The Concept of Noise in Robust Design

When we use a mfg. process & materials to make a product,...

when we use a product in the real world, outside of the development lab…

...the quality of the product (& its performance) will vary.

- We call the causes of this variability ***noise factors***

- Noise factors are defined as...

...*anything that causes a functional characteristic or response to deviate from its target value.*

 - noise effects can be quite subtle or dramatic

They are the aspects of physical law that degrade & assail the _IDEAL FUNCTION_ of a product or mfg. process.

For example:

- The effect of high power transmission lines on an AM radio receiver

- Water in automobile gasoline

- Wear in a punch press die

- Contamination in a coating process

- Vibration in an automobile engine

Another way in which to consider noise has to do with the ***conversion of energy***.

Whether it is...

> ...kinetic, chemical, thermal, potential or in any other form,...

...we are interested in the ***efficiency*** of the transformation of energy from one form to another.

Mfg. processes convert energy in order to deliver some desired <u>*functionality*</u> or <u>*characteristic*</u> to a component.

We are interested in accounting for & manipulating the detailed <u>*path*</u> taken in the various transformations of energy.

To meet customer needs we seek to carefully <u>*select*</u>, <u>*harmonize*</u> & <u>*control*</u> the **laws of physics...**

...that affect the mean <u>***&***</u> std. deviation of critical mfg. process & product characteristics.

In order to build & run mfg. processes that possess high levels of *on target performance* ...

...we must first have a clear understanding of the *nature of noise*.

There are three types of noise factors:

1. External Noise Factors

2. Unit to Unit Noise Factors

3. Deterioration Noise Factors

The latter 2 are sometimes referred to as **Internal Noise Factors** because they relate to the physics of variation *inside* the product or process.

External Noise Factors:

External noise factors can be defined as sources of variability that come from ***outside the product***.

Examples of external sources of variability are:

- The environment in which a product is used
- The load to which a product is subjected
- Any input of energy into a process that was not intended & to which it is sensitive.

Specifically we see the following as potential external noises:

- temperature
- humidity
- contamination
- input voltages
- electromagnetic interference
- vibrations
- human error
- misuse
- abuse

Unit-to-Unit Noise Factors:

Unit-to-unit noise is a phenomenon based in the physical dilemma of never being able to make any two items exactly alike.

Manufacturing processes are common sources of unit-to-unit variability in product components.

Process non-uniformity & process drift are common indicators of sources of variability in this context.

Some typical examples of unit-to-unit variability are:

- Incoming material characteristics
- Amount of tension in a process web
- Sensor-to-sensor differences in a process
- Dimensions from any metal forming or removal process
- Batch-to-batch concentrations of chemicals

Deterioration Noise Factors:

It is common for certain materials to "age" during use or storage such that their performance deteriorates.

Examples of "*internal*" noise factors:

- Hardening of rubber washers in a faucet resulting in leaks
- Mass loss of tungsten filament with use resulting in dimming and burn out
- Plasticizer loss in an auto dash board resulting in fading & cracking
- Corrosion of car battery terminals
- Loss of adhesion between paint & house siding resulting in peeling paint
- Worn brake pads on a car

Selection of the Noise Factors

Noise factors are parameters that...

- ***Cannot*** be controlled during manufacturing or use
- Are ***difficult*** to control
- Are **expensive** to control

To get started, identify all the noise factors that can introduce variability in the function of the product or mfg. process…

Your multifunctional team should conduct *brainstorming sessions*...

Interview customers, service personnel, suppliers, manufacturing personnel, assembly personnel etc.

A good brainstorming session will generate a long list of noises

Remember...

There are <u>many</u> sources of variability.

If you are having difficulty generating many noises here are some guidelines to help focus the discussion:

- Try to find noises related to the different sources:
  - **External**
  - **Unit-to-Unit**
  - **Deterioration**
- Try to identify the various energy transformations in the ***<u>system</u>***, *make sure you have noises that act as sources of variability for each of the energy transformations*
- Consider noise surrogates such as **time**, **location**, **replication**, etc.

Ideally, your brainstorming will result in a dozen or more sources of variability.

It is now time to shift your focus from comprehensive identification of noise factors…

…to specific identification of the *CRITICAL FEW* noise factors.

Prioritize the list. (Pareto process)

Condense the list. *Compound factors* based on interrelationships between noises

(Don't test what you already know!)

The Noise Factor Experiment

The noise factor experiment has at least **four goals**:

1. Identify the important noise factors that contribute to most of the variability. *Don't want to waste time in the Main Robustness Experiment trying to control unimportant noises.*

2. Benchmark the performance of the baseline design (*can be used to aid in concept generation & selection when used early in product concepting*)

3. Perfect the experimental procedure - results in a smoother Main Robustness Experiment, which is a more critical process.

4. Test the magnitude of uncontrollable noise, i.e. *measurement & experimental error* - *replicates are needed* at this point in your use of a designed experiment. (won't need to take them later)

Designing a Noise Experiment:

Select 11 factors from the final brainstorming list.

Assign 2 levels for each noise factor

- One that drives avg. performance **high**
- One that drives avg. performance **low**

Study the 11 factors in 12 experimental runs using the **L12 Orthogonal Array**:

The L-12 Orthogonal Array…

Run	1	2	3	4	5	6	7	8	9	10	11
1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	2	2	2	2	2	2
3	1	1	2	2	2	1	1	1	2	2	2
4	1	2	1	2	2	1	2	2	1	1	2
5	1	2	2	1	2	2	1	2	1	2	1
6	1	2	2	2	1	2	2	1	2	1	1
7	2	1	2	2	1	1	2	2	1	2	1
8	2	1	2	1	2	2	2	1	1	1	2
9	2	1	1	2	2	2	1	2	2	1	1
10	2	2	2	1	1	1	1	2	2	1	2
11	2	2	1	2	1	2	1	1	1	2	2
12	2	2	1	1	2	1	2	1	2	2	1

Analysis of the Noise Factor Experiment

The L12 array has a *special property*…

All interactive effects between the noise factors tested in the experiment are spread out uniformly over all the columns...

- tending to suppress *aliasing or confounding error* for any co-dependencies between noise factors as they effect the average response.

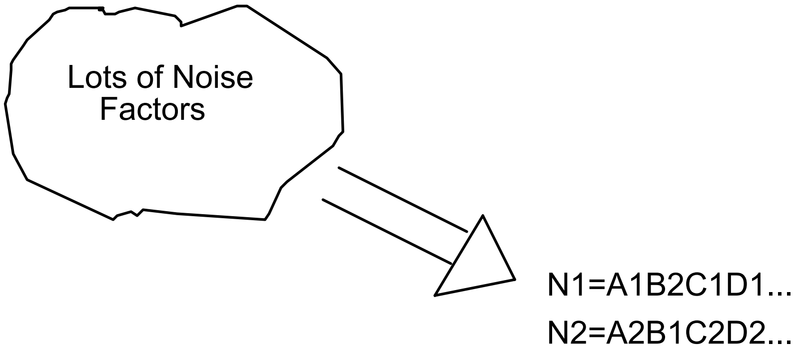
Caution! Be careful to think through the energy transformations to isolate noise factors that can mask or undo the negative effects of other noise factors.

Using the L12 means that you can analyze the experiment simply by finding the average response value corresponding to each column used in the array.

This is referred to in your book as...

Analysis of the Mean (ANOM).

Compounding of Noise Factors:



N1 → Drives Quality Characteristic High
N2 → Drives Quality Characteristic Low

This process links noises with large ***magnitudinal*** effects with noises that possess similar ***directional*** effects on the response.

We call these **Noise Vectors**.

Their use as ***compounded noise factors*** reduces the total number of experimental runs in the Main Robustness Experiment...

...thus *increasing experimental efficiency* while *adequately stressing* the design or mfg. process.

Knowing that we have identified the "*heavy hitters*", we can quantitatively prove that we are properly stressing the design to assure we are robust against the significant noise factors.