

Aspects of maintenance on test facilities for rocket engines

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Abstract

The department “Test facilities” in the DLR Institute Space propulsion is responsible for the overall management of different test and supply facilities for rocket engines, especially for the European launcher program. The main department’s missions are: operating and maintaining all respective test benches and supply facilities for cryogenic and storable propellants. The maintenance includes all technical, management and administrative actions, which are realised in order to guarantee a complete nominal status of the rocket engine test benches and the entire technical infrastructure installations. Different kinds of maintenance activities (like preventive, continuous and corrective maintenance) are performed as well as the so called upgrade and renewal of assets. With respect to this context, the paper presents an overview of the test facilities and the different maintenance activities, followed by a detailed description of the systematic and organisation of 1) upgrading a system to comply with new or modified laws and regulations and of 2) renewing an asset due to obsolescence or non-availability of spare parts in the future. Some examples of realised upgrades (i.e. wrt explosion protection rules) and renewals (i.e. refurbishment of GN2 supply station) are presented and finally organisational aspects are described.

1. Introduction

For 50 years now, the test facilities in Lampoldshausen have been playing an important role in Europe’s independent access to space, testing rocket propulsion systems or components at sea level or high altitude conditions and using either cryogenic or storable propellants. Beneath some DLR owned test installations, the department Test facilities of the Institute of Space propulsion is exploring and interfacing in the context of ESA Launcher program the following ESA test benches and entire technical infrastructure installations as:

- Test benches P3.2, P4.1, P4.2 and P5
- MCC centres M7 and M8
- Gas supply facilities D22 and D57
- Cooling water towers
- Cryogenic storage areas
- Storable propellant areas

- Security centre
- Transformer stations and supply-centre
- Accessible underground duct
- Technical ducts and
- Roads.



Figure 1: Test centre Lampoldshausen

All test benches and supply facilities in the European test centre Lampoldshausen are essential in order

- To develop space propulsion systems up to their first flight operations,
- To test flight engines,
- To guarantee their quality during operational life and
- To participate in Europe's independent access to space.

In this context, DLR Test site in Lampoldshausen is playing and will play a major role together with its partners in the actual and future programs under the responsibility of ESA.

2. Testing and maintenance

The technical installations of the different test- and supply-facilities basically comprise

- the facility with all its necessary equipment and supply systems,
- the security system,
- the data acquisition and control systems

and with respect to the test and maintenance activities in the European test centre Lampoldshausen, the benches and supply facilities can have different statuses, which are defined as:

- a. Operational: the facility is currently performing (a) test campaign(s), maintenance is nominal;
- b. Active waking: after an operational period the facility runs down to active waking status and needs a run-up phase in order to acquire again its operational configuration, maintenance is reduced;
- c. Cocooning: the maintenance is reduced to a minimum, operational status only after partly reconfiguration;
- d. Stopped: Non availability of the facility, a complete reconfiguration phase is necessary for a return to an operational status, no maintenance is performed.

All activities which are realised in order to maintain the facilities in an operational status during a (the) test campaign(s) are defined as nominal maintenance.

A test campaign can be interrupted by a yearly maintenance phase for a delay not longer than 6 weeks in case main systems have to be maintained or maintenance is mandatory. During the period of yearly maintenance the facility becomes non-operational, and no activities for engine tests are possible then.



Figure 2: Operations on P5

In case of no use of a facility between two test campaigns, the reduced maintenance, also called “Basic Maintenance”, covers all activities maintaining the facility in a pre-defined status (active waking or cocooning).

Another aspect to keep a facility in operational conditions is the **upgrade** of systems to comply with new or modified laws and regulations as well as the **renewal** of equipments because their obsolescence has to be taken into account, see [Ref 1]. More information and details are given in chapter 3.

In contrary, a modification of a system or subsystem is defined as a non-direct maintenance action, because it changes the required function of an asset.

Regarding the priority question between operational testing and maintenance, the coherence in the overall planning of on one side the testing plans of production acceptance, development and ARTA tests

operations and on the other side the maintenance needs has to be established. Maintenance activities are assigned the highest priority in case that safety aspects or operation permit by the German authorities are concerned.

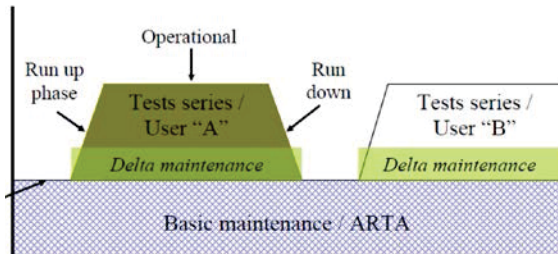


Figure 3: Repartition Operation/Maintenance

Taken into account, that the performance of the yearly maintenance is mandatory after the maximum yearly operation period for a test facility, in case of no agreement between a client USER and DLR, a common ESA/DLR decision will be agreed on the basis, that in general the fulfilment of needs for an operational rocket engine has a higher priority.

In this context, another aspect has to be considered: two integrated teams of mechanics, technicians and engineers are each operating and maintaining two test benches. This organisational structure was decided in order to keep the team as small as possible; as a consequence it is not possible to keep the two greatest test benches in an operational status at the same time.

3. Upgrades & Renewals

The test benches and associated supply facilities have been designed to be operated for a long period of time. During this operational phase not only the technical know-how and the state of the art are changing but also legal requirements and official orders may change, so in order to guarantee an operational status the so called renewals and upgrades program for the test- and supply-facilities is in place.

An upgrade of a system, subsystem or piece of equipment becomes necessary when statutory or legal regulations change.

A renewal of a system, subsystem or piece of equipment becomes necessary when:

- The item cannot be maintained any more due to its obsolescence or the obsolescence of its main component parts (i.e. no longer procurable),
- The item cannot be maintained any longer due to the fact that the sole supplier ceases operations or
- The operating and maintenance costs become so high (e.g. due to necessary repairs) that its use is no longer cost-effective.

In order to identify possible and necessary Upgrades and Renewals the following data sources are available:

- Database of laws and regulations applicable for DLR Lampoldshausen,
- Information from authorities about changes in laws and regulations,
- Risk analysis or technical studies including evaluation of MTBF (mean time between failure) and determination of the criticality of the equipment,
- Information from suppliers and manufacturers,
- Results of internal and external audits,
- Results from NCR treatment and performance of maintenance activities,
- Information about the life time and use of the equipment, life cycle of the equipment,
- Evaluation of maintenance costs and cost factors.

A detailed technical interpretation as well as a business assessment of these data sources results in a listing of a great number of possible items and so a final choice has to be made.

WP	Anlage	Gerät/Subsystem
21100	Area	Fire protection measurements (part 1)
21200	Area	Lightning protection P3, P4, T23, T58 (part 1)
21300	Area	Security LH2 discharge
21400	M8	Adaptation to hygienic demands
23100	P3	Exproof adaptation
24100	P4.2	Cooling machines
31100	T58	Study Replacement of LH2 pilot tank
31200	Area	Intercom P3, P5, M7, M8, G56, D22, D57
31300	M8	Refurbishment gas analyse system P3.2, P4.1 & P5
31400	N25	Pre-softening in purification plant
31500	Area	Refurbishment air supply M7-E24
31600	M8	Additional frequency transformers
31700	G56	Additional cooling system for heat exchangers
31800	M8	Refurbishment of draining water line
31950	T16	Refurbishment of storable propellant area T16
31960	Area	Replacement of T21 with T18B
31970	Area	Cooling Water P4/P5
31980	Area	Study Refurbishment airline D59 - P5
33100	P3	Regulation valve control units
33200	P3	Removal MCC (I2=>M7/M8)
33300	P3	Exchange of pressure sensors (britteling)
33400	P3	Refurbishment of building P3
33500	P3	Refurbishment of ESS (S5=>S7)
33600	P3	Renewal of P3 Fire detection system
33700	P3	Regulation valve control units (part 2)
34100	P4.2	Water sluice valve 402
34200	P4.1	Study Exchange of core diffuser
34300	P4	Crane
34400	P4.1	Improvement of cooling water supply
34500	P4	Upgrade Dynawork licences
35100	P5	Bench LOx-lines TXP6 & TXP13
35200	P5	Study refurbishment of civil works
35300	P5	Roof refurbishment
35400	P5	Refurbishment of guide tube & deflector
35600	P5	Renewal of progr. Logic Contr. for ASM & ASS
35700	P5	GN2 pressurisation line Lox runtank
35800	P5	Reverse engineering PTM
35850	P5	Refurbishment of civil works (part 2)
35860	P5	Refurbishment of guide tube & deflector (part 2)
35900	P5	Renewal of propane burner command ignition system

Table 1: Listing of Upgrades and Renewals

The department Test Facilities has established a selection method (see [Ref 6]) for defining and prioritizing the upgrades and renewals, which takes into account the following common criteria:

- The time needed to design, manufacture, install and accept a new equipment and
- The total costs for the new equipment.

These two common criteria are completed individually for Upgrades by:

- The due date (the urgency) of the realization with respect to legal regulations,

and individually for Renewals by:

- The probability of failure of the equipment in the near future,

- The age of the equipment,
- The possible influence on testing activities and
- The non-availability of the equipment in the last year.

After analysing each of the identified possible and necessary Upgrades and Renewals by application of these criteria, a proposal of items to be realised during a certain period is established, negotiated with the client and finally contracted in a work order to the main contract.

For the period 2011-2013 the above mentioned items (see Table 1) have been agreed between ESA and DLR.

Hereunder some examples are detailed. They have been realised since the relevant Upgrades and Renewals program is in place.

Example N°1, figure 4: Replacement of obsolete MCC parts of computer system for P4 test bench and steam generator.



Figure 4: Replacement of obsolete MCC parts

Example N°2, figure 5: Due to new rules for electrical explosion prevention, the exchange of electrical motors of GHe- and GH2- compressors was necessary.



Figure 5: Upgrade of compressor motors

Example N°3, figure 6: Substitution of refrigerant R22 in chillers of P5 test bench's air conditioning system based on legal requirements.



Figure 6: Upgrade of A/C system P5

Example N°4, figure 7: Renewal of the GN2 production facility by replacing 32MPa and 80MPa pumps as well as two evaporators.



Figure 7: Refurbishment of GN2 station

4. Management

Maintenance is a continuous activity, which objective is to ensure the availability of the facilities as specified. The maintenance workload and the relating costs are depending on the status of each facility and are related to:

- The maintenance team and manpower
- Spare parts and consumables
- Maintenance/outsourcing contracts
- upgrade and renewal of systems or equipments
- Miscellaneous (amortisation, insurances, etc.)

For five years, the maintaining in operational conditions, called MCO, has been directly contracted from ESA to DLR. The overall maintenance budget is financed by the client ESA as economic owner of the test benches and supply facilities and the users Snecma and Astrium. This budget is divided (see [Ref 4]) into the following two parts

- Basic maintenance as defined in chapter 2, covered by ESA and
- Delta maintenance fee, applicable during transient periods as run-up and run-down from/to active status and during the operational status (nominal maintenance) of a facility, covered by users.

This repartition is contractually fixed by all concerned parties and documented by

- the so called ESA Asset Agreement, which is the "Agreement between ESA and the Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR) concerning the installation and utilization of certain assets located at Lampoldshausen" in place since 1975,
- The ESA/DLR frame contract,
- The general rule: „Cost Sharing and Utilisation Conditions of ESA Launchers Engines Tests Facilities" and
- The user contracts between Snecma / DLR and Astrium / DLR.

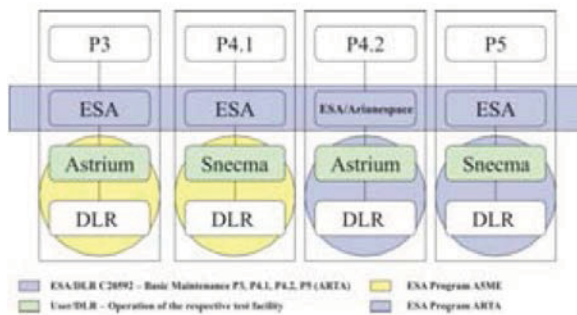


Figure 8: Contract schematic

The above shown graphic clarifies this repartition between client, customers and contractor.

5. Summary

The department “Test Facilities” is exploring different test benches and supply facilities with their infrastructures and has the challenge to coordinate operational and maintenance activities. In this paper a special aspect of maintaining the assets in operational conditions is detailed, the so called upgrades and renewals of technical systems. This aspect underlines that maintenance of all test benches and supply facilities in the European test centre Lampoldshausen is essential in order to continue

- The development of space propulsion systems up to their operations,
- To test flight engines,
- To guarantee their quality during operational life and
- To participate in Europe’s independent access to space.

6. Acronyms, References and credits

Acronyms:

A/C Air conditioning

ARTA Ariane Research and Technology Accompaniment
 DLR German Aerospace Centre
 ESA European Space Agency
 MCC Measurement, Control, Command
 MCO Maintaining in Operational Conditions
 MTBF Meantime between failures
 NCR Non Conformance Report
 RA Institute Space Propulsion
 VEA Department Test Facilities

References:

- 1) DLR e.V.: Institute of Space Propulsion, Status Report 2011
- 2) ESA: ESA/DLR Asset Agreement
- 3) ESA: ESA/DLR frame contract
- 4) ESA: General rules for the cost sharing and utilisation conditions of ESA Launchers engines test facilities, 2008
- 5) Internal report: Maintenance Organization ESA Test benches and Supply facilities in Lampoldshausen
- 6) Internal report: Systematic and organization of Upgrades and Renewals of ESA assets in Lampoldshausen
- 7) Schürmanns, R.: Aspekte der Instandhaltung von Raketenprüfständen, 1. Mosbacher IndustrieForum, 2011
- 8) www.dlr.de/ra

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- Figure 1: DLR/RA
 Figure 2: RA/VEA
 Figure 3: ESA/APT
 Figure 4: RA/VEA
 Figure 5: RA/VEA
 Figure 6: RA/VEA
 Figure 7: RA/VEA
 Figure 8: DLR/AD