WHAT RELIABILITY MEANS TO SAC

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The reliability of strategic weapon systems, including missiles, of the Strategic Air Command is of great concern to the Commander in Chief and planners. It is not enough to just say that it is desirable to have reliable equipment. Neither is a design goal of high reliability just an objective or number; it must eventually be demonstrated and become a valid planning factor upon which we can depend. We have these planning factors available from the hundreds of thousands of aircraft sorties, but the missile systems pose an entirely different proposition. In spite of the difficulties in forecasting missile capability, the numbers, types, basing, and the targeting of the missile force is dependent upon such a forecast. Therefore, it is not only necessary to have a reliability factor, but it must be sufficiently demonstrated to establish proven confidence levels.

Confidence can be more vital than basic reliability. To oversimplify this; for targeting you would prefer a 100% confidence level in low reliability to a low confidence in 100% reliability. Whatever the reliability, you must know it, take it into consideration in your plans, and then set about bringing it to the level of effectiveness required. Improvement of reliability after a system is in the field is usually a most expensive complicated program. The ECP and mod-program costs for limited improvement to be gained have to be weighed against the effort necessary to obtain a whole new issue. It is usually more practical to initiate system development with a proper emphasis on an "Optimum allocation of funds for reliability programs of guided missiles." That last phrase, by the way, is the title of a paper by Dr. Pieruschka (with the Redstone Arsenal) back in 1955.

In large ballistic missiles you have faced problems of precise control, timing, metering, and other factors that lead to integrated system complexity. This was initially accompanied by a general lack of experience and reliability data. There have been many studies and papers on the subject of reliability programs necessary to develop the weapon systems, and there will be some fine presentations by individuals during this symposium as well. But if we are ever to know what our military capability is, we must exercise the full system in the field and eventually fire the missiles. While a launch from an operational site is desirable, as yet SAC has not had the approval to do this. At present flight demonstrations must be

conducted at Vandenberg Air Force Base into the Pacific Missile Range, or at Patrick Air Force Base on the Atlantic Missile Range. When discussing the minimum number of each type to be exercised, we must consider statistical validity, and of course, some of these must be launched each year. Spending too little for reliability demonstrations is a false economy; failure to establish precisely correct confidence levels is militarily dangerous.

Now, if we would discuss specific factors, some definitions are probably in order. Some you will recognize, but where the connotation differs, the user's ideas will be presented.

Overall Operational Reliability of a missile weapon system is the probability that once the execution order is received, and the commit sequence button pressed, the missile will be launched and its warhead will explode with design yield on the specified target, within the CEP definition. This may vary somewhat from R&D reliability, for performance within a designed reaction time is also measured, automatic sequencing replaces manual operation, and the environment is different. This probability is expressed by a decimal number between zero and one. Zero probability means, of course, no chance of the event happening; 0.5 probability means a 50% chance of the event happening; and a probability of 1.0 means the event is certain to happen.

Measured Reliability is the "success ratio" obtained in a series of tests; in other words, the number of successful tests divided by the total number of tests.

Confidence Level is the probability that the true reliability lies between two limiting values, or somewhere above a certain value. A confidence level may be thought of as a probability of a probability.

Confidence Limits are the limiting values between which the true reliability will be for a given confidence level. These limits depend on the number of measurements, or sample size.

The overall operational reliability factor used by the Strategic Air Command for a particular missile weapon system is not easily ascertained. It is recognized that flight reliability of the missile depends on reliabilities of the many individual sub-systems, such as propulsion, flight-control, guidance and re-entry sub-systems. These, in turn, are affected by the many component reliabilities. In addition, the propellant loading systems, erectors, shelter doors, operating consoles, cabling, etc., are all involved. Overall reliability then, is influenced by many individual probabilities,

including those subject to personnel factors, ground support equipment (GSE) and the missile itself.

The complexity of the problem to determine the reliability of a missile weapon system is further complicated by the difficulty of making measurements under actual operating conditions. For instance, a system developed in Florida and demonstrated in California, does not necessarily give SAC a true measure for a Wyoming based missile. In some instances, there is a tendency to make gross extrapolations from reliability factors determined under research and development conditions to use as operational planning factors. It should be realized that we must endeavor to get test results under conditions as near to actual operating conditions as possible, not only geographic, but climatic as well. By conducting some tests on a "No notice" basis the pressures on personnel and equipment that are likely to occur in time of conflict, may be duplicated in order to obtain useful and valid data.

The number used for overall operational reliability of a missile weapon system is not simply the product of all applicable measured success ratios. Nor can a theoretical extrapolation of the product of these measures values be used to obtain a realistic success ratio to be expected under anticipated operating conditions. In arriving at the value for the overall operational reliability of a weapon system, confidence limits associated with measured success ratios must be taken into consideration. These confidence limits are based on an assumed binominal distribution for test results. To illustrate confidence limits, consider the following example: Suppose a measured reliability, or success ratio, of 0.50 was obtained in testing 10 missiles fired under as realistic operating conditions as possible. The true reliability of similar missiles fired under the same conditions would be somewhere between 27% and 73%, at the 80% confidence level. The true reliability would lie between 19% and 41%, at the 95% confidence level. If the 0.50 measured success ratio had been obtained in testing 20 missiles instead of 10, the true reliability would lie between 0.34 and 0.64 at the 80% confidence level, and between 0.27 and 0.73 at the 95% confidence level. The interrelation of demonstrated reliability, confidence factors and sample size is familiar to all of you.

A realization of what effect reliability has on force size may be realized by noting that we will not receive authority to expend our missile force until after an enemy strike has been initiated. It would seem reasonable that this strike would have been planned for 90 or 95% probability of success. This leaves us in the position of attempting deterrence with those surviving, maybe 5 or 10% of the total force. This remaining force is further degraded by in-commission rate reliability.

As an example of what reliability then means in terms of surviving missiles after an enemy attack, let us assume that we require 95% probability of destruction of 200 separate enemy targets. Let us further assume for simplicity's sake, that we have missiles of a type that one delivered warhead would destroy a target. Then, 400 surviving missiles with 80% overall operational reliability would do the job. But if the reliability was only 40%, 1200 surviving missiles would be required to destroy the 200 targets. This is a difference of 800 surviving missiles, or several thousand additional missiles of the less reliable type required for original inventory that must be manned and maintained.

The importance of reliability of missile weapon systems is perhaps most striking in a situation where it is of utmost importance that particular aiming points be destroyed, and the measured reliability is based on a small number of firings. Assume our missiles to have 5-MT yield, and 1-NM CEP. (CEP is defined as the radius of a circle about the aiming point in which half of the missiles are expected to fall.) Now, consider a situation where our missiles are targeted against weapon systems so protected that 10 psi overpressure would be required to destroy them. Let us assume again that a 95% probability of destruction is desired. A delivered warhead will destroy its target in this example, but the lack of confidence in measured reliability of our missiles requires more than one missile per target. Consider two cases: the measured reliability is 0.40 in one case, and 0.80 in the other, each determination being based on 20 firings of missiles in as nearly an operational environment as possible. With 90% confidence, we know that the true reliability is equal to or greater than some value lower than the measured one. In the first case this lower limit is 0.25, and in the second case, 0.65. Using these lower limits of reliability as planning factors, 10 of the less reliable missiles per aiming point are required; while only 3 per aiming point are required of the more reliable missiles.

The effects of missile reliability and the confidence with which it is known are even more pronounced for hardened targets. In the preceding example, had the target been able to withstand overpressures up to 100 psi, one could not assume that one of the same delivered weapons would destroy that target. Now it would require 25 of the missiles of 0.40 reliability to have a 95% probability of destruction, while 9 of the missiles of 0.80 reliability would suffice for the specified 90% confidence in both cases. This is a difference of 16 missiles per aiming point scheduled in the targeting plan. Please realize that the examples I have used are not indicative of any true capability or plan; they are for illustration only.

Having posed the user's problem of determining reliability and confidence, and the importance of this determination in his planning factors, we should look at the solution to the problem. Air Force Regulation 80-14 defines three categories of weapon system testing:

Category I - Subsystem Test. This is the shake - rattle - roll, hot-blowing fungus, etc., with which the manufacturers are all familiar.

Category II - Integrated System Test. In missile weapon systems this should include the GSE and facility as well. A military capability is also implicit in this phase. This is usually met by integrating the using command unit personnel into the test program in ever increasing numbers and with increasingly greater responsibilities.

Category III - Operational System Test. This is the user's responsibility, though he will be joined by the commands responsible for the various inputs to the whole system. ARDC As the developer, AMC as logistic support manager, and ATC as the personnel pipeline manager. This may be likened to an Inspector General giving the new commander a report on the unit he has just inherited.

In addition to participation in test and evaluation of the system as it has been issued, the user has another fine source of data to help him "figure" his capability. This source is his exercise of the system during unit training (we call this integrated weapon system training, IWST), during the ORI (operational readiness inspection), normal SAC "No-notice" alerts, and the recurring combat training launches each year. You will remember that we do not now have permission to launch from all operational sites, and therefore the validity of the data must be adjusted somewhat.

Gentlemen, we have looked at the user's requirement for high confidence in a known reliability and the effect on his force size, desires for mod-programs, basing, manning and operational planning. The Air Force has a user reliability program in effect, so that he may have confidence in a demonstrated reliability. I am sure the manufacturers and developers will have some interesting things to tell us in the next two and a half days about how to meet those requirements in the most efficient way. This symposium has promise of being a very interesting experience.