Assembly verification: the Proton M case study

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Proton is an expendable launch system used for both commercial and Russian government space launches. The Proton-M is heavy-lift launch vehicle derived from the Proton. On 2 July 2013 a Proton M vehicle crashed 30 seconds after liftoff. The preliminary report of the investigation indicated that three of the first stage angular velocity sensors, responsible for yaw control, were installed in an incorrect orientation. As the error affected the redundant sensors as well as the primary ones, the rocket was left with no yaw control, which resulted in the failure. It turned out that there were two ways each sensor could be glued to its mount. In the investigation it was found that the three yaw sensors were installed the wrong way around.

Each of those sensors had an arrow that was supposed to point toward the top of the vehicle, however multiple sensors on the failed rocket were pointing downward instead. As a result, the flight control system received wrong information about the position of the rocket and tried to "correct" it, causing the vehicle to swing wildly and, ultimately, crash.

The paper trail led to a young technician responsible for the wrong assembly of the hardware, but also raised serious issues of quality control at the Proton's manufacturing plant. It appeared that no visual control of the faulty installation had been conducted, and that electrical checks could not detect the problem since all circuits had been working correctly.

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, yaw measurements are continuous system variables, and as such, they may be used for assembly verification. Apparently, in the Proton M case, the developers did not conduct any assembly testing: the assembly error was detected only later, following the liftoff.

Learning from other industries

In engineering, there are plenty of opportunities to learn from accidents in other industries. One such opportunity may be based on the MX981 accident reported elsewhere (Harel, 2024). Currently there are no standards for enforcing assembly testing.

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 angular velocity sensors, such as in the case study, the safety and initial notification limits should depend on the specific brand of missiles.

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 Proton M design did not include this feature.

Conclusions

The Proton M 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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