BLG 111E Poster Report

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Mars Climate Crasher

Mars Climate Orbiter (MCO) was launched from Cape Canaveral Air Force Station (CCAFS) Space Launch Complex 17 (SLC-17) on December 11, 1998 with Boeing Delta II 7425. Onboard scientific instruments were Mars Color Imager (MARCI) and Press Modulator Infrared Radiometer (PMIRR) for detailed atmospheric observations of Mars. MCO arrived to Mars on September 23, 1999 while 196.2 million km away (10 min 49 sec with speed of light) from Earth. The latest signal from the spacecraft was at 09:04:52 UTC on Thursday, September 23, 1999 during the Mars Orbit Insertion (MOI) maneuver, just before going behind the planet Mars.

The economic cost of the disaster to NASA was US $125 million. They formed three groups to investigate the disaster. Phase I report stated that a failure in converting English units - that are used by construction team - to metric units which are actually used by operators caused in miscalculations of SM_FORCES software that was responsible for correcting the angular momentum caused by solar radiation effect on asymmetrical solar array of MCO during nine month journey to Mars. As a result MCO was on a 170 kilometers lower trajectory than planned during the MOI maneuver which probably leads to its destruction in the atmosphere. In addition to this root failure of MCO, deeper investigations showed that whole mission was managed careless due to “Faster, Better, Cheaper” and “Prove something is wrong” philosophy of NASA. They immediately took actions and changed their future agenda to “Mission Success First” and “Prove all is right”.

The project desperately needed more professional and adequate personal with more organized team work. Staff did not have enough training in different areas such as complex navigation systems of operations or reporting of anomalies in activities. Furthermore this not enough educated personal was not in the supervision of more experienced professionals. Also there was no track of engineering status of systems -which was vital and desperately required- and double-checking process on a fixed basis.

Communication between different teams of engineers and/or other staff was a complete disaster itself. There was serious issues with the process of validating necessary technical requirements between teams of staff. Overall synchronization of the crew wan not even near to being satisfactory.

In addition, another significant problem was risk management and issue control. Risk analysis was far from being satisfactory. There have been no serious discussion on most of the important issues. NASA have just ignored them all.

Observations and recommendations:

1) Conduct software audit for specification compliance on all data
2) Transferred between JPL and Lockheed Martin Astronautics
3) Train Navigation Team in spacecraft design and operations
4) Take steps to improve communications
5) Augment Operations Team staff with experienced people to support entry, descent and landing
6) Conduct independent reviews on all mission critical events
7) Assign overall Mission Manager

Ariane Rocket Goes Boom

Ariane 5 is a rocket from Ariane family which is made up in Europe by Astrium (a European space company). It is an expandable launch system used to deliver payloads into geostationary transfer orbit (GTO) or low earth orbit (LEO). These rockets are launched from the Guiana Space Centre in French Guiana. Its development took about ten years and cost $7 Billion. The ariane 5 rocket was launched on 4 June 1996 and unexpectedly ended in a failure. The main cause of the failure was loss of the control and altitude information, 37 seconds after launching it from Kourou-French Guiana. When it reached the 40^{th} second and about 3700m, the launcher has deviated from its path, broke up and exploded. The failure was caused by the loss of guidance on the launcher, on its first voyage. The investigations on the crash showed up that the cause of failure was a software error in the inertial reference system. This loss of information was due to specification and design errors. Specifically a 64 bit floating point number relating to the horizontal velocity of the rocket with respect to the platform was converted to a 16 bit signed integer. The number was larger than 32,767, the largest integer storeable in a 16 bit signed integer, and thus the conversion failed.

The Internal Navigation System (INS) of Ariane 5 was the same system that ESA used on Ariane 4. That was the main source of the problem. INS software of Ariane 4 have been using a 64-bit floating point variable to store horizontal velocity. However, Ariane 5's horizontal velocity at it's first flight was much more higher than Ariane 4's horizontal velocity. Memmory space for a 16-bit signed integer was enough to store Ariane 4's horizontal velocity but it was not enough for Ariane 5. Thus, when INS tried to convert 64-bit floating point type velocity data of Ariane 5 to 16-bit signed integer, the memmory space was not enough and an overflow error occured which leaded to a complete shutdown of INS. A backup computer took action but it was no use since it used the exactly same software. Backup computer gave the same runtime error. Both computers sent an error report to the main computer and main computer used some wrong and absurd value to navigate the rocket. With wrong navigation, rocket could not withstand the enviromental forces affecting it and eventually, was destroyed.

On the basis of its analyzes and conclusions, the Board makes the following recommendations:

1) Switch off the alignment function of the inertial reference system immediately after lift-off. More generally, no software function should run during flight unless it is needed.

2) Prepare a test facility including as much real equipment as technically feasible, inject realistic input data, and perform complete, closed-loop, system testing. Complete simulations must take place before any mission. A high test coverage has to be obtained.

3) Do not allow any sensor, such as the inertial reference system, to stop sending best effort data.

4) Organize, for each item of equipment incorporating software, a specific software qualification review. The Industrial Architect shall take part in these reviews and report on complete system testing performed with the equipment. All restrictions on use of the equipment shall be made explicit for the Review Board. Make all critical software a Configuration Controlled Item (CCI).

5) Provide more data to the telemetry upon failure of any component, so that recovering equipment will be less essential.

6) Wherever technically feasible, consider confining exceptions to tasks and devise backup capabilities.

7) Include trajectory data in specifications and test requirements.

Comments

Process of programming is not all about coding. A professional programmer must put great effort on the testing and debugging phases. As it can be seen in the case of Ariane 5 first launch disaster, a very simple mistake programmer makes at code writing phase can have horrible consequences. Especially on a software of vital importance like in this example must be coded very carefully. However, independent from how cautious he/she is, a programmer is a human being. A programmer can make mistakes on a daily basis. This is where testing and debugging starts. A well made stage of debugging after some serious and in-depth testing can correct all mistakes that have been made in code writing. In this specific example, a realistic simulation of flight followed by a debugging process could save millions of Euros, one year of research and development, a brand new rocket and four satellites.

Communication between other programmers and other engineers/professionals is another important aspect of software engineering. In example of the Mars Climate Orbiter's crash, it can easily be seen that how terrible consequences a communication breakdown between team of engineers and other staff can have. Only a misinterpretation, usage of wrong units on a software, caused NASA to lose years of work and millions of dollars. This is a good example of why a programmer must be in a healthy communication with people whose lives, jobs, projects etc. are directly affected by the software written by that programmer.

Our modern world is depending on software written by computer engineers. A world without software would just collapse. This is why health of process of coding in every aspect is remarkably important. Not just for the engineer, but for the whole world.

Contribution of Each Group Member

Ali Osman Atik: Made research on Mars Climate Crasher. Found articles about topic that have been used in both the preparing poster and the writing report. Found images about Mars Climate Crasher that has been used in poster. Helped about drawing poster and wrote parts on the report.

Umut Yazgan: Made research about Ariane Rocket Goes Boom. Designed and drew the complete poster on Photoshop. Found articles about topic that have been used in both the poster and the report. Found images Ariane Rocket Goes Boom that has been used in poster. Wrote comments parts on both the poster and the report. Made many additions to both topics in report and then re-edited the report.

Orhan Kurto: Made research about Ariane Rocket Goes Boom. Found articles about topic that have been used in both the poster and the report. Wrote parts on the poster and the report.

Baran Kaya: Made research about Mars Climate Crasher. Found articles about topic that have been used in both the poster and the report. Wrote parts on the poster and the report.

İbrahim Türkmen: Made research about Mars Climate Crasher. Found articles about topic that have been used in both the poster and the report. Wrote parts on the poster and the report.

Emrecan Yanık: Made research about Ariane Rocket Goes Boom. Found articles about topic that have been used in both the poster and the report. Wrote parts on the poster and the report.

Aybars Yılmaz: Made research about Mars Climate Crasher. Found articles about topic that have been used in both the poster and the report. Wrote parts on the poster and the report.

Recep Can Babaoğlu: Made research about Ariane Rocket Goes Boom. Found articles about topic that have been used in both the poster and the report. Wrote parts on the poster and the report.

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