# Assembly verification: the MX981 case study

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## The MX981 case study

MX981 was a testbed for the development of ejection seats for space and supersonic jets. The system tested the effect of high speed on the human body (Seedhouse, 2013). The engineer who developed the testbed was the famous Eduard Murphy (Spark, 2013). One experiment involved a set of 16 accelerometers mounted to different parts of the subject's body. During the installation, the reading was zero, which was very unlikely. It turned out that there were two ways each sensor could be glued to its mount. In the investigation it was found that all the sensors were installed the wrong way around.

## Assembly verification

SEBoK defines an assembly procedure as “a set of elementary assembly actions to build an aggregate of implemented system elements”

In engineering, assembly verification is the testing of the system operation at the system assembly, prior to launching the system. Sebok does not require special testing at the assembly or installation stage.

A simple method proposed recently for detecting unexpected risks is based on risk indicators. These are continuous system variables, accompanied by a range of values with high likelihood. These indicators are used to notify the operators when reaching a value that does not fall in this range (Harel, 2020).

Obviously, acceleration measurements are continuous system variables, and as such, they may be used for assembly verification. Apparently, in the MX981 case, the developers did not conduct any assembly testing: the assembly error was detected only later, at the launching stage.

## Failure investigation

In engineering, in case of failure we investigate and conduct Root Cause Analysis (RCA). The idea is that we need to learn from failure, to change the design so that similar failures will not repeat.

A barrier to learning from operational failure is the accountability bias, namely, attributing failure to an operator, instead to the design (Dekker, 2007). The problem with the accountability bias is in diverting the investigation focus from the design problem to blaming. In the MX981 case, Edward Murphy, the engineer in charge of the system design, could have proposed to learn from the failure, and have suggested a method for assembly verification. Instead, Murphy chose to blame his assistant for the assembly error. Consequently, he missed the opportunity to contribute to the discipline of assembly engineering.

## Controllability requirements

To enable the assembly verification, the operational requirements should specify a range of measurement values that should be acceptable, and the verification program should provide an indication when a measurement does not comply with this range.

Assembly verification relies on a tiny addon to the sensor driver. This addon may enable setting the control parameters, verify that the measurements comply with the control requirements, and activate a procedure for notifying about crossing the limits.

The control requirements are that the readings are within the range of acceptable values. The control parameters may include:

- Safety limits for the measurements
- Initial limits for notifications
- The acceptable rate of false alarms.

In the case of acceleration sensors, such as in the case study, the safety and initial notification limits should depend on the specific design of the MX981 system.

During the operation, the driver should update the statistics and verify the likelihood of the measurements, namely, that the readings are within the limits. In case of crossing the safety limits, the system should alert and disable subsequent operation. Otherwise, when crossing the notification limits, the system should just notify on the exceptional readings.

Apparently, the MX981 design did not include this simple feature.

## Conclusions

The MX981 incidence demonstrates a need for early detection of assembly errors, and a method based on capturing exceptional values of the sensor measurements. This simple method may be applied to many sensors of continuous variables and contribute to the productivity and safety of many systems, in many industries.

Moreover, this method may be applied to any system variable, such as component performance, process time, and inter-state and process transition time.

It is proposed here that system engineering standards may include a chapter on when and how to apply this method.

## References


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