MATED (Model And Test Effectiveness Database) Improvement and Added Value on Industry

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ABSTRACT

The Model And Test Effectiveness Database (MATED) is a comprehensive European repository of AIV and Ground & Flight anomalies information with regard to concluded and on-going space projects.

MATED Objective is to improve the effectiveness of the selected model, assembly, integration test and verification (AIV&T) approaches for new projects. TASI is the main ESA contractor for MATED development & Improvement

The paper will outline the MATED data improvement done by loading new project space data (i.e. Project Data, AIV Data, NCRs Data, Flight Anomaly Data) and the use of MATED on industry as tool to be used for optimization of future IVVQ campaign

KEY WORDS: Test effectiveness, satellite, assembly, integration, verification, test, ground test failures, non-conformances, flight anomalies, data base.

1. INTRODUCTION

Space projects or satellite systems comprise a space segment, a ground segment and a launch service segment. The life cycle of space projects in ESA is organized in 7 phases, from Phase A (mission analysis and need identification) to Phase F (disposal).

Assembly, Integration and Verification is stretching over the phases C (detailed definition), D (qualification and production) and E1 (launch campaign until in orbit commissioning) and is consuming a considerable amount of the project budget (Messidoro et al. 2011).

The required effort is directly related to the selected verification approach, which defines what, how (verification methods, verification levels, model philosophy and verification tools) and when verification activities are performed (ECSS-E-HB-10-02A, 2010). Our defined verification methods are test, analysis, review of design and inspection. This list shows the order of precedence that, in general, provides more confidence in the results. The verification level identifies the product architectural level at which the relevant verification is performed (system, module, subsystem, equipment). The model philosophy defines the optimum number and the characteristics of physical models required to achieve confidence in the product verification (qualification and acceptance) with the shortest planning and a suitable weighting of costs and risks.

Ever increasing cost and schedule constraints require the optimization of the AIV process which makes use of tailoring of standards and which relies largely on the experience of the System Manager and of the AIV manager. However knowledge can get lost over the years and the necessity to systematically gather relevant data to support future choices has been identified.

The ESA Model and Test Effectiveness Database MATED exists for this purpose, collecting such data and providing analysis means, to derive feedback for the optimization of model and test philosophies of future projects and to substantiate eventually the updating of related standards.

Industry literature has identified AIV processes for space systems to comprise approximately 35% of the overall program budget. If these proportional AIV costs and the associated schedule can be reduced without significant additional technical risk, it would be possible to provide high quality space capabilities faster and more economically than current standard practices.

2. MATED STATUS

MATED is installed on a server at the European Space Agency (ESA) and is accessible by all registered MATED users via HTTPS (Hypertext Transfer Protocol Secure) using a standard web browser. This makes it very convenient to access MATED from outside ESA.

It is used by European agencies and industries who are partners of the MATED initiative and who contribute data to the data base. The mode of operation is that each partner can see the details only of his own data, but he can use all the data for statistical analysis. The extent of the analysis capabilities of each partner is related to their contribution of data (Brunner 2011).

The type of data stored in MATED is described in Figure 1. In addition, the database includes:

- Theoretical data, i.e. comparable statistical data from other publications
- Lessons learned derived from analyses of the data collected
- Files with background information providing a trace to original data that has been processed for MATED and other peculiar details.

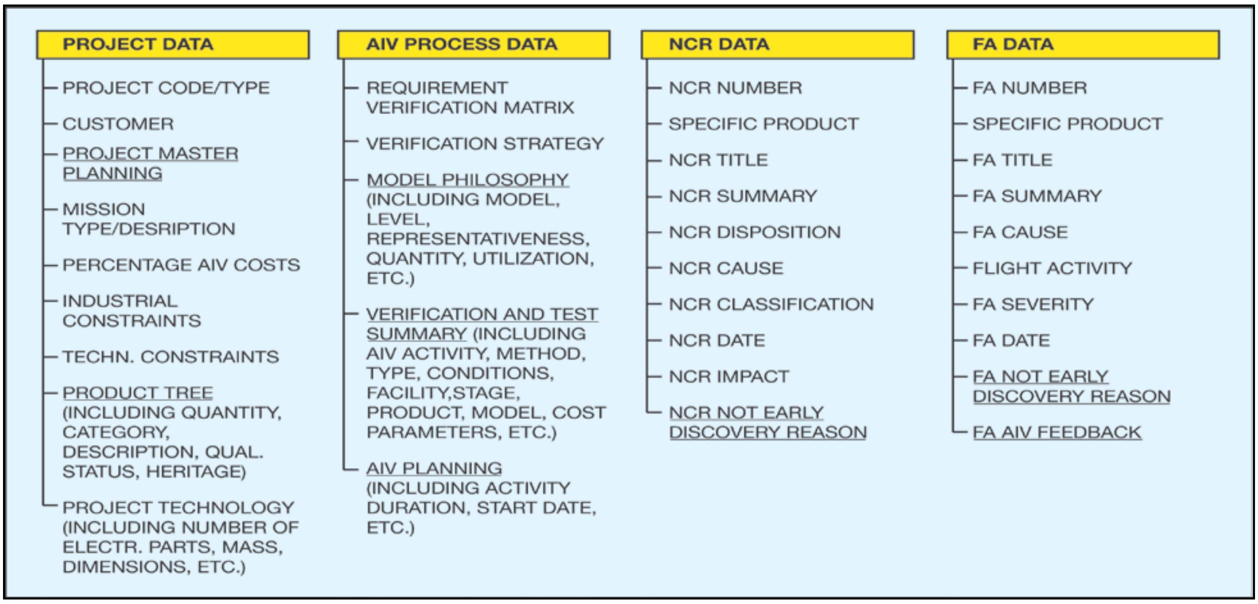

Figure 1: MATED Data

The data collection effort in ESA concentrates naturally on ESA projects and the goal is to have data of all flying ESA satellites in MATED.

The database include data of

- 30 projects (15 scientific, 4 telecommunication, 7 earth observation and 4 pressurized module projects, of which 18 projects are ESA projects)
- 130 models
- 2083 product tree records
- 7640 AIV activity planning records
- 4420 non-conformance records (NCR) i.e. ground test failures or anomalies
- 448 flight anomalies

In MATED are only non-conformances and flight anomalies related to AIV activities stored.

Four levels of analysis are defined in MATED:

- L1: on-ground, in-orbit and combined failure statistics
- L2: technical and financial test-effectiveness evaluations
- L3: model and test-effectiveness-index evaluations and time/cost parameter simulations
- L4: risk assessment, risk/cost comparison, sensitivity analysis and optimization.

As shown in the following Figure

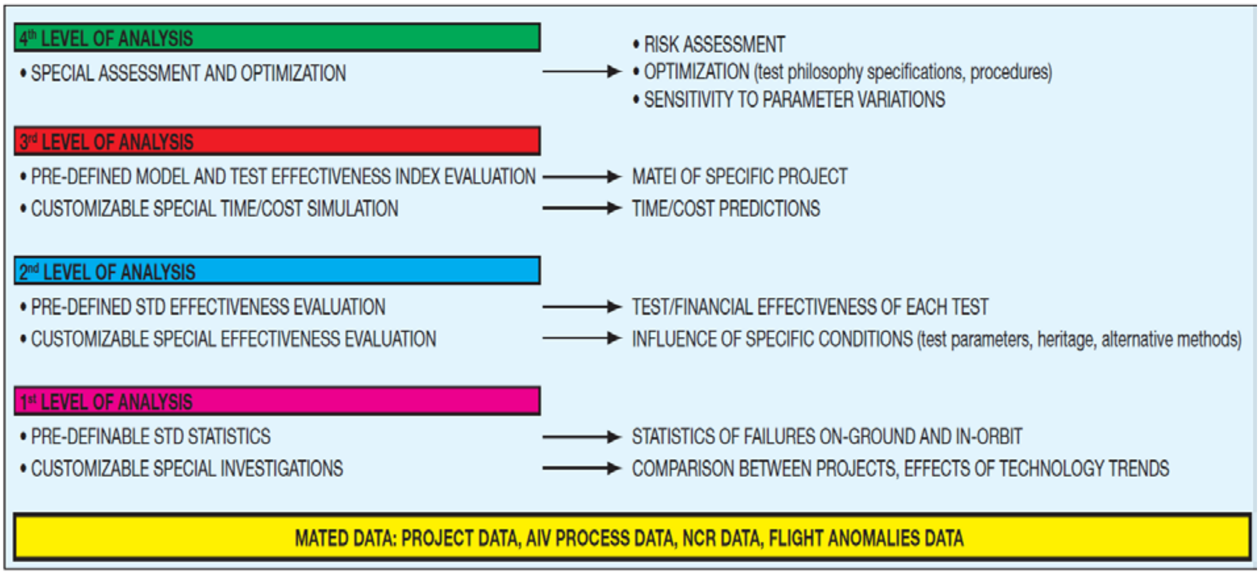

Figure 2: MATED Analyses

3. DATA IMPROVEMENT

MATED data have been improved selecting and loading the Project DATA, AIV DATA, NCR DATA and Flight Anomaly Data of an ESA MARS program: Exomars 2016 relevant the Trace Gas Orbiter (TGO) satellite and the Entry Descent Module (EDM) Schiaparelli.

ExoMars is a cooperation program between ESA and the Russian Space Agency, with some contributions from NASA, for the exploration of Mars consisting of two missions, the first launched in March 2016 and the second with launch planned in summer 2020:

- The 2016 Mission composed of a Orbiter (TGO) carrying four scientific instruments, and an Entry Descent and Landing Demonstrator Module (EDM)
- The 2020 Mission composed of a Carrier shipping the descent module that contain the EXM Rover and a set of scientific experiments

EDM and TGO Proto-Flight Models (PFMs) were integrated and underwent mechanical, functional, thermal and EMC tests in the course of year 2015. During the test campaign some unexpected events and delay in the science instrument and units deliveries led to changes in the nominal Assembly, Integration and Test (AIT) flow, adopting some work arounds, but always maintaining the completeness of the verification approach.

Despite the above problems, the environmental test campaign was successfully closed in early December 2015. After that the two modules were separated once again and shipped to the Baikonur Cosmodrome for the 12 week launch campaign which concluded with a successful launch on the first day of the planned launch window, on March 14th, 2016.

The TGO data loaded on MATED were a lot, namely

- PRJ_DATA_TGO
    - Record filled # 152
- AIV_DATA_TGO
    - Record filled # 914
- NCR_DATA_TGO
    - NCR analysed # 223
    - Record filled # 447
- FA_DATA_TGO
    - FA analysed # 32
    - Record filled # 65

The EDM data loaded on MATED hereafter:

- PRJ_DATA_EDM
    - Record filled # 358
- AIV_DATA_EDM
    - Record filled # 475
- NCR_DATA_TGO
    - NCR analysed # 125
    - Record filled # 255
- FA_DATA_TGO
    - FA analysed # 10
    - Record filled # 21

The IXV project Data will be loaded on MATED as well in order to improve the data base with data relevant re-entry mission

4. ANALYSIS

Hereafter some of the analysis at Level 1 done using the MATED data after the improvement of Exomars 2016 program, TGO and EDM.

In particular hereafter are shown the following analysis: NCRs vs Type of test, NCRs vs Detailed Cause, NCRs vs Type Of Subsystems, On Orbit Failure vs Cause Category, On Orbit Failure vs Cause Category, Orbit Failure vs Time into Operations.

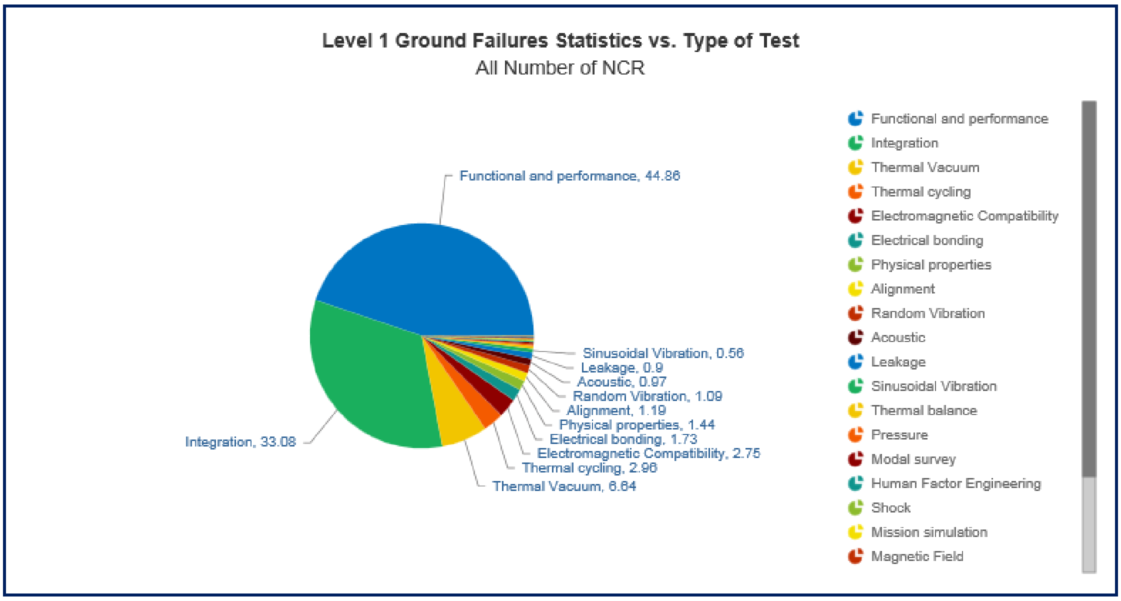

Figure 3: NCRs vs Type of test

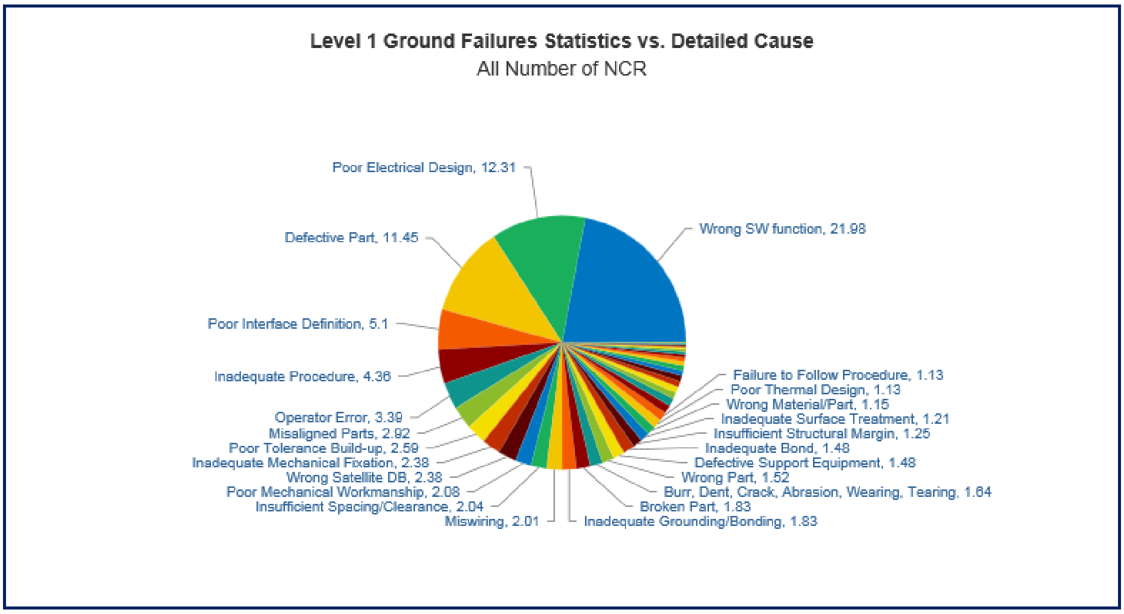

Figure 4: NCRs vs Detailed Cause

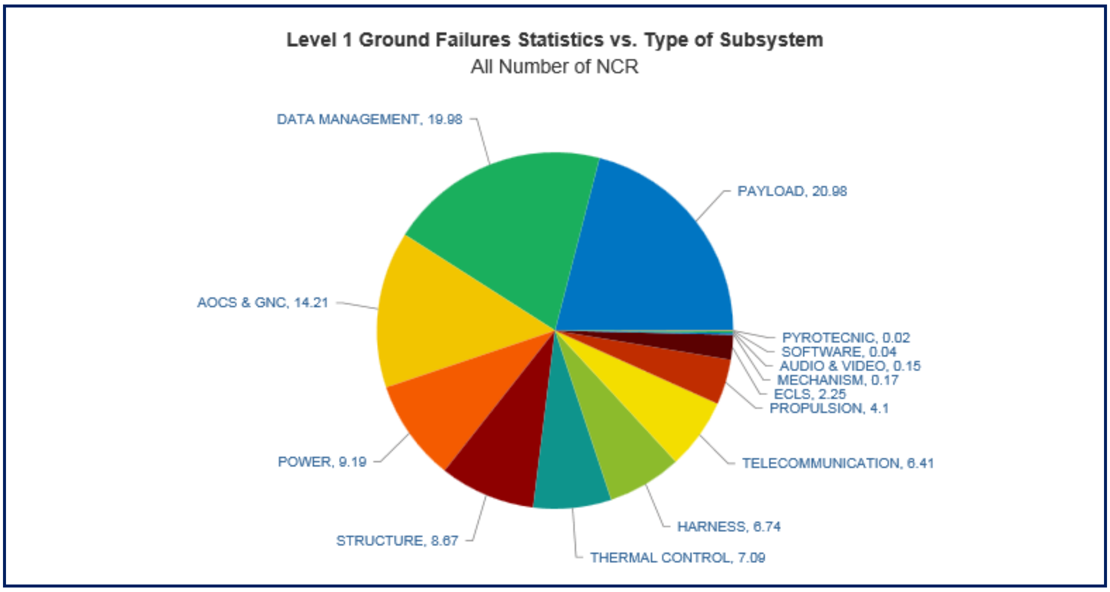

Figure 5: NCRs vs Type Of Subsystem

The above figures shown as the main anomalies on Space Project coming from MATED data base are due to Software problem (see figure 4 - NCRs vs Detailed Cause) which is correlate to the analysis (Figure 5: NCRS vs Type Of Subsystem) which shown that the Subsystems with major anomalies during ground tests are the one which includes the mission software like Data Management and AOCS & GNC, and furthermore the type of test where are encountered the major numbers of anomalies are the Functional and Performance tests

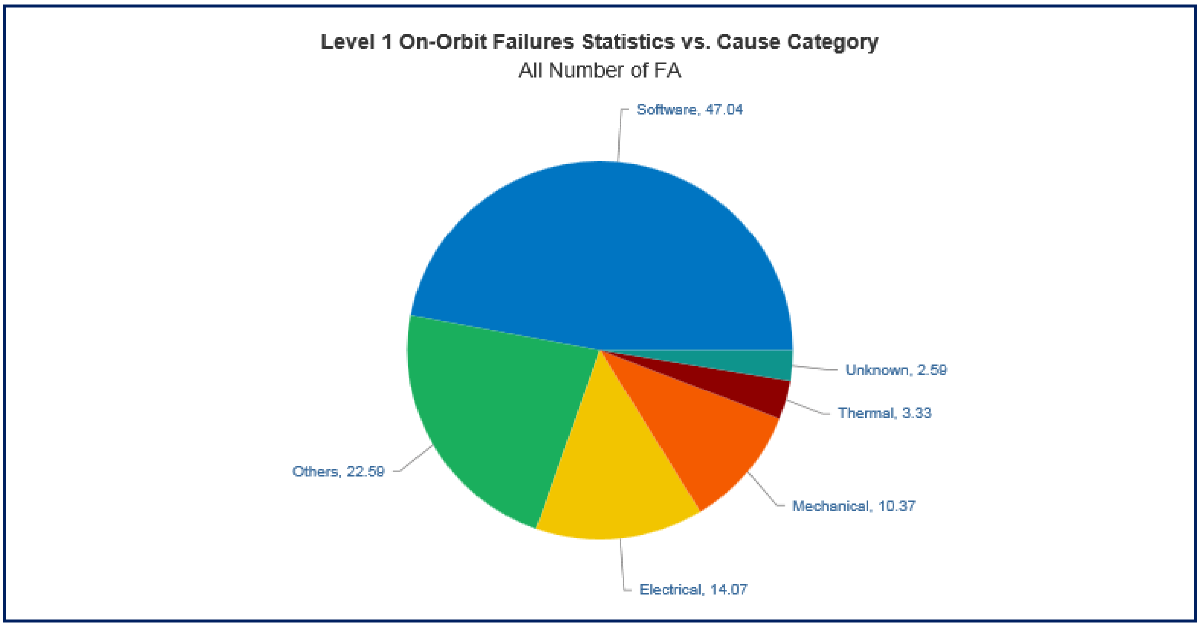

Figure 6: On Orbit Failure vs Cause Category

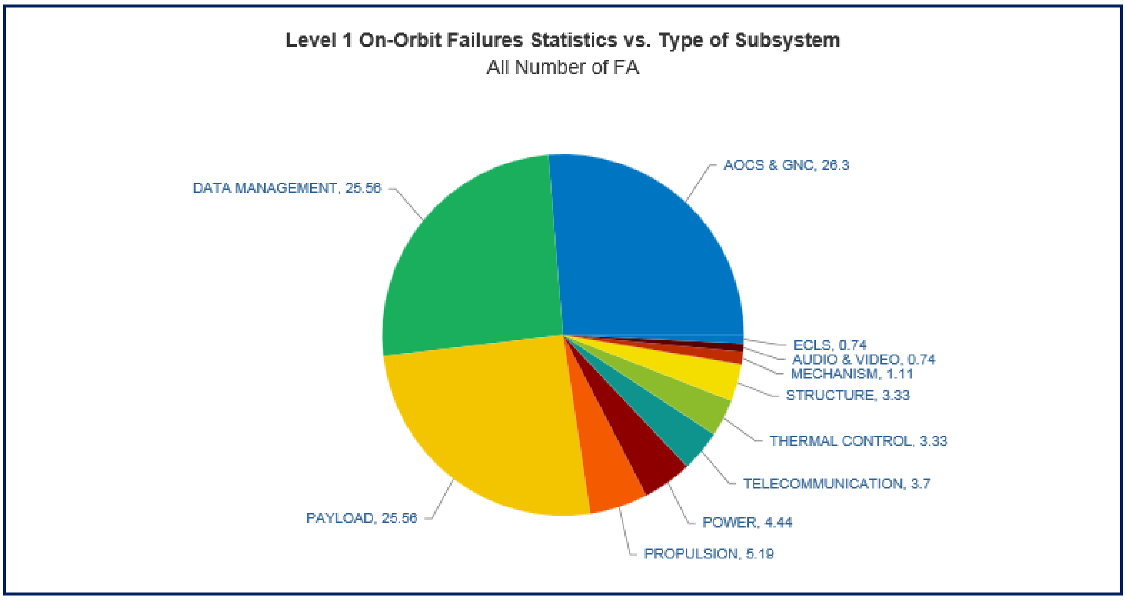

Figure 7: On Orbit Failure vs Type Of Subsystem

Also on the Flight anomalies the major one are due to Software and to the related Subsystems, Data Management and AOCS & GNC.

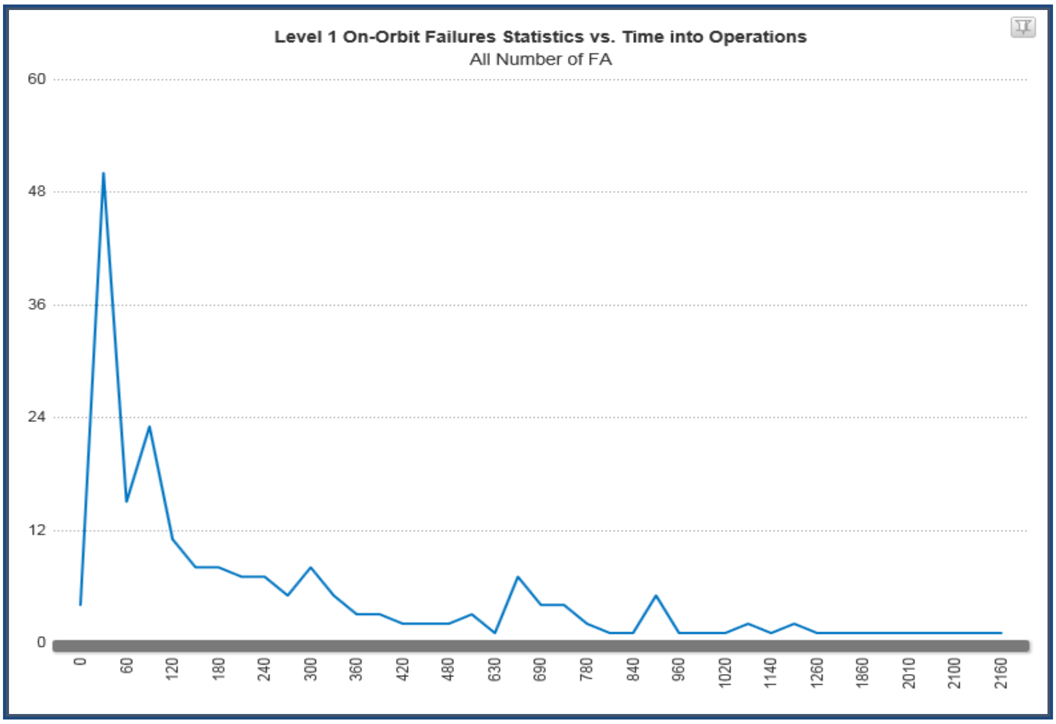

Figure 8: On Orbit Failure vs Time into Operations

5. MATED UTILIZATION ON INDUSTRY: GOCE SATELLITE

The MATED analysis capabilities are being utilized for risk/cost/schedule/test effectiveness evaluations of past programs for the prediction of new space projects.

The possibility to perform a preliminary prediction of possible early flight anomalies of GOCE on the basis of the completeness of the project Model and Test Philosophy (i.e. project's MATEI) is here exploited.

To reach this objective the following methodological approach has been applied:

- Performing of L3 MATEI analysis on the GOCE project
- Introduction of the project's MATEI into the "Early Flight Anomalies vs MATEI diagram" in comparison with ECSS
- Automatic estimation of the corresponding Early Flight Failures (normalized in 105 number of Electronic Parts)
- Evaluation of the actual number of probable early flight failures (in the first 120 days of mission) multiplying the above value for the number of electronic parts in 105

The MATEI analysis result w.rt the ECSS for the GOCE project is shown in the print-screen of next Figure 3. It consists of a .MATEI of 81.68 which takes into account GOCE Test Philosophy deviation wrt the ECSS test standard mainly in the following areas:

- mechanical dynamic and thermal tests protoflight approach
- reduced alignments on SM and PFM campaign
- deletion of Sine Vibration test on PFM
- reduced modal survey and static load test
- reduced number of cycle in Thermal Vacuum on PFM

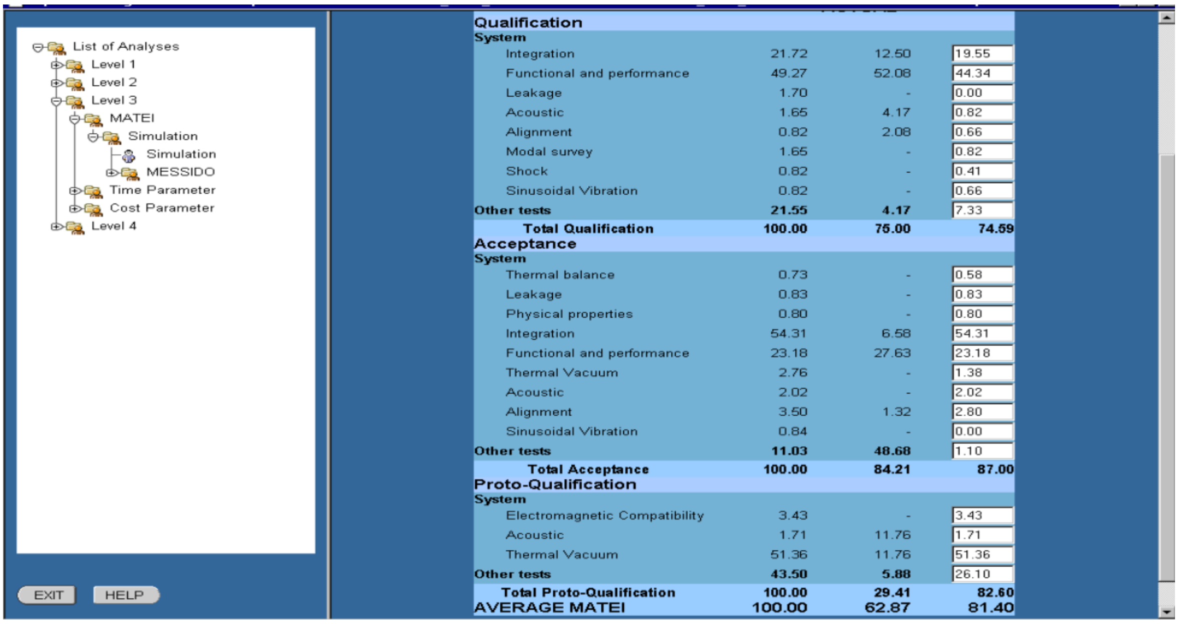

Figure 9. MATEI Analysis Result

The "Early Flight Failures" Vs MATEI Diagram (ECSS) is shown in Figure 4 - Early Flight Failures vs MATEI Diagram (ECSS), the GOCE project's MATEI of 81.40 , as shown in Figure 13, has been introduced deriving a value of 0,79 early flight failures per 105 electronic parts

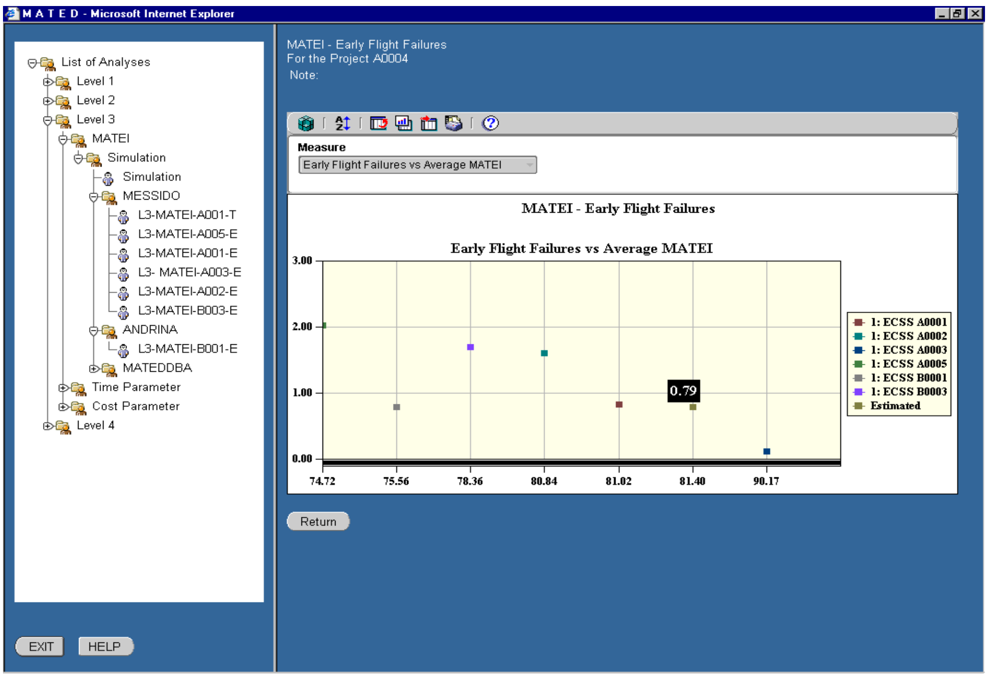

Figure 10. Early Flight Failures vs MAT€I Diagram (ECSS)

In the GOCE Project a preliminary number of 7.3 105 of electronic parts has been estimated. This means that "probably" the GOCE satellite will be subjected to a number of Flight Anomalies

(classified as MJ or CR per the MAT€D definition = MJ4: Delay to operations; MJ3: switch to redundancy; CR2: Loss of partial functionality; CR1: Mission Interruption) equals to 6 (5.77) in the first 120 days on orbit (early flight) which is comparable with other similar projects
The actual GOCE Flight Anomalies encountered during the first 120 days of mission, classified as Major, were 7 (MJ4) on the first 120 days (from 17 March to 30 June 09) in line with the MATED Analysis

6. MATED UTILIZATION ON INDUSTRY: IVV EFFICIENCY

The Integration , Validation and Verification approach for the Space project can be improved by using the Model And Test Effectiveness Database (MATED) .

MATED provides functionalities in order to generate statistical evaluations, to optimize AIV&T planning and to improve cost estimations based on real program data.
MATED analysis capabilities are used to improve IVV efficiency vs IVV models, IVV campaign, schedule and cost reduction , and to optimize the test effectiveness for programs.

MATED is used in TAS on the frame of the IVV efficiency , with the main objective to improve the IVV approach in order to prepare a competitiveness B2/C/D phase proposals (i.e. IVV , models and tests best approach, cost reduction, technical risk , schedule optimization), and to evaluate for the program in phase B2/C/D benefit and risk of a different IVV approach/scenario vs the baseline one .
Furthermore is used on program in phase B2/C/D to evaluate the completeness of project verification program w.r.t. ECSS standard and to evaluate benefit and risk of a different IVV scenario vs the baseline one .

We established formats to manage the Integration, Validation, Verification & Qualification plan in order to optimise (based on heritage and MATED) vs. ECSS baseline. This has been applied to Exomars 2016 and IXV programmes.

CONCLUSION

Streamlining of the model and test philosophies for Europe’s future spacecraft and space systems is crucial to reducing the time, and hence the investment, needed for their development whilst still keeping the degree of risk under control. The proposed sharing through the MATED database initiative of the European space sector’s AIV knowledge and experience accumulated over many years would represent a major step forward in this respect. For MATED to be a success, therefore, as many participants and inputs as possible are needed, in order for the results to be statistically significant. It is therefore hoped that the many companies, agencies and organizations both in Europe and around the World working in the space domain will be motivated to join in this initiative, which holds the promise of substantial mutual financial benefits for the participants.

MATED constitutes a tool and a data repository with a large amount of data about space projects, their AIV process and related on-ground and flight anomalies. It is used by European agencies and industries, via secure internet interface, to support effective verification and test planning, realistic schedules and to improve cost estimations for the AIT process at the initial phase of a new project.

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BIOGRAPHIES

Vittorio Ancona graduated in Electronic Engineering at University of Palermo. He has been working for Alenia Spazio (the former name of Thales Alenia Space) since 1989 in the System Engineering, Verification and Testing area. He has had verification, requirements management and interfaces responsibilities for manned and unmanned spacecraft including scientific satellites and International Space Station modules as head of the relevant Unit. Presently Member of Engineering Executive Board as Engineering Performance responsible, Domain Exploration & Science . He is TAS MATED responsible. Since 2017 Mr. Ancona has served as an external Professor at the Politecnico di Torino giving lectures in Systems Engineering and Verification in the International Master course SEEDS (SpacE Exploration and Development Systems).. He is also International coordinator of the Aerospace Testing Seminar and Chairman of the 6th International Workshop on Verification and Testing of Space Systems

Dirk Hagelschuer. AIV engineer at senior level in the Test Support Section at the European Space Research and Technology Centre (ESTEC), of the European Space Agency (ESA), in Noordwijk, the Netherlands. He has been working in the area of AIV and test facilities since 1985. He was involved in many space projects from the German Aerospace Centre (DLR) and ESA, the latest as Sentinel-1A AIV lead engineer. Furthermore Mr. Hagelschuer was responsible for the Collimation Mirror project of the ESA Large Space Simulator. He has given AIV support to many CDF (Concurrent Design Facility) studies using MATED data. He graduated from the Humboldt University of Berlin, Germany, Electrotechnical Faculty.

Piero Messidoro graduated in Nuclear Engineering at the Politecnico di Torino, retired since 2017. He has been working for AleniaSpazio (the former name of Thales Alenia Space) since 1975 in the System Engineering, Verification and Testing area. He has had direct verification and test responsibilities in manned and unmanned spacecraft including scientific satellites and International Space Station modules. Presently, he is Chief Technical Officer of Thales Alenia

Space Italy. Based on his experience in the optimization of verification and test processes, he was active in the European Cooperation for Space Standardization initiative, in particular as Convenor of the ECSS-E-10-02 “Verification” Working Group and member of the ECSS-E- 10-03 WG. He is also member of the Organizing Committee of the ESA Environmental Testing Symposium and International coordinator of the Aerospace Testing Seminar. Since 2001 Mr. Messidoro has served as an external Professor at the Politecnico di Torino giving lectures in Systems Engineering and Program Management in the International Master course SEEDS (SpacE Exploration and Development Systems).