability in terms of shorter length, the engineers may shorten the barrel to achieve that shorter length. In that case, the user may be forced to sacrifice some Accuracy and some Terminal Ballistics.

TRADEOFF EXAMPLE # 2: As another common example, perhaps the user wants to increase the firearm's Rate of Fire. That increase may degrade Accuracy, Controllability,

Durability and/or Portability of the firearm. In a handheld firearm, a higher Rate Of Fire can make the firearm more difficult to shoot accurately or even just to control. The higher Rate of Fire may also cause parts to wear faster, degrading Durability. And, if designers add weight to counteract the recoil effects of the higher rate of fire, they degrade Portability.

Based on these few examples, I'll bet that you can look at all of the requirements listed above and easily envision other interactions and tradeoffs among them.

Table 1 below lists potential interactions. The actual interactions depend on the specific design in question.

TABLE 1

ENHANCING	MAY DEGRADE
Reliability	**Accuracy, Portability, Terminal Ballistics**
Durability	**Portability, Terminal Ballistics**
Portability	**Ammo Capacity, Durability, Terminal Ballistics**
Rate Of Fire	**Accuracy, Controllability, Durability, Portability**
Ammo Capacity	**Durability, Portability**
Controllability	**Rate of Fire, Portability, Terminal Ballistics**
Safety	**Features, Terminal Ballistics**
Accuracy	**Reliability, Portability**
Terminal Ballistics	**Durability, Portability, Reliability, Safety**
Muzzle Flash	**Portability**
Ergonomics	**Features, Terminal Ballistics**
Features	**Maintainability, Portability, Reliability**

Unless you are experienced in firearm's design, these interactions may not be obvious to you. And a thorough explanation of them would require a several-hour course. The important thing for you to remember from this Technical Note is that every single user requirement interacts with multiple other requirements. It is absolutely critical to the development of an effective firearm that the user/engineer team recognize ALL of those tradeoffs and balance them appropriately.

V. SOURCES OF REQUIREMENTS:

Hopefully users and their engineering counterparts work together to develop a set of requirements that are reasonable. But, for a new firearm to be adopted, it must be significantly better (more effective) than its predecessor. Therefore, it must push the state of the art. So, the user/engineering team does not know for certain that the requirements can be met. Often, the requirements must be modified during development to reflect the characteristics that the engineers can provide in their prototypes. The final set of requirements is often a combination of original requirements and requirements based on actual performance of engineering prototypes.

VI. ENGINEERING TESTS VERSUS USER TESTS:

During development, engineers would like to have all testing very controlled. Controlled tests are very repeatable. But they may not be realistic.
On the other hand, during development, users want to know how the new firearm will perform in their real world. User testing does reflect "real world" conditions. But, it's hard to reproduce those real world conditions repeatedly.
How is this dichotomy resolved? Simple. During development, both controlled engineering and real world user (operational) tests are conducted. In-depth analysis of both types of tests is conducted to assess how the firearm will perform once it's in production.

VII. R&D TESTING VERSUS PRODUCTION TESTING:

As was mentioned in Section II above, the purpose of testing during R&D is to demonstrate that the prototype design meets all user requirements. Once that is established, the firearm can go into production. Testing during production has an entirely different purpose. The purpose of testing during Production is to assure that the performance demonstrated during R&D isn't degraded during production. Because the purposes of R&D testing differ from the purpose of Production testing, the tests themselves differ.

To put the difference between R&D and Production testing more simply, we can merely say that the purpose of R&D testing is to demonstrate that the engineers have designed a firearm that meets the users needs (Design/Engineering testing). The purpose of Production testing is to assure that the QUALITY of firearms in production gives performance at least as good as the performance achieved in R&D (Quality Assurance testing).

During R&D, the engineers prepare a set of drawings and specifications that exactly describe the firearm in terms of its dimensions, tolerances, materials, heat treatments and protective finishes. In addition, requirements for inspection levels and packing/packaging requirements are included. Taken together, these drawings and specifications are called a Technical Data Package (TDP). During the production phase, inspections against these TDP requirements as well as physical tests are used to insure that production firearms meet user requirements.

Table 2 below compares typical R&D tests versus Production tests.

TABLE 2

TESTS/INSPECTIONS	R&D	PRODUCTION
Targeting/Accuracy	**X**	**X**
Function	**X**	**X**
Endurance (Durability)	**X**	**X**
Interchangeability	**X**	**X**
Rate of Fire	**X**	**X**
Trigger Pull	**X**	**X**
Safety function	**X**	**X**
Firing Pin Indent	**X**	**X**
Chemical Resistance (of plastic/rubber parts)	**X**	
Environmentals (Hot, Cold, Mud, Dust, etc)	**X**	

Portability (Weight, Length, etc)	**X**	
Muzzle Flash	**X**	
Drop (Rough Handling)	**X**	
Ergonomics (5% to 95% user)	**X**	
Barrel Life	**X**	
Maximum Sustained Rate of Fire (Cookoff)	**X**	
Muzzle Velocity	**X**	
Operational (User) testing	**X**	
Inspections against TDP requirements		**X**
Interchange among Production Facilities		**X**
Packaging/Packing		**X**

As you may have noted from reviewing the above table, many of the tests in R&D that do not continue during Production are those associated with the basic design, materials, and finishes. Once demonstrated in R&D, and captured in the specification, those physical attributes essentially are inherent to the final design.

VIII. PERFORMANCE SPECIFICATION VERSUS FULLY DISCLOSED TECHNICAL DATA PACKAGE:

In Section VII above, we briefly explained the contents of a Technical Data Package. In essence, a fully disclosed TDP COMPLETELY describes every component and assembly of a firearm as well as describing how to inspect, pack, and package the firearm. Such a TDP is called a "fully disclosed" Technical Data Package. Because a fully disclosed TDP completely defines every component and assembly of the firearm, interchangeability of parts is assured. Thus, both firearms and spare parts can be purchased from multiple sources with confidence that the parts will fit and function correctly. Components can even continue to be purchased long after firearm production has ceased. So, previously-purchased firearms can be supported indefinitely. Because of these advantages, a fully disclosed TDP is normally employed.

But, sometimes, a fully disclosed TDP isn't practical. Sometimes it's far more economical to simply purchase a commercial product off the shelf (or to only specify requirements that are critical to performance). Examples of such military firearms are riot shotguns and rimfire training rifles and pistols. The military simply does not purchase enough of such firearms to make a fully disclosed TDP practical. It makes far more economic sense to purchase such firearms from a manufacturer who already sells them to the public.

Even though the military wants to purchase a commercial firearm, they want to make certain that the firearm meets their needs. So they prepare a performance specification against which they will purchase. The Performance Specification does not contain all of the component drawings and specifications that would be found in a fully disclosed TDP. However, it does contain a combination of the performance and physical requirements normally found in a Requirement Document and a fully disclosed TDP. It typically also includes inspection and packing/packaging requirements.

Because a Performance Specification based TDP does not include all of the individual component drawings of a fully disclosed TDP, the Performance Specification must compensate by adding testing that would normally only be conducted during R&D.

Table 3 is a comparison of typical R&D testing versus Production testing based on a fully disclosed TDP versus Production testing based on a Performance Specification.

TABLE 3

TESTS/INSPECTIONS	R&D	PRODUCTION	PERF SPEC
Targeting/Accuracy	**X**	**X**	**X**
Function	**X**	**X**	**X**
Endurance (Durability)	**X**	**X**	**X**
Interchangeability	**X**	**X**	**X**
Rate of Fire	**X**	**X**	**X**
Trigger Pull	**X**	**X**	**X**
Safety function	**X**	**X**	**X**
Firing Pin Indent	**X**	**X**	**X**
Chemical Resistance	**X**		**X**
Environmentals	**X**		**X**
Portability	**X**		**X**
Muzzle Flash	**X**		**X**
Drop (Rough Handling)	**X**		**X**
Ergonomics (5% to 95% user)	**X**		**X**
Barrel Life	**X**		**X**
Max Sustained Rate of Fire	**X**		**X**
Muzzle Velocity	**X**		**X**
Operational (User) testing	**X**		
Inspections against TDP reqmts		**X**	**X**
Interchange among Production Facilities		**X**	
Packaging/Packing		**X**	**X**

One of the disadvantages of a Performance Specification is that, without complete component drawings, there is no way that the buyer can assure that all components will be fully interchangeable. Without component drawings, the buyer cannot purchase interchangeable components from another company. In fact, the buyer may not even be able to purchase interchangeable components at a later date from the original company.

A current trend within the U.S. military is to use performance specifications as a basis for purchasing a wide variety of equipment, including firearms. Military economists often believe that Performance Specifications are more economical than dictating the detailed design. Their position seems to be "Just give me an item that fits within my interface/envelope requirements and performs the functions I have identified." Simple/great. The reality is that the manufacturer of the firearm uses drawings to manufacture and inspect it. In order to assure that he is purchasing what he needs, the purchasing agency must inspect the performance. From a risk perspective, testing associated with a Performance Specification must be more rigorous than the testing associated with a fully disclosed TDP. Because the purchasing agency doesn't have complete control of the design, the agency is slave to extensive testing lot after lot in order to verify performance.

IX. FIRST ARTICLE TESTING VERSUS LOT ACCEPTANCE TESTING:

Typically, at the start of every production contract, the first-produced firearms undergo what is called "First Article Testing (FAT). First Article Testing includes very thorough testing/inspection of the initial production hardware. While it does not incorporate all the development engineering testing, it typically does involve a wide variety of rigorous, detailed tests and inspections. FAT may include 100% inspection of all dimensions on all components in the First Article sample (typically 5 to 10 firearms). Those inspections confirm that the production hardware does, in fact, conform to the already proven design (drawings). Also as part of FAT, a full spectrum of production tests is conducted. These tests would normally include endurance, function firing, accuracy, targeting, firing pin indent, trigger pull, etc. FAT tests may be longer in duration than subsequent lot tests, and include multiple samples. For example, the FAT may require three 10-shot targets be fired for accuracy by each of the 10 FAT firearms, where in normal production, each firearm might be fired only one 5-shot target. Endurance testing would generally be performed on several FAT samples, whereas during production only one of hundreds of production firearms would be endurance tested.

First Article Testing is a risk mitigating prove-out action to assure not only that the hardware is conforming to the approved design using production processes, but also the capability of the manufacturer to verify his abilities to test and inspect correctly

X. SAMPLING VERSUS 100% TESTING/INSPECTION DURING PRODUCTION:

During production, some tests may be conducted on every firearm produced. Other tests may only be conducted on a sample of firearms. The choice of whether to test every firearm, or only a sample, is based on economics, risk, expected firearm-to-firearm variation, and effect of the testing on the firearm.

Table 4 lists tests that are typically conducted on 100% of the firearms versus tests conducted on only a sample of firearms (when production is based on a fully disclosed TDP).

TABLE 4

PRODUCTION TESTS/INSPECTIONS	100%	SAMPLE
Targeting/Accuracy	**X**	
Function	**X**	
Endurance (Durability)		**X**
Interchangeability		**X**
Rate of Fire		**X**
Trigger Pull	**X**	
Safety function	**X**	
Firing Pin Indent		**X**
Inspections against TDP reqmts		**X**
Interchange among Production Facilities		**X**
Packaging/Packing		**X**

And, here's a similar table (Table 5) when production is based on a Performance Specification.

TABLE 5

PRODUCTION TESTS/INSPECTIONS	100%	SAMPLE
Targeting/Accuracy	**X**	
Function	**X**	
Endurance (Durability)		**X**
Interchangeability		**X**
Rate of Fire	**X**	
Trigger Pull	**X**	
Safety function	**X**	
Firing Pin Indent		**X**
Chemical Resistance		**X**
Environmentals		**X**
Portability		**X**
Muzzle Flash		**X**
Drop (Rough Handling)		**X**
Ergonomics (5% to 95% user)		**X**
Barrel Life		**X**
Max Sustained Rate of Fire		**X**
Muzzle Velocity		**X**
Inspections against TDP reqmts		**X**
Packaging/Packing		**X**

As you can see, lack of a fully defined TDP forces many more tests when a Performance Specification is used as the basis for purchasing firearms.

XI. MILITARY TESTING VERSUS COMMERCIAL TESTING:

It should seem reasonable to you that military firearms must undergo much more rigorous and extensive testing than commercial firearms undergo (both in R&D and in Production). Military firearms must function reliably in a wide variety of environments. They must function with minimal maintenance. They are fired many more rounds than most commercial firearms ever will be. They must be manufactured with completely interchangeable parts so that they can be repaired as near the battlefront and as rapidly as possible. And, most importantly, lives depend on every one of them.

Certainly commercial firearms could be designed and manufactured to military standards. But, the more stringent military performance and test requirements cost money. In a free-market price-competitive environment, the additional requirements may reduce the economic competitiveness of the firearm.

If a commercial customer wants “military grade” firearms, he can purchase them, albeit at a higher than normal price.

XII. CUSTOMERS AS “BETA TESTERS”:

A definition of Beta Testing found an online Business Dictionary is:

"Second level, external pilot-test of a product before commercial quantity production. At the beta test stage, the product has already passed through the first-level, internal pilot-test (alpha test) and glaring defects have been removed. But (since the product may still have some minor problems that require user participation) it is released to selected customers for testing under normal, everyday conditions of use to spot the remaining flaws."

So, "Beta Testers" are intended to be a small group of users/customers who test the firearm in real world conditions. Beta testing is fine as long as users are made aware that they are testing products that may not be fully developed. ArmaLite uses Beta Testing with a select group of experienced "outsiders" to assure that our products will withstand the rigors of use among all of our customers.

However, some companies may merely release new products to all users/customers without telling them that they are Beta testers.

Certainly every firearm (and every other imaginable product) continues to mature after it is initially released to customers. But, manufacturers should make reasonable effort to assure that the firearm is adequate for its intended customers prior to releasing it for production. We believe that expecting unknowing customers to finish development of a firearm by finding its flaws is NOT good practice.

XIII. SUMMARY:

Hopefully, this Tech Note has provided you with some insight into testing and inspection requirements for firearms throughout their life cycles. As a minimum, you should remember that:

1. Testing/inspection requirements depend heavily on:

-- the phase of the firearm's life cycle (R&D testing is substantially different than testing during Production);

--whether production is based on a fully disclosed Technical Data Package or a Performance Specification;

--whether the customer is a professional whose life will depend on the firearm or a recreational shooter.

2. Military testing requirements are usually much more extensive and stringent than testing required for law enforcement and commercial customers. But, that additional testing isn't free. And, firearms built to military standards must be more expensive than similar firearms built to commercial standards.

3. An achievable Requirements Document is a military customer's "wish list" tempered by design engineer's input.

4. All performance requirements interact with each other. A good firearm's designer recognizes and balances these interactions (tradeoffs).

5. A Production contract can be based on a fully disclosed Technical Data Package or on a Performance Specification. Both of these bases have advantages, disadvantages and situations where one or the other is preferable.

6. Every significant production contract will be supported by both extensive First Article testing and by less comprehensive Lot Acceptance Testing.

7. "Beta testing" in the real world can help identify less-obvious problems. But, it's not good practice to rely on unsuspecting customers to be your beta-testers.

 THE WIZ