Chapter 2
Operational Aspects of the Rocket Engine and the Test Facility

Design, construction and production are essential phases in the development of a rocket engine. As soon as the engine subcomponents are at a satisfactory development status, a complete engine, ready for operation, is examined on a test facility which is specially designed for this very engine. The aim of an engine test is to check and optimize the operational cycle of the engine and finally to confirm the readiness of the rocket engine for use on the launcher. When the rocket engine is used during flight, or when it is tested on the ground facility, the operational aspects of the rocket engine have to be considered. This means the engine dynamic behaviour during start up, during transit from one to another operational point, the characteristics at extreme operational points and during shut down of the engine.

The bench systems are adjusted to this operational cycle. The bench supplies the engine with propellant, secondary fluids (see Appendix J), electrical power and control signals. The operation on the facility also requires simulation of the conditions which will be met later on during actual flight. Furthermore, conditions have to be handled which have their origin in the engine operation itself (e.g. noise, exhaust jet, risks). In a wider sense, the safety of the engine environment is also part of the operational aspects as well as the measurement of the physical parameters. These measurements are necessary for the regulation, for monitoring of important engine parameters, for evaluation of the engine test and for evaluation of the engine behaviour during flight. Running the required bench systems and procedures to resolve these tasks is the subject of the operational aspects of the test facility.

An engine test can also be executed on the launch pad of the rocket (Fig. 2.1). In this case the test objective is the validation of the launch preparation related to the engine and its interaction with the stage (see Appendix E, Fig. E.1), including an ignition and a regular shut-down.

2.1 Propulsion Systems

The main components of a propulsion system of a rocket are the rocket engine, the fuel tank, the oxidiser tank and a pressurisation system. The first and second stages of a launcher basically consist of almost only the propulsion system. Even on satellites the propulsion system forms the major part of the weight and structure.
Fluids which are gaseous at ambient temperature but stored at low temperatures, below their boiling point, are called **cryogenic fluids** and rocket engines running on at least one cryogenic fluid (as fuel or oxidiser) are called **cryogenic engines** (Figs. 2.2 and 2.3). One of the first cryogenic rocket engines was used on the V2 rocket during World War II. The oxidiser of this engine was liquid oxygen (LOX).

LOX forms, together with liquid hydrogen (LH₂), a **high-level energy combination**. A typical specific impulse of such an engine is between 4,000 and 4,500 m/s. The **Pratt & Whitney RL-10**, developed in the 1950s was the first LOX/LH₂ engine used for spaceflight (Table 2.1).

**Remark 2.1** An aerospace scientist or engineer talking about the **engine cycle normally means the cycle in which the engine produces its propellant** (gas generator cycle, expander cycle, etc.), the **propulsion cycle**. In thermodynamics, the engine cycle is very close to the **Joule cycle**, and we could also talk about the life cycle of an engine type (design, production, test, flight service). The focus in this book is the **test cycle** or **operational cycle**. On the facility the engine goes several times through the cycle of pre-tests, final preparation, hot run and post-tests. On the launcher this cycle only happens once for an expendable engine.

The special properties of a cryogenic fluid (see **Appendix J**) have to be considered within the operational aspects, particularly when it comes to preparation of a hot run. Vessels and lines need sufficient insulation, the feed system has to be free of pollution and a chill down phase is required before the hot run. The purging and venting of the rocket engine and the feed system starts immediately after shut-down and a cryogenic fluid must not be trapped in any of the line segments or engine components.

### 2.2 Test Facilities

To launch rockets just for test purposes or even in the development phase is history, at least for large launchers. A rocket engine dedicated for use on a launcher definitely needs its maturity for flight. The investment to lift a payload into orbit is in the region of some hundred million Euros and therefore, from first use on,