

→ 6 SOUNDING ROCKETS

This chapter is aimed at providing new and experienced users with basic information regarding the utilisation of sounding rockets for microgravity experiments.

6.1 Introduction to sounding rockets

6.1.1 What are sounding rockets?

Sounding rockets have been used for scientific research since the late 1950s and were originally implemented in meteorological and upper atmosphere studies. ESA has been using this type of platform to carry out low gravity experimentation since 1982. They are constructed from three major parts, i.e. a single or two-stage solid-fuel propulsion system, the service systems (rate control, telemetry module, recovery system) and the scientific payload (the section that carries the instruments to conduct experiments). Sounding rockets are sub-orbital carriers, which means that they do not go into orbit around Earth. The rockets follow a parabolic trajectory from launch to landing, which, for the case of the rockets used by ESA, provide a low gravity environment of between six and 13 minutes.

The rockets originally take their name from the nautical term 'to sound,' which means "to take measurements".

6.1.2 What do sounding rockets offer?

Sounding rockets offer users the following:

- six to 13 minutes of low gravity;
- a weightless environment with levels $\leq 10^{-4}$ g;
- 260-480 kg payload mass;
- quick access (a payload usually flies between two and three years after experiment approval);

Sounding Rockets

6-13 min microgravity time
 10^{-4} g low gravity environment
1 campaign/2 years
4-5 experiments/campaign
260 - 480 kg payload mass



Image 6-1: Launch of MASER 11

Table 6-1: Main characteristics of sounding rockets used by ESA

PROJECT	MANAGED BY	MICRO-G TIME (min) EXPERIMENT	TYPICAL NUMBER OF MODULES	PAYLOAD DIAMETER (cm)	SCIENTIFIC PAYLOAD LENGTH (m)	SCIENTIFIC PAYLOAD MASS (kg)	SPIN RATE (during launch) (Hz)
TEXUS	Airbus Defence and Space, Bremen (D)	6	4	43.8	3.4	260	3-4
MASER	SSC, Solna (S)	6	4	43.8	3.4	280	3-4
MAXUS	Airbus Defence and Space, and SSC	13	5	64.0	3.8	480	≤ 0.5

- direct involvement of the experimenters in developing the hardware, and in the preparation and execution of the experiment;
- minimum safety constraints for the experiments;
- extensive use of interactive experiment operation (“telescience”) from the launch site;
- possibility of late experiment installation (“late access” – up to one hour before launch) and fast sample retrieval after the flight (“early retrieval” – typically within one hour after launch);
- comprehensive user infrastructure at Esrange launch site in Kiruna, Sweden (e.g. laboratories, accommodation);
- availability of a large number of flight-proven experiment modules for different scientific disciplines.

6.1.3 Why use sounding rockets?

Sounding rockets are excellent platforms for the performance of independent microgravity investigations and preparatory experiments for the ISS and other long duration flight opportunities. Furthermore, they are platforms for in-flight verification of scientific innovations, especially in cases where no prior microgravity experience exists. They enhance options to obtain valuable scientific return from longer-duration missions and are low cost. From a scientific point of view, sounding rockets provide the opportunity to carry out research over a wide range of disciplines in materials science, fluid physics, combustion, fundamental physics and biology.

6.1.4 Principal characteristics of sounding rockets used by ESA

In Europe there are currently three different sounding rocket lines offered by industry to any paying customer for microgravity research. Normally these missions are used by ESA and the German Space Agency (DLR), but in the past they have also been used by Japanese users and JAXA. The main characteristics of the three sounding rocket lines that are used by ESA are summarised in Table 6-1.



Image 6-2: Preparation of TEXUS 50

A major redefinition of Sounding Rocket procedures and systems is expected to be outlined in 2015 which will streamline procedures between ESA and its Sounding Rocket partners as well as providing new characteristics of Sounding Rockets offered to users. That said, the information about Sounding Rockets currently in use, outlined in this chapter, provide users with a generic overview of what to expect when contemplating the use of Sounding Rockets.

6.1.4.1 TEXUS

The TEXUS Sounding Rocket Programme (Technologische EXperimente Unter Schwerelosigkeit) was initiated in 1976 by the German Ministry for Research and Development, as a preparatory programme for the first Spacelab mission in 1983.

The first TEXUS mission was successfully launched from Esrange, Kiruna on 13 December 1977. ESA's first experiment flew on the German TEXUS 6 mission in 1982. Since then ESA has flown more than 100 experiments up to the TEXUS 46 mission (November 2009). Skylark VII two-stage solid fuel launchers (first stage: Goldfinch IID, second stage: Raven XI) manufactured by British Aerospace, were usually employed in the TEXUS programme. The mission-related tasks (such as the provision of the rocket motor, the service systems and the launch service) are covered by an industrial consortium led by Airbus Defence and Space (Bremen, Germany). Since TEXUS 42, in December 2005, the Brazilian two-stage solid propellant VSB30 rocket motor has been used for TEXUS and MASER missions. This rocket motor has a

Table 6-2: TEXUS and MASER sounding rocket characteristics

PARAMETER	VALUE/ CHARACTERISTIC TEXUS	VALUE/ CHARACTERISTIC MASER
Overall length	13 m	13 m
Scientific payload diameter	0.57 m	0.57 m
Max. scientific payload length	3.4 m	3.4 m
Total payload module mass	~400 kg	~400 kg
Scientific hardware mass	260 kg	280 kg
Microgravity time	~6 min	~6 min
Apogee	260 km	260 km
Microgravity level achieved	$\leq 10^{-4}$ g	$\leq 10^{-4}$ g
First stage type	S-30	S-30
1 st Stage propellant type	Solid	Solid
1 st Stage nominal thrust	102 kN	102 kN
Peak acceleration	10 g	10 g
First stage burn time	20 s	20 s
Coast phase after 1 st stage burn out	2.5 s with negative acceleration	2.5 s with negative acceleration
Second stage type	S-31	S-31
2 nd Stage propellant type	Solid	Solid
2 nd Stage nominal thrust	240 kN	240 kN
Peak acceleration	7.5 g	7.5 g
2 nd Stage burn time	11 s	11 s
Analogue video channels	2-6	
Analogue telemetry channels	192	
Digital telemetry channels	180	
Spin rate (at motor separation)	4 Hz	4 Hz
Digital video channels		2-6
Digital video downlink	Not available	Available

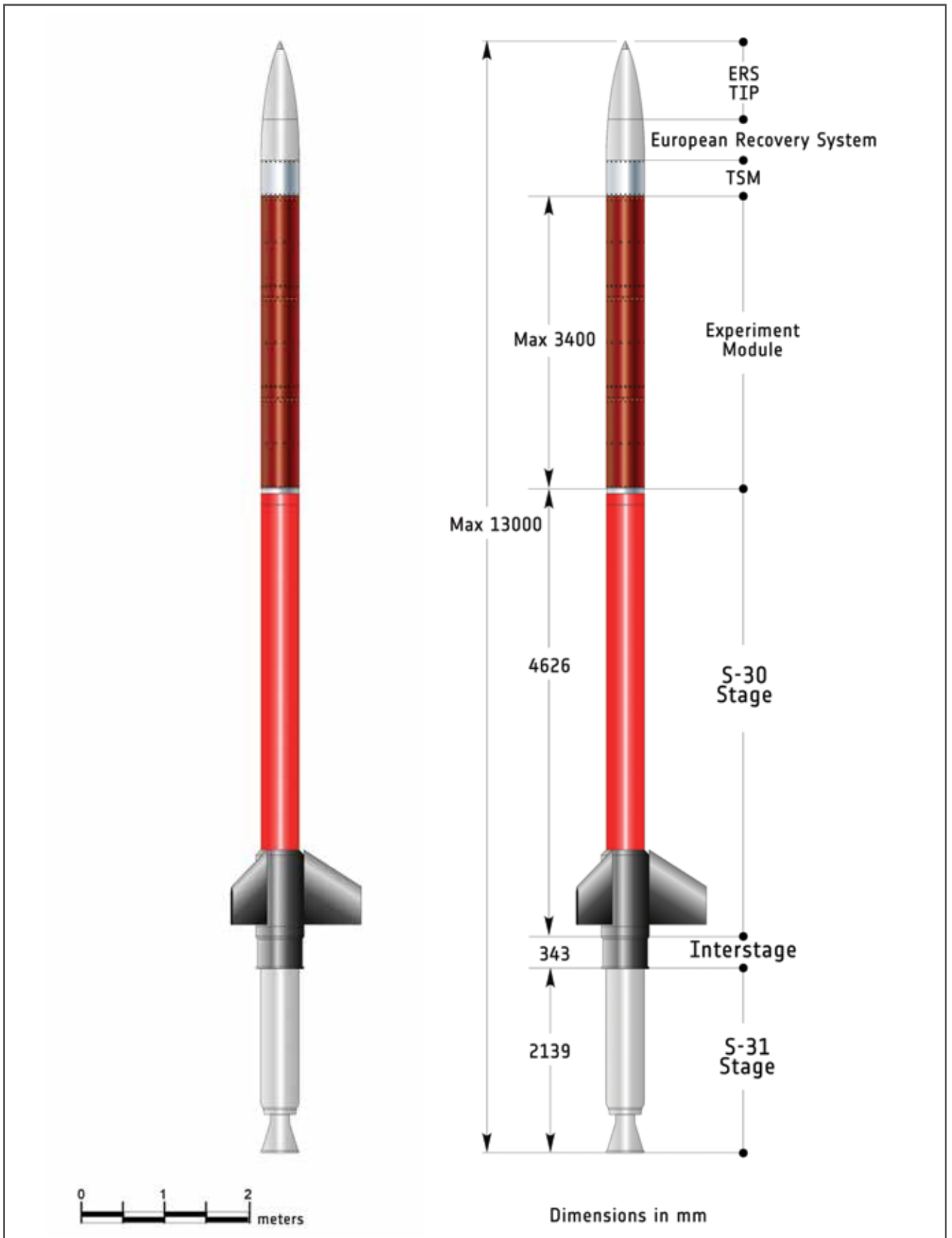


Figure 6-1: TEXUS sounding rocket

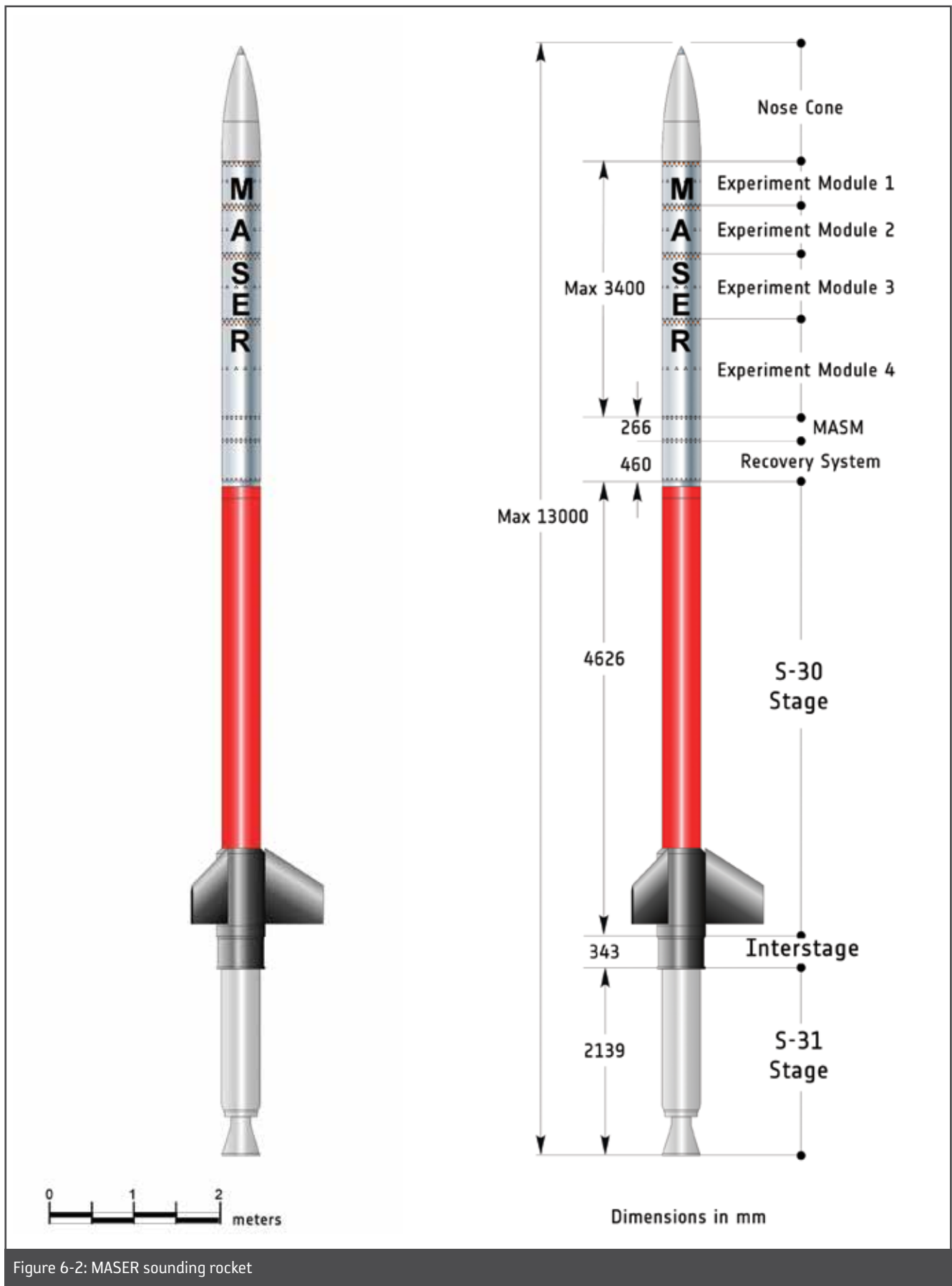


Figure 6-2: MASER sounding rocket



performance that is slightly superior to the Skylark VII. Table 6-2 summarises the major characteristics and features of the TEXUS sounding rocket and the MASER sounding rocket.

6.1.4.2 MASER

In 1986, Sweden began its own sounding rocket programme called MASER (MATERIAL Science Experiment Rocket). The first successful launch – MASER 1 – took place at Esrange in March 1987. ESA has participated in all 12 MASER missions, and the sixth to tenth missions were totally funded by ESA. The MASER missions are managed by the Swedish Space Corporation (SSC).



Image 6-5: MAXUS 8 prepared for launch

Table 6-3: MAXUS sounding rocket characteristics

PARAMETER	VALUE/ CHARACTERISTIC
Overall length	16.2 m
Max. diameter	1 m
Scientific payload diameter	0.64 m
Scientific payload length	3.8 m
Gross launch mass	12 300 kg
Total payload mass	800 kg
Scientific hardware mass	480 kg
Microgravity time	13 min
Apogee	705 km
Microgravity level achieved	$\leq 10^{-4}$ g
Analogue video channels	2-6
Digital video downlink	Not available
Analogue telemetry channels	384
Digital telemetry channels	360
Motor	Morton Thiokol Castor IVB
Propulsion module diameter	1 m
Propulsion module length	9.2 m
Propellant type	Solid
Vacuum thrust	430 318 N
Peak acceleration	13 g
Burn time	64 s
Spin rate	≤ 0.5 Hz

6.1.4.3 MAXUS

The European long-duration sounding rocket programme - MAXUS - started in 1990. The mission-related tasks (such as the provision of the rocket motor, the rocket systems, the service systems and the launch service) are covered by an industrial joint venture formed by Airbus Defence and Space (based in Bremen, Germany) and the Swedish Space Corporation – SSC (Sweden). The MAXUS programme offers 13 minutes of microgravity time for experiments. All eight MAXUS missions flown up to 2010 have been totally funded by ESA. The following table summarises the major characteristics and features of the MAXUS sounding rocket.

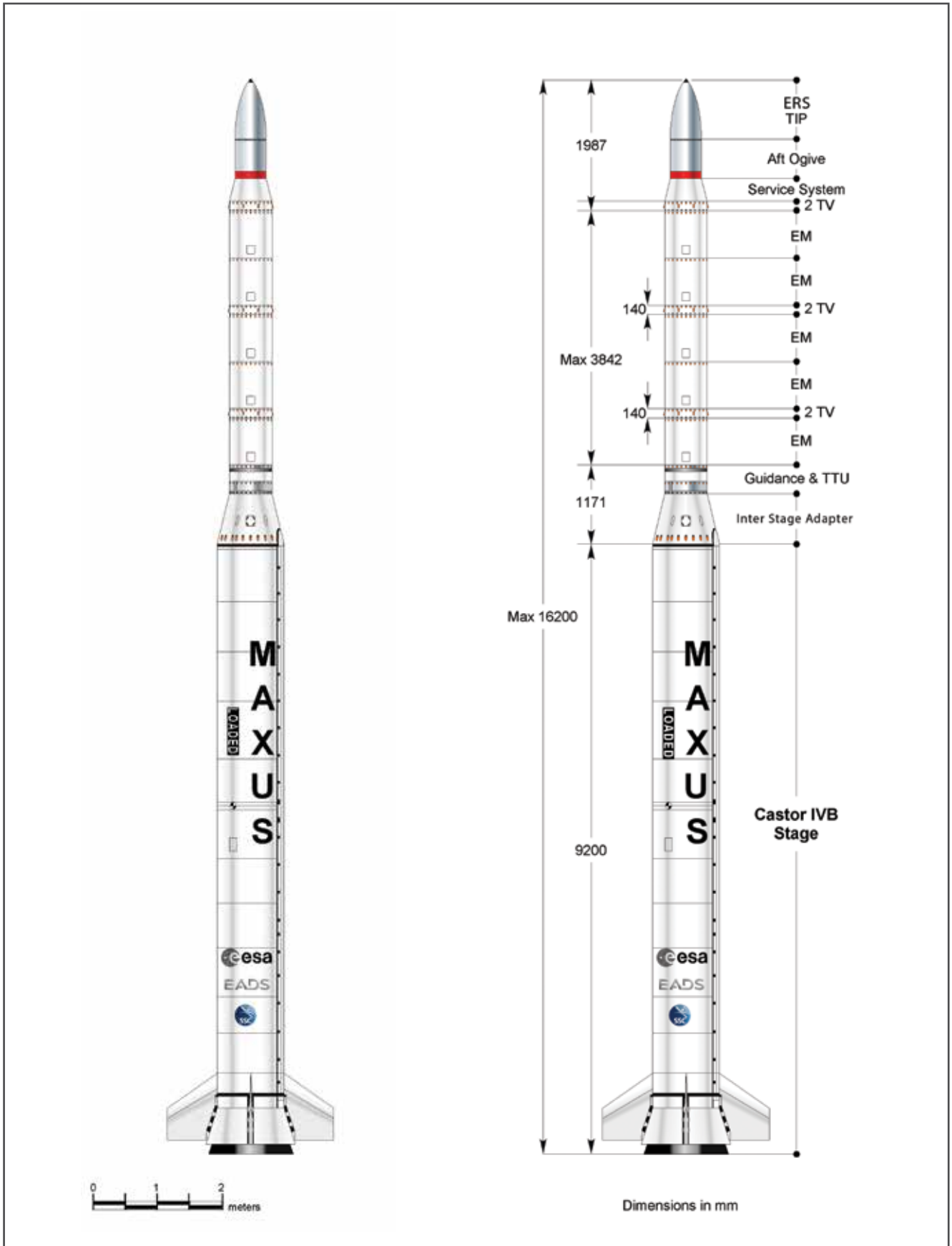


Figure 6-3: MAXUS sounding rocket

6.1.5 Sounding rocket mission profile

The sounding rockets used by ESA (i.e. TEXUS, MAXUS and MASER) are all launched from the Esrange launch site east of Kiruna, northern Sweden (67°54' N, 21°05' E). All rockets follow a steep parabolic trajectory with similar sequences of events occurring at different altitudes and times.

Figure 6-4 shows the typical altitudes achieved during the flight of the three different sounding rockets compared to the ISS, and the subsequent tables and figures summarise the flight sequences for each individual launcher. The values reported may vary from mission to mission, depending mainly on the total payload mass. During ascent, for flight stabilisation,

the TEXUS and MASER rockets spin around the longitudinal axis at a rate between 3-5 Hz. After the second stage burnout a yo-yo de-spin system is activated to decrease the spin rate to about 0.1 Hz. Then the motor is separated from the payload and a Rate Control System (RCS) with nitrogen thrusters is activated. If any of the angular motion rates (pitch, yaw, roll) exceed a given threshold, the corresponding thruster is activated until the rate decreases below the threshold. On MAXUS, which uses a non-spinning rocket, no yo-yo de-spin system is needed and only the Rate Control System is used to stabilise the payload, and to spin it up shortly before re-entry.

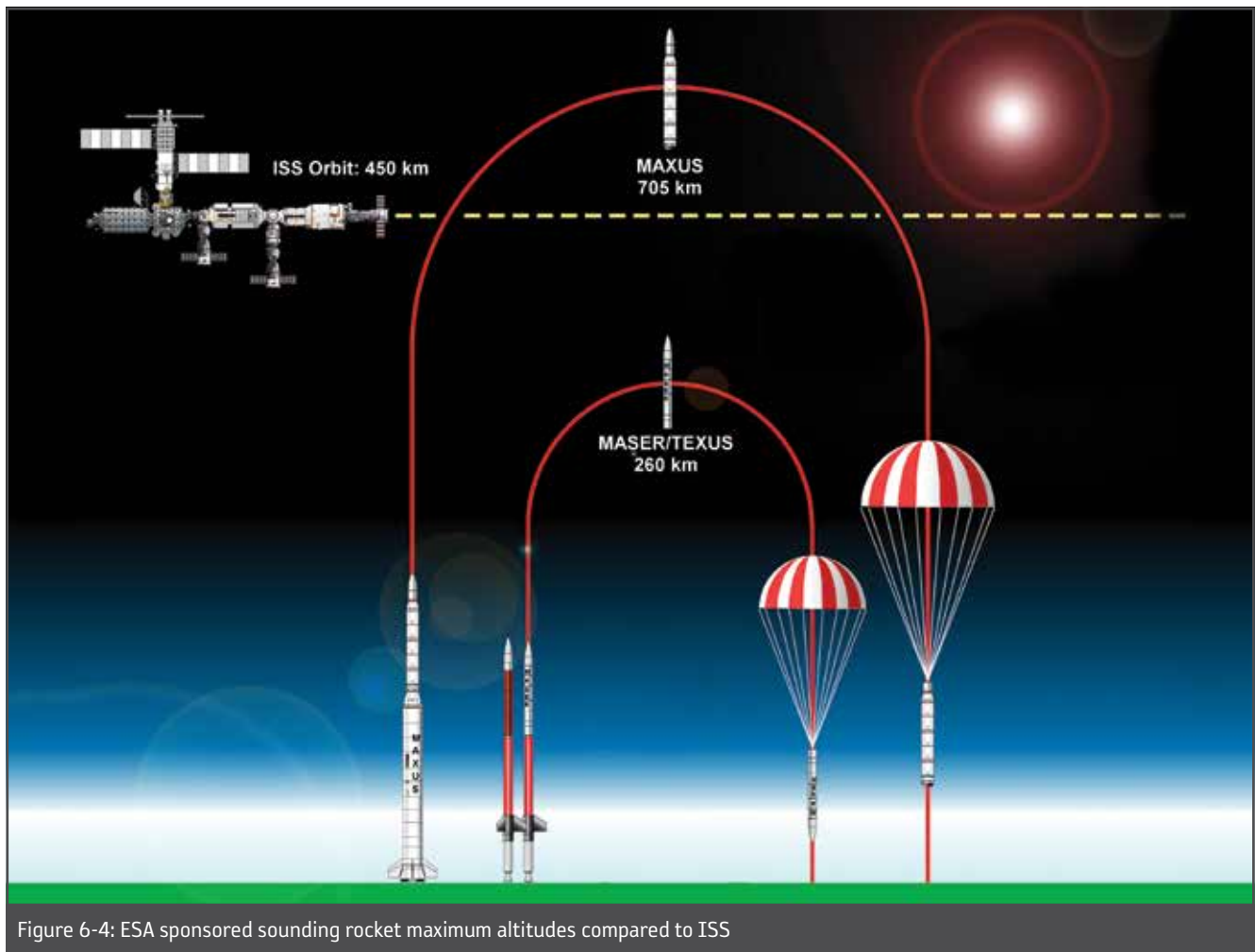


Figure 6-4: ESA sponsored sounding rocket maximum altitudes compared to ISS

6.1.5.1 TEXUS and MASER

Table 6-4: TEXUS and MASER principal mission events

EVENT	TIME FROM LAUNCH (S)	ALTITUDE (KM)	GRAVITY LEVEL (G)
Launch: Ignition first stage	0	0	1
First stage burnout	3.7		10
First stage separation	5.5	1.4	0.002
Ignition second stage	6.5	1.55	Up to 7.5
Burnout second stage	45	43.1	
Nose cone ejected	55	68	
Yo-Yo de-spin activated	56	69.9	
Yo-Yo de-spin completed	57.5	72.7	4×10^{-3}
Motor/payload separation	59	75.4	
Rate Control System (RCS) activation/start of microgravity period	75	100	$<10^{-4}$
Apogee	260	260	$<10^{-4}$
End of microgravity period	440	100	$<10^{-4}$
Start of re-entry	490 (max. velocity 2 km/s; max. outer skin temp. 180 °C)	30	50 (peak)
Beacon activated	540		
Heat shield released	570		
Drogue parachute deployed	578		
Main parachute released	590		
Payload retrieval	3600-7200	0	

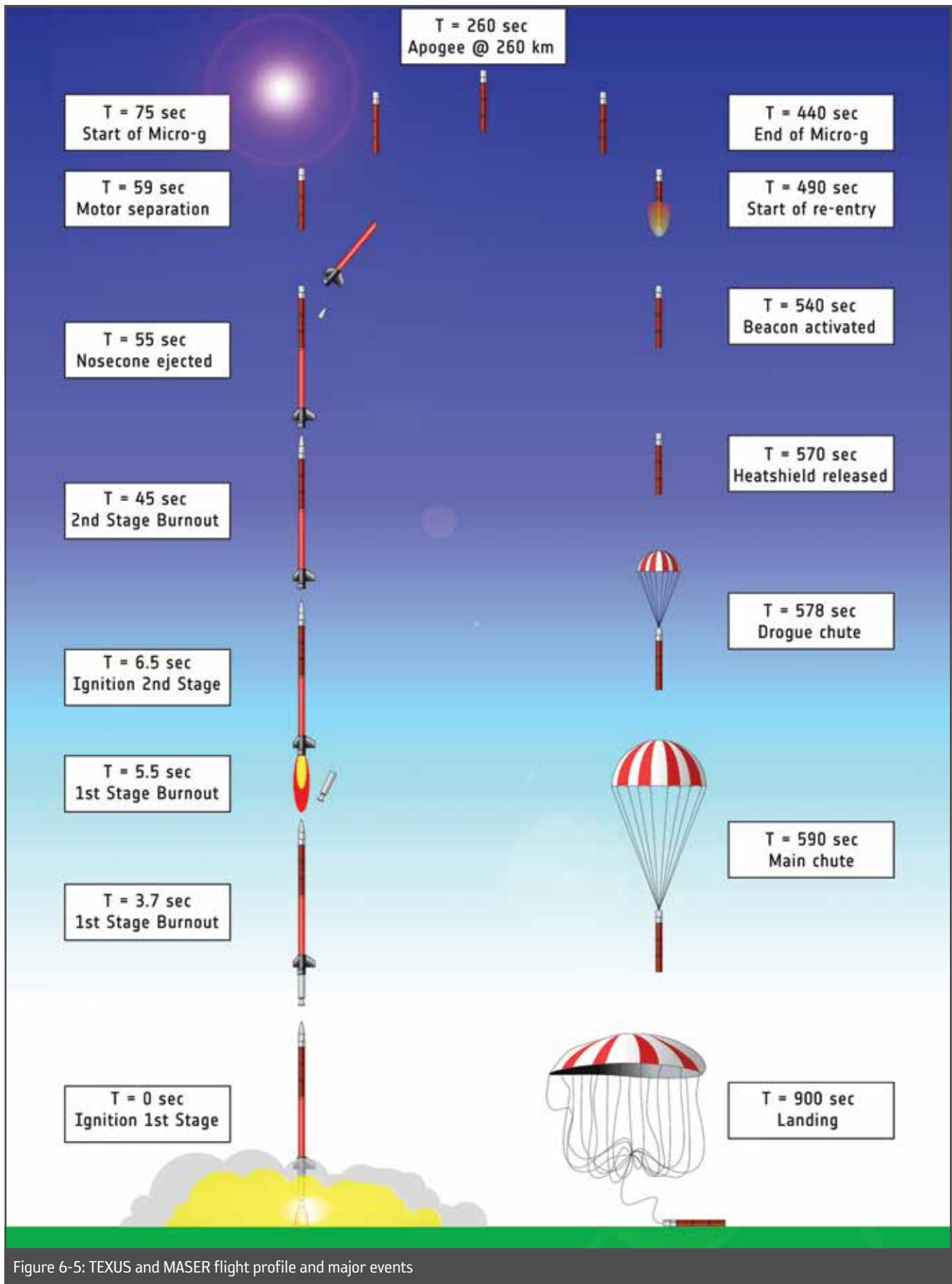


Figure 6-5: TEXUS and MASER flight profile and major events

6.1.5.2 MAXUS

Table 6-5: MAXUS principal mission events

EVENT	TIME FROM LAUNCH (s)	ALTITUDE (km)	GRAVITY LEVEL (g)
Launch: Ignition of single stage	0	0	
Burnout	64	75	~13 at T+60 s
Nose tip released	68		
Motor/Payload separation	86 (spin rate ≤ 0.5 Hz)	10 0	
Rate Control System (RCS) activation	86	103	$<10^{-4}$
Start of microgravity period	96	110	$<10^{-4}$
Apogee	460	705	$<10^{-4}$
End of microgravity period	836	100	$<10^{-4}$
Spin-up command	847		
Start re-entry period	855 (max. velocity 4.5 km/s; max. outer skin temperature 250 °C)		40 (peak)
Beacon activated	870		
Heat shield released	945		
Drogue parachute deployed	952		
Main parachute released	960		
Payload retrieval	4500-5400	0	

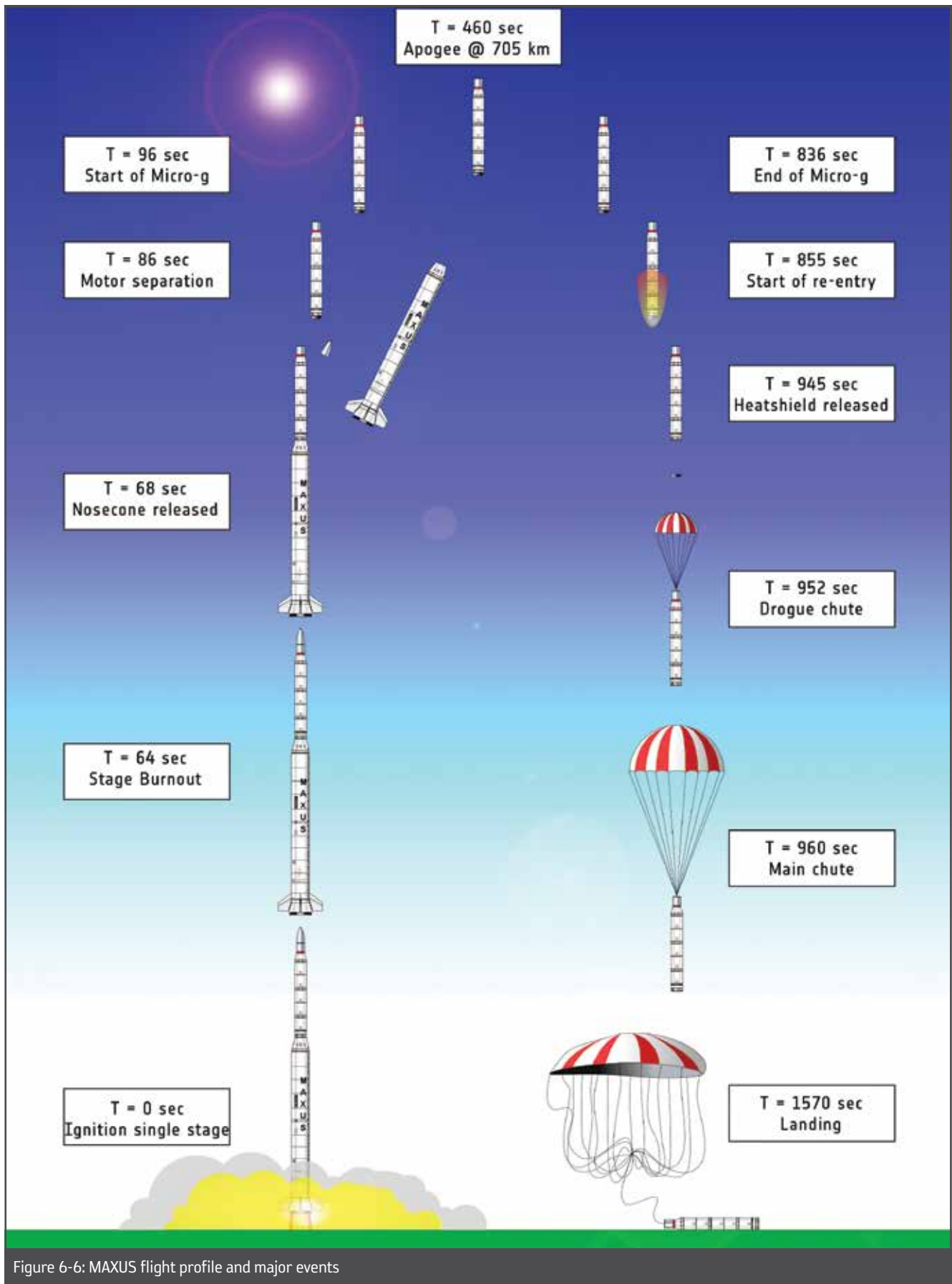


Figure 6-6: MAXUS flight profile and major events

6.1.6 Launch and landing site

The Esrange launch site (67° 54' N, 21° 04' E) is located in northern Sweden 200 km above the Arctic Circle and 43 km east of the town of Kiruna. The European Space Research Organisation (ESRO) established Esrange in 1966 mainly as a launch facility both for sounding rockets and stratospheric balloons. In 1972 the ownership of Esrange was transferred to the Swedish Space Corporation (SSC). Access to Kiruna is very good with two daily flights to and from Stockholm. The range covers an area of 20 square kilometres and has the following infrastructure:

The 'main building area' is located in the Vittangi river valley, comprising the main building, the Telecom building, Hotel Aurora and garages. Close to this is the area for balloon launches, including two buildings for operations control and payload preparation. Further east is the launching area for rockets, which includes a blockhouse, rocket and payload preparation halls, biology laboratories and launch pads. The rocket storage is located another kilometre further east, while one kilometre south of the launch tower there is a mobile radar station belonging to DLR. The satellite receiving station, and a GPS reference station are situated on top of a hill two kilometres southwest of the main building.

The rocket impact area (Figure 6-7) is located north of Esrange in the Swedish tundra region. This area is divided into three zones, A, B, and C, with a total area of 5600 km². Zone A, the impact area for boosters, can be extended when rockets with long-range boosters are launched. Zones B and C are impact areas for second and third stages as well as payloads. Zone C is not accessible during the period May 1 - September 15 and therefore no flights take place in that period. The nominal impact point normally chosen is situated 75 km north of the launch pads.

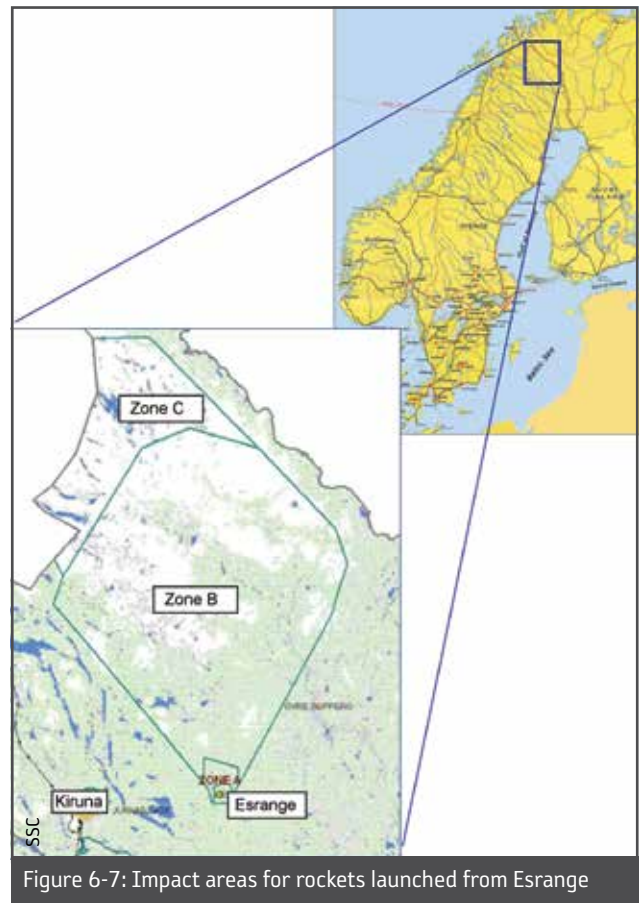


Figure 6-7: Impact areas for rockets launched from Esrange

6.2 Physical environment

6.2.1 Acceleration levels

For microgravity experimentation, sounding rockets offer one of the best environments in terms of time and quality of microgravity. The acceleration levels to which these rockets are subjected reach approximately 10-13 g (i.e. 10 to 13 times the gravitational acceleration measured at sea level) during the ascent phase, then drop to less than 10^{-4} g during the microgravity phase and are then (for a very few seconds) subjected to very short peak accelerations of more than 40 g during the re-entry phase.

Figure 6-8 shows the acceleration levels, as multiples of 'g', measured along the flight-path axis during the early ascent phase of the MAXUS 5 mission, as a function of the mission elapsed time (seconds).

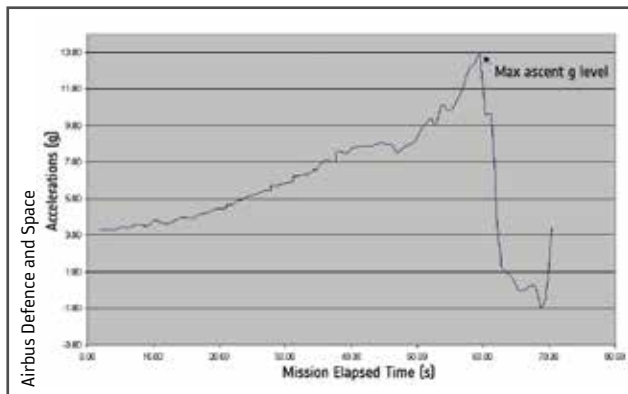


Figure 6-8: Acceleration (g levels) measured along the flight-path axis during the ascent phase of the MAXUS 5 mission

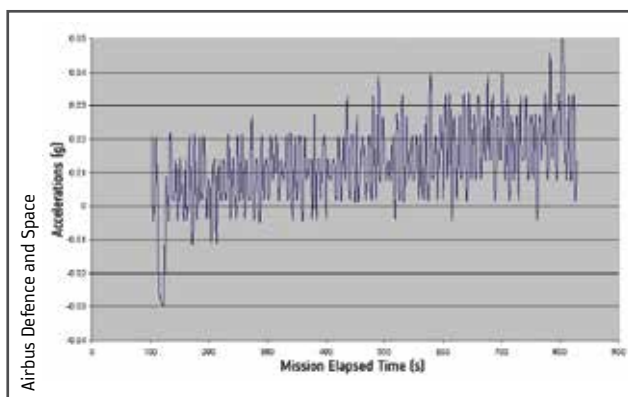


Figure 6-9: Acceleration (milli-g) measured along the flight-path axis during the microgravity phase of the MAXUS 3 mission

The maximum value of approximately 13 g is a typical value for MAXUS missions.

Figure 6-9 displays the acceleration levels (in milli g) measured during the microgravity phase of the MAXUS 3 mission (i.e. between 100 and 840 seconds after launch). From this figure it can be noted that, on average, the absolute value of the microgravity levels during this phase can be typically less than 0.04 milli-g, i.e. $< 4 \times 10^{-5}$ g.

6.2.2 Thermal environment

The payload thermal environment is kept under control during the pre-launch phase. The sounding rocket housing air temperature before launch is usually around 18 °C with a range of ± 5 °C. Measurements performed during the ascent phase of the sounding rockets launched from Esrange, have shown that the payload module outer structure reaches a maximum temperature of approximately 250 °C for MASER and TEXUS missions and 300 °C for MAXUS missions. Upon re-entry the outer structures are heated up to much higher values. The experiment design must take care that in particular the temperature increase during ascent does not badly affect the performance of the experiment. During the countdown, temperature sensitive experiments can be connected to a remotely controlled external liquid cooling loop.

After impact of the payloads on the ground the experiment modules may be subjected to snow and cold air for a period of up to two hours. The seasonal temperatures in the periods when sounding rocket campaigns take place (usually October-November, March-May) are typically sub-zero, and the minimum temperatures range typically between -30 °C and 0 °C.

6.3 Scientific research topics suitable for sounding rockets

Figure 6-10 highlights the various scientific fields for which sounding rockets have proven to be a suitable platform. It is important to note, however, that these fields are based on the data from current and past research carried out on sounding rockets, and should therefore not be considered exhaustive. Furthermore, the lists include areas that require further study in future research, identified by scientists contacted during a sounding rocket study carried out on behalf of ESA in 2001. Scientists should view the fields presented below as a guideline, but are encouraged to propose new research areas, as long as their experiments can be executed within sounding rocket flight limitations.

For more information on the science conducted on Sounding Rockets please read the Human Spaceflight Science Newsletter or visit the Erasmus Experiment Archive:

[wsn.spaceflight.esa.int/docs/
HumanSpaceflightScienceNewsletters/2011/
Newsletter_July_2011.pdf](http://wsn.spaceflight.esa.int/docs/HumanSpaceflightScienceNewsletters/2011/Newsletter_July_2011.pdf)

eea.spaceflight.esa.int



FUNDAMENTAL PHYSICS

Complex plasmas and dust particle physics

Cold atoms and quantum fluids

- Critical phenomena
- Energy transport

MATERIALS SCIENCE

Thermophysical properties

- Thermophysical properties of melts

New materials, products and processes

- Solutal diffusion and crystal growth in metals and alloys
- Composites
- Solidification interfaces in metals and alloys
- Multiphase and multicomponent solidification
- Reaction kinetics in glasses and ceramics
- Phase separation in glasses and ceramics
- Nucleation in glasses and ceramics
- Crystal growth from solution & melt
- Vapour crystal growth
- Semiconductors
- Undercooling
- Metallic foams
- Zeolites

FLUID AND COMBUSTION PHYSICS

- Liquid fuel sprays and droplets
- Fuel particles and dust clouds
- Premixed gas flames
- Gaseous diffusion flames
- Flame spreading
- Combustion synthesis
- Smouldering combustion

Structure and dynamics of fluids & multiphase systems

- Multi-phase flow and heat transfer
- Bubble/Drop nucleation
- Boiling with/without electric field
- Colloids
- Magneto-rheological fluids
- Foams
- Granular systems
- Fluid spreading
- Wetting phenomena
- Critical point studies
- Liquid drop dynamics
- Gas bubble dynamics
- Capillarity
- Magneto/electro hydrodynamics
- Surface driven bulk flows

BIOLOGY

Plant physiology

- Gravitropism/graviperception

Cell and developmental biology

- Gravitaxis/gravikinesis
- Graviperception
- Signal transduction pathways
- Cytoskeleton
- Gene expression
- Metabolism
- Self-organisation of molecules
- Evolutionary biology
- Reproduction
- Normal development functions
- Cell morphology
- Unicellular organisms
- Multicellular organisms
- Endocrinology

Biotechnology

- Protein crystal growth
- Electrophoresis
- Electrofusion

Figure 6-10: Research fields carried out on sounding rockets, based on past experiments

6.4 Payload accommodation

The design concept of payloads flown on ESA- sponsored sounding rocket missions is based on re-usable autonomous experiment modules. The scientific payloads are made up of combinations of experiment modules, assembled together with the service systems necessary for in-flight support (i.e. telemetry, rate control, recovery). Use of these modules assures maximum integration and operational flexibility and the minimum number of interface connections between experiments and the service module. Under this arrangement, basic experiment resources are decentralised, and standardised as support subsystems and components (i.e. module structure, batteries and power supply, etc.). Experiment modules flown on TEXUS and MASER are accommodated within a 438 mm diameter cylindrical payload envelope on a one- or two-platform structure. This layout groups experiment services (power supply and electronics) in the lower part of the module, under the experiment-dedicated equipment (e.g. experiment chamber, furnace, diagnostics, etc.) assembled on the upper platform. The modules for the MAXUS programme have a diameter of 640 mm and are in most cases assembled on a single platform, with the service components grouped around the experiment facilities. This approach of assembling autonomous modules: provides users great flexibility in meeting experiment and mission requirements; facilitates testing at module level and has proven to be a cost-effective solution in all phases of the programme. Within the framework of its microgravity programme, ESA has funded the development of many sounding rocket experiment modules for a broad spectrum of scientific investigations.



Image 6-7: TEXUS Experiment Module

6.5 Available flight resources

The payload service systems are designed in a modular style similar to that selected for experiments. This approach offers the following advantages:

- assures maximum flexibility of payload assembly to meet centre of gravity requirements;
- ease of integration with experiment modules by means of standard interfaces;
- ease of servicing, maintenance and checkout;
- modifications to individual services can be implemented with minimum impact on other flight systems;
- maximum commonality between the different flight systems.

6.5.1 Service Module

Typically, the Service Module consists of the Telemetry System, the Telecommand System, the Rate Control System and the acceleration sensing assembly.

6.5.1.1 Telemetry System

The Telemetry System multiplexes and transmits experiment and housekeeping data from the experiment modules and the in-flight service systems to the ground. In general, for each experiment module the following are available for telemetry:

- analogue channels: 32 to 64, 0 – 5 V;
- digital channels: 36, 12 bit.

6.5.1.2 Telecommand System

A total of 40 telecommand channels are available for experiment operations. Update (refresh) interval = 50 ms.

6.5.1.3 Rate Control System

The function of the Rate Control System is to keep evolving body rates of the payload in all three axes below predetermined limits of $0.1^\circ/\text{s}$ and $1.5^\circ/\text{s}$. This is achieved by applying opposite thrust to the disturbance vectors by means of cold gas thrusters. The quality of the microgravity environment is determined by this system. Rate gyros provide input signals to the system. The acquisition of the rate control system occurs after separation from the launch vehicle and despin by the yo-yo system (n.b. this applies only for TEXUS and MASER).

6.5.1.4 Acceleration measurement

The acceleration measurement system typically has the following measuring ranges:

- coarse measurement (accelerometers): $\pm 75 \text{ g}$, resolution $3.66 \times 10^{-2} \text{ g}$;
- fine measurement (microgravity sensors): $\pm 12.8 \times 10^{-3} \text{ g}$, resolution $6.25 \times 10^{-6} \text{ g}$.

6.5.2 TV module

The TV module for analogue video transmission comprises two TV transmitters. It can be integrated into the payload as required. Typically, one or two TV modules are accommodated in various areas along the scientific payload. Analogue video transmissions to the ground are usually in the S-band at 10W nominal RF power.

Each TV module is equipped with four antennas and an antenna switching system to ensure that for the transmission to the ground station the antenna with the highest link margin is used. MASER is equipped with a fully science-oriented Digital Video System (DVS), which allows for high resolution and high speed video data acquisition, processing and transmission to ground.

6.5.3 MAXUS Rocket Systems

For a MAXUS mission besides the above described payload service systems the so-called Rocket Systems are also needed. They consist of the Telemetry and Tracking Unit (TTU), the Guidance Control System (GCS) and the conical Interstage Adapter.

6.5.3.1 Interstage Adapter

The conical Interstage Adapter, developed by SSC (Sweden), is the connecting hardware between the Castor IVb rocket motor with a diameter of 1018 mm and the payload with a diameter of 640 mm. It provides the power for the stirring mechanism of the rocket nozzle, it activates the ordnance system of the rocket motor upon telecommand from the ground, it contains a radar transponder for the radar tracking of the motor and it accommodates the separation system that separates the payload from the motor after burn out.

6.5.3.2 Telemetry and Tracking Unit (TTU)

The TTU, developed by SSC in Sweden, is mounted on top of the Interstage Adapter. Its lower end is shaped as a re-entry cone which functions as a heatshield during the re-entry phase and as a shock absorber upon the payload's impact on the ground. The TTU contains a video camcorder that records the separation of motor and payload. It further accommodates a telemetry system to downlink the rocket motor data, the GCS data and the GPS data, and to receive telecommands from the ground station.

6.5.3.3 Guidance Control System (GCS)

The GCS, supplied by RUAG Space AB (Sweden), is located on top of the TTU. Its task is to control the deflation of the rocket motor nozzle in order to stabilise and navigate the vehicle along the calculated trajectory. This reduces the dispersion of the impact point. This is achieved by means of an inertial platform with rate gyros.

6.5.4 Recovery system

Except for MASER 1-3 and 6-10, which used aft-end recovery systems, the recovery system for a microgravity sounding rocket mission is located in the nose cone of the payload. Under normal conditions it enables the recovery of the payload without any major damage. This is important since many investigators, besides the downlinked telemetry and video data of their experiments, also need their samples back for detailed investigations in their home institutes. If a digital video system is used, this also applies to the uncompressed video images of the experiments as they are stored onboard. Another big advantage of recovering the payload is that the service systems and experiment modules can be reused after refurbishment. This leads to a considerable cost saving.

6.5.5 External temperature control

A number of experiments require active regulation of temperature prior to launch. Some metallurgy experiments require the sample to be molten at the start of microgravity operations, while biology experiments frequently require thermal conditioning of the sample to support biological activity. Ground-based water-cooling loops are available where needed, the supply disconnecting from the module at launch. Cooling can be maintained during ascent either by

means of Peltier elements or by making use of the thermal capacity of the experiment module.

6.6 Ground support facilities

6.6.1 Main building

The main building has a total floor area of 3930 m². In the basement there is storage for consumables. The main building also contains mechanical, electrical and carpentry workshops. For staff and guests there is a sauna and showers. The ground floor houses offices for Esrange administration and technical facilities, a reception desk, a switchboard (which on working days and from countdown to end of operation is staffed), a canteen, two conference rooms for 15 and 30 people, and a lounge. The first floor has offices for operational staff, the operations centre for sounding rockets and rooms for timing, telemetry and scientific instruments (Scientific Centre). In an annex on the same floor, there are offices and guest rooms. The top floor (second floor) has a large conference room for about 80 people, and offices. The Main Building area also includes hotel accommodation (see section 6.6.8 below).

6.6.2 Launching area

The launching area is located in an area about one kilometre east of the main building. All operations that are required from storage to preparation, assembly, integration, testing and launch of sounding rockets with complex payloads are performed in this area. During countdowns the road to the area is closed by a gate, and only authorised personnel are allowed to work in the launching area. To pass the gate a badge is needed, which can be obtained from the safety officer in charge.

6.6.2.1 Offices

Three offices are available to users (i.e. industry and scientists). They are situated in the laboratory annex in close connection to the payload assembly hall. Each office is equipped with standard furniture, telephone and internet access. When entering Esrange, each campaign participant receives a personal code for his/her office phone calls, and another code for private calls. By means of these codes each telephone at the range can be used. Use of mobile phones is permitted in recreational areas only. There is also a small common space and toilets in this area. Near the

main entrance there is a well-equipped kitchen and a TV-room for convenience.

6.6.2.2 Payload assembly hall

The payload assembly hall has a floor area of 10.5 m by 20 m and a height of 3.9 m, except for the central portion, which has a higher ceiling to allow vertical assembly of longer payloads. A single rail electric gantry crane is installed for payload handling. If required, the area can be divided into sections by means of movable screen-walls. The area is equipped with workbenches with electric power outlets.

Single phase and 3-phase power and also two cold water supplies are available. The main access door to the hall is 4.08 m high and 3.81 m wide.

6.6.2.3 Laboratories

Apart from standard tools and instruments, a variety of equipment for laboratory work, is available for use. Four laboratories are available for advanced biological work. They are all equipped with gas, warm and cold water, fume hoods, laminar airflow cabinets (horizontal or vertical), refrigerators, deep freezers, and lockable cupboards to store poisonous materials. One electronic laboratory is reserved for the launch crew. The laboratory equipment available to users includes:

- a high-temperature 3-litre oven. Thermostat controlled up to 1200 °C ± 1 °C;
- a vacuum medium-temperature 130 litre oven 1 mbar thermostat controlled up to 250 °C (LeyboldHeraeus VT5050EK);
- an oil-diffusion pump, 10⁻⁶ mbar (Edwards diffstak CR100/300M);
- a turbomolecular pump, 10⁻⁶ mbar (Balzer TSU170);
- an ultrasonic cleaner, 5.5 litre (Bransonic 32);
- three 50 litre containers for liquid nitrogen;
- three 100 litre containers for liquid helium (Alfax RS101);
- one 250 litre container for liquid helium;
- a weighing-scale 0-1200 g capacity, with 0.1 mg resolution (Satorius 1206 MP);
- a stereo-zoom microscope. Magnification 30x to 210x. Reflected light and camera adapter with 35 mm Contax camera (F:1.7), Bausch & Lomb Stereo Zoom;
- microscope Nikon, Diophot + accessories;
- microscope Nikon, SMZ-2B, 2 pcs;

- microscope Nikon, SMZ-2T;
- Schott coldlight source, KL 1500, 3 pcs;
- centrifuge Hettich Universal K2S + accessories;
- deepfreeze Colora, UF85-110T;
- autoclave Denley BA 852;
- magnetic Stirrer Nuova II, SP 18420-26;
- Vortex mixer Eckli 600;
- distillation apparatus Schott 2481100;
- water demineralisation Seradest S750/5200;
- transportbox Veba electronics, #378 37 °C;
- transportbox Veba electronics, #379 37 °C;
- transportbox Veba electronics, #833 4-22 °C;
- transportbox Veba electronics, #832 4-22 °C;
- transportbox Veba electronics, #828;
- accu charger;
- accu 12 V/65AH, 2 pcs;
- Nikon 801 + AF Nikon 50 mm;
- cleaner for laboratory glassware, Miele G 7733 automatic;
- conductometer, Knick type 600;
- electronic precision balance, range 3000 g, resolution 0.01 g, PAG Oerlicon, Precisa 3000 C;
- microscope illumination, Volpi type Intralux 5000;
- incubator, Memmert type BE 60;
- large shaker, GFL type 3020;
- magnetic stirrer, IKA-Werk type Ikamag RCT;
- pH-meter, Knick type 646;
- pipetting guide, Technomara type Pipetboy;
- reagent glass shaker, Heidolph type Reax 2000;
- shaking water bath, Julabo type SW-20 C;
- steam sterilizer, Heuss u. Partner, type Varioklar 400 E;
- refrigerated centrifuge, Heraeus, type Omnifuge 2.0 RS;
- refrigerated centrifuge, Sigma, type Sigma 3 K-1;
- ultracentrifuge, Kontron Instruments, type TGA 55;
- water bath, GFL type 1013;
- water bath, Memmert type WU 600;
- Intralux 5000 cold light source.

6.6.2.4 Workshop

One small mechanical workshop is available.

6.6.2.5 Users' blockhouse

To accommodate the large amount of ground control equipment, mainly used for microgravity payloads, a dedicated blockhouse is available. Its roof and walls are reinforced to the same standards

as the main blockhouse. The floor area is 8.0 m by 7.5 m.

6.6.2.6 Storage

A cold storage, 10 m by 16 m, is situated 50 m south of the payload assembly hall main entrance. It is used for long term storage of launch support equipment, and temporary storage of user's equipment.

6.6.3 Scientific Centre

The Scientific Centre in the main building (for MASER missions only) hosts scientific observations. During a sounding rocket mission, the telemetry and video data from the experiment modules are displayed in the Scientific Centre to enable the scientists to follow their experiments.

6.6.3.1 Telemetry

The telemetry station is very flexible and can be quickly adjusted for different missions. Several telemetry links can be maintained simultaneously. RF downlinks in P, S, or L-band can be used. For the telemetry and analogue video downlink of microgravity missions only the S-band is used. Equipment for demodulation and recording of PCM, FM and TV signals is included in the station. Signal decommutation and conditioning for quick look data is also performed. Flight data are

presented in real time or post-flight, using several different media and formats. For microgravity sounding rocket missions, besides the Esrange TM station, the DLR telemetry station is also used for redundancy.

6.6.4 Telescience

Besides manipulating onboard experiments during flights from the blockhouse at Esrange it is also possible to do so from remote laboratories all over the world. Data, TV-video signals and telecommands can be transferred between Esrange and remote sites by terrestrial telecommunication links or broadband satellite links, which enables the real-time telescience. Figure 6-11 shows a generic ground segment layout for a sounding rocket campaign.

6.6.5 TV centre

Two stations receive the transmitted TV signals from the sounding rockets. Each analogue TV channel is received in two polarisation directions and distributed to the TV centre in the Main Building. An operator chooses the best signals for recording and further distribution to the Blockhouse and the Scientific Centre. S-VHS video recorders are used for recording. The TV centre is the property of Airbus Defence and Space (Germany) and can, when the necessary agreements have been made, be used for TV selection and distribution if needed.

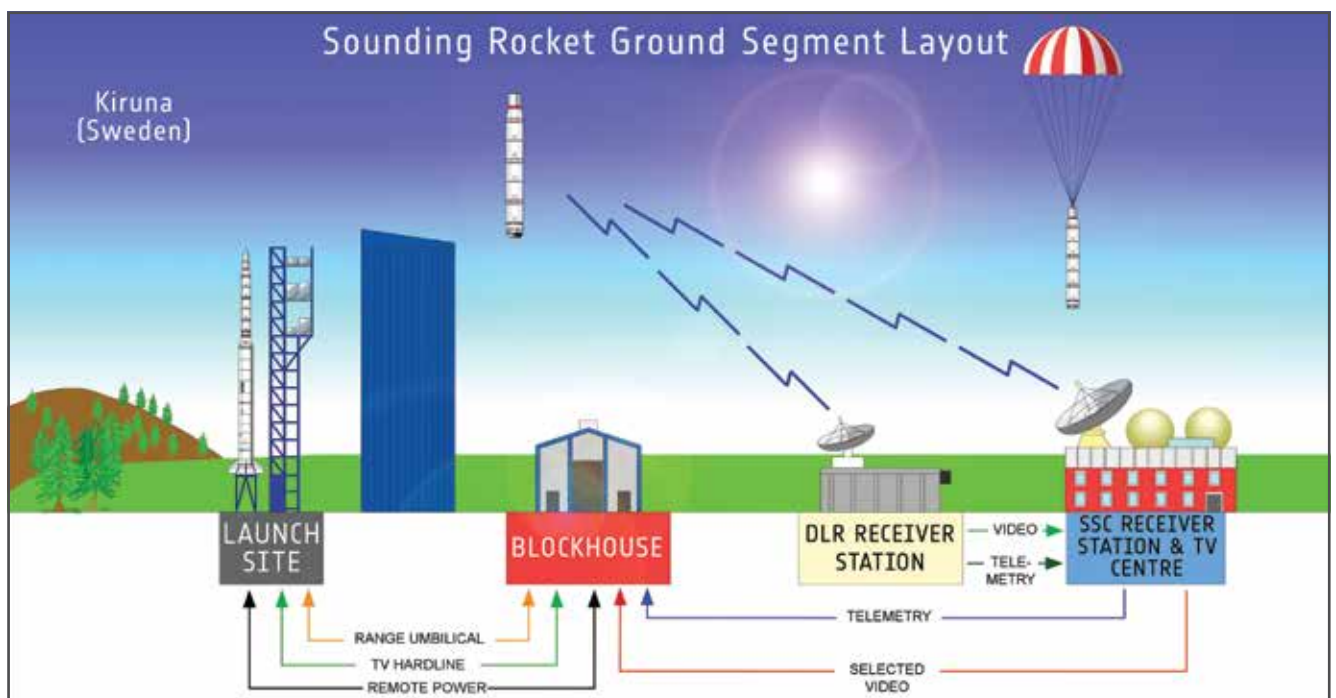


Figure 6-11: Generic sounding rocket campaign ground segment layout

6.6.6 Late access/early retrieval

In conjunction with the on-site laboratories, biologists, as well as other users with experiments that have to be prepared late in the countdown cycle, can take advantage of insertable “late access” assemblies to delay integration of the samples into the payload up to one hour before launch. This is achieved by inserting the late access unit into the experiment module through a hatch in the outer structure. This approach also makes it possible to extract late access units from the payload at the landing site, so that they can be returned to Esrange by a special helicopter and handed over to the experimenter before the payload is brought back to the range.

6.6.7 Recovery of payloads

Recovery of payloads is standard procedure at the range. The impact area makes Esrange very suitable for all kinds of flights where recovery is necessary. The open landscape allows smooth payload landing contributing to a minimum of impact damage. To ensure a quick and successful recovery, all microgravity payloads are equipped with homing devices (e.g. beacons, GPS transmitters). All other parts, without beacons, such as motor cases, nosecones, etc., are recovered as soon as they have been located. The helicopter support from pilots well acquainted with payload recovery in this uninhabited region of Scandinavia makes it possible to maintain a very high probability for fast and successful recovery.

6.6.8 Accommodation at Esrange

The Aurora hotel at the Esrange site offers a total of 96 single rooms of varying standards at very reasonable rates. There are also showers and kitchens. With the distance to Kiruna being roughly 40 km this is very practical for most visitors. Also, there is a restaurant at Esrange, which is generally open for breakfast, lunch and dinner during campaigns.

For more information regarding accommodation, recreation, climate and travel, users are advised to consult the Esrange website at the following URL: www.sscspace.com/esrange-space-center-3

Also, users can contact Esrange by sending an e-mail to the following address: info@sscspace.com

6.7 Legal aspects

In general, Swedish laws and safety regulations apply to activities at Esrange. The Work Environment Act contains the basic provisions concerning occupational safety and health questions in Sweden. This act is a general act of law, which is backed up by special rules and regulations in different fields. The specific safety rules and regulations that apply for work at Esrange are defined in the 'Esrange Safety Manual', which is available on site at Esrange (<http://www.sscspace.com/esrange-space-center-3>).

Toxic substances, infectious or living biological materials, or animals/organisms that are brought to Esrange as either sample material or for experiment preparation, have to be permitted by the relevant Swedish authorities.

6.8 Safety

6.8.1 Safety organisation

The safety organisation at Esrange is based on the following main functions:

- the General Manager for the Esrange Division is responsible for implementing the range safety policies and criteria;
- the Head of Operations and Safety is responsible for conducting the operations in accordance with the Esrange Safety Manual;
- during operations, the responsibilities are delegated to personnel conducting the actual operational tasks;
- the Head of Launch Team is responsible for all handling of explosives at Esrange. He is also responsible for ground safety in the launch areas during countdown and build-up of a campaign.

6.8.2 Operations and Scientific Centres

Signs with the text 'No Access' are placed above the doors to the Operations Centre and the Scientific Centre. When these signs are illuminated, only authorised personnel have access.

6.8.3 Dangerous materials

Dangerous materials are defined as all materials containing micro-organic, explosive, pyrotechnic, poisonous, infectious, corrosive, or radioactive materials. When an investigator intends to use dangerous materials, for his/her experiment, this must be notified to Esrange well in advance. The same applies if living cells or animals are to be used for the experiment.

6.8.4 Experiment module safety

The responsible module team shall establish a list of hazardous and living materials to be used in the module during flight and flight preparations, and shall communicate it to Esrange at the first Project Meeting. This information should also accompany the module itself.

6.9 Payload Assembly, Integration and Test (AIT)

The payload system AIT is performed at Airbus Defence and Space, Ottobrunn (Germany) for TEXUS and MAXUS, and at Innventia AB in Stockholm (Sweden) and starts, typically, five weeks before the planned start of the launch campaign. At the start of the AIT all flight hardware (experiment modules and service systems) must have successfully passed their Acceptance Reviews. Upon completion of the AIT, the Flight Acceptance Review is held.

6.9.1 Experiment module status at delivery

Before entering the payload system AIT, each experiment module should have successfully passed the Module Acceptance Test and the Module Acceptance Review. As a minimum requirement it is suggested that the affiliation responsible for the module, conduct the following qualification/acceptance tests:

- electrical/functional tests;
- vibration tests;
- vacuum and thermal tests;
- flight simulation test.

6.9.2 Module Incoming Inspection

All modules delivered to the payload AIT will undergo mechanical and electrical interfaces inspection upon delivery.

6.9.3 Payload assembly and interface tests

The experiment modules will, in due order, be integrated to the payload. All interfaces are checked and tested systematically during the assembly.

6.9.3.1 Mechanical interface test

The mechanical joints are checked by mounting the module to the interfacing modules. Orientation of umbilicals, feed-through harness, venting holes, etc. are checked.

6.9.3.2 Electrical interface test

The electrical interface test verifies the compatibility of the interfaces and the functioning of the related hardware. Interface compatibility for dangerous signals, protection mechanisms and voltage regulations are

checked systematically during assembly. Details have to be defined for every individual module/subsystem. The test is performed by the module manufacturer under supervision of the prime contractor.

6.9.4 Payload system tests

The main system tests are listed in the following sections.

6.9.4.1 Module checkout

The module is connected to the telemetry system and all channels used are checked with the module power 'on' and in experiment mode.

6.9.4.2 Mass properties and balancing

The mass properties of the payload are measured. The following measurements are performed:

- payload mass;
- centre of gravity;
- spin balance;
- moments of inertia.

If necessary the payload is balanced by adding ballast.

6.9.4.3 Spin test

The payload is rotated with a constant spin rate of 5 rps for two minutes to verify the spin balancing.

6.9.4.4 System Electrical Test 1 and Electromagnetic interference check

These tests are performed with all flight hardware electrics working and (as far as possible) in their flight configuration. Telemetry transmission is carried out via the antennas or via cable. All signals will be recorded at the telemetry ground station. The modules and service systems will be monitored and controlled from their Experiment Ground Support Equipment.

6.9.4.5 Vibration test

The payload will undergo vibration testing in the x, y and z directions, with each axis following the a, b, c sequence defined below.

- a. Low level sine sweep
- the payload is vibrated with sine sweep to identify resonances;

- frequency: 5-2000 Hz;
- amplitude: 0.25 g;
- sweep: 2 octave/min;
- no. of sweep: 1 up.

b. Random vibration

The input levels in all 3 axes will be:

- for 20-1000 Hz frequencies: 0.01 – 0.1 g²/Hz, increasing with 1.8 dB/oct;
- for 1000-2000 Hz frequencies: 0.1 g²/Hz;
- total RMS (Root Mean Square): 5.9 for MAXUS, 5.6 for TEXUS, MASER;
- the duration of the random input will be 60 seconds in each direction.

c. Low level sine sweep

In order to check if any changes have occurred the sine sweep test is repeated.

6.9.4.6 System Electrical Test 2

After the vibration test an electrical function test is performed. Each module responsible decides which tests to carry out. However, a complete telemetry system test must be included before disassembling the payload.

6.9.4.7 Flight Simulation Test

After successful results in the various tests, the payload is ready for a Flight Simulation Test (FST). Each module is monitored and controlled by the module ground support equipment. When all modules are running nominally, a complete countdown and flight sequence is performed. During the test all telemetry signals are recorded in the telemetry ground station.

6.10 Payload life cycle and major milestones

The payload life cycle varies from experiment to experiment, and depends strongly on the complexity of the hardware as well as the channel through which access has been obtained to fly on a sounding rocket mission. For experiments approved following submission of a proposal in answer to an Announcement of Opportunity (AO), the time from experiment approval (following the review process) to assignment of a flight can vary from six to 36 months. The period that elapses from the moment that an experiment is assigned to a specific campaign, to the start of the campaign, ranges from 12 to 24 months. For the example provided below, the time from proposal approval to flight assignment will be taken as six months.

Figure 6-12 represents a typical timeline with major milestones of an experiment for a sounding rocket campaign. The user must keep in mind that, although the tasks displayed in the timeline are standard, the periods are based on a generic case, and will differ, as described above, from experiment to experiment. The timeline is given in terms of months with respect to the launch (L).

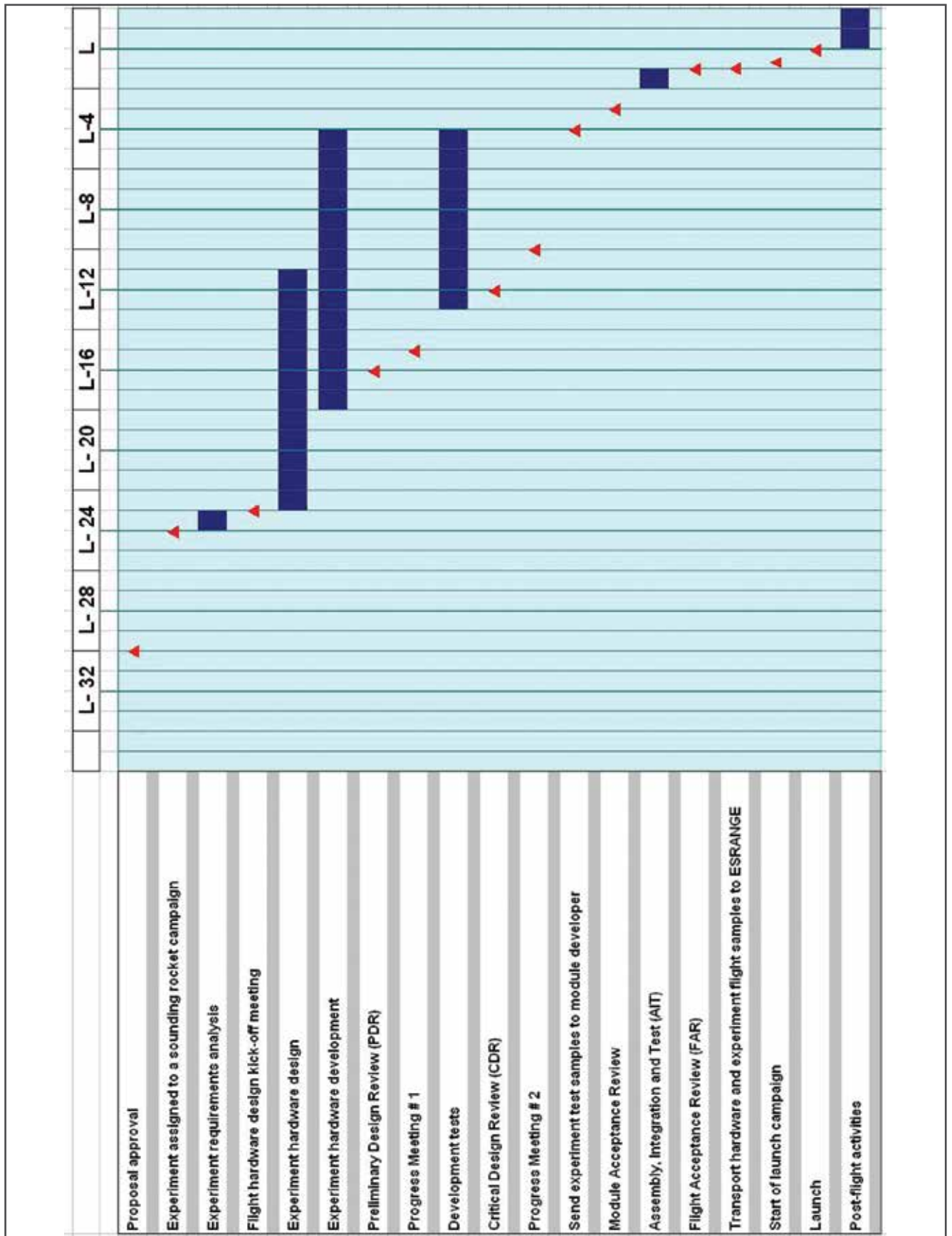


Figure 6-12: Typical timeline for an experiment on a sounding rocket flight campaign

6.11 Operational cycle of a sounding rocket campaign

Table 6-6 provides a general outline of the major events that take place during the operational cycle of a sounding rocket campaign. Scientists should use this as a reference and should keep in mind that the list below may vary from mission to mission. (“L” refers to the time of launch of the sounding rocket).

Figure 6-13 summarises the sequence of events during a sounding rocket campaign.

For more information on sounding rockets please visit the following web pages:

www.esa.int/Our_Activities/Human_Spaceflight/Research/Sounding_Rockets

Table 6-6: Major events in a sounding rocket campaign operational cycle

TIME	EVENT
L – 14 days	Users travel to and arrive at the Esrange launch site near Kiruna, Sweden.
L – 13 days	Unpacking and checking of flight hardware delivered to Esrange prior to arrival of users.
L – 12 to L – 6 days	Preparatory activities relative to the experiment modules.
L – 12 to L – 6 days	Preparatory activities relative to the service system.
L – 7 to L – 6 days	Range compatibility tests.
L – 6 days	Payload bench tests.
L – 5 days	Payload integration.
L – 4 days	Payload RF-test and flight simulation test.
L – 3 days	Payload installation at launcher.
L – 3 days	Blockhouse preparation.
L – 2 days	Overall RF-Test and final payload check.
L – 1 day	Practice countdown and dress rehearsal.
L – 4 hours	Begin 1 st Hot Countdown.
L – 45 minutes	Recovery helicopters sent out to report on weather and impact area.
L	Launch of sounding rocket.
L + 1 hour	Payload retrieval.
L + 1 day	Post-flight activities and transport preparation.
L + 2 days	Departure of payload teams.

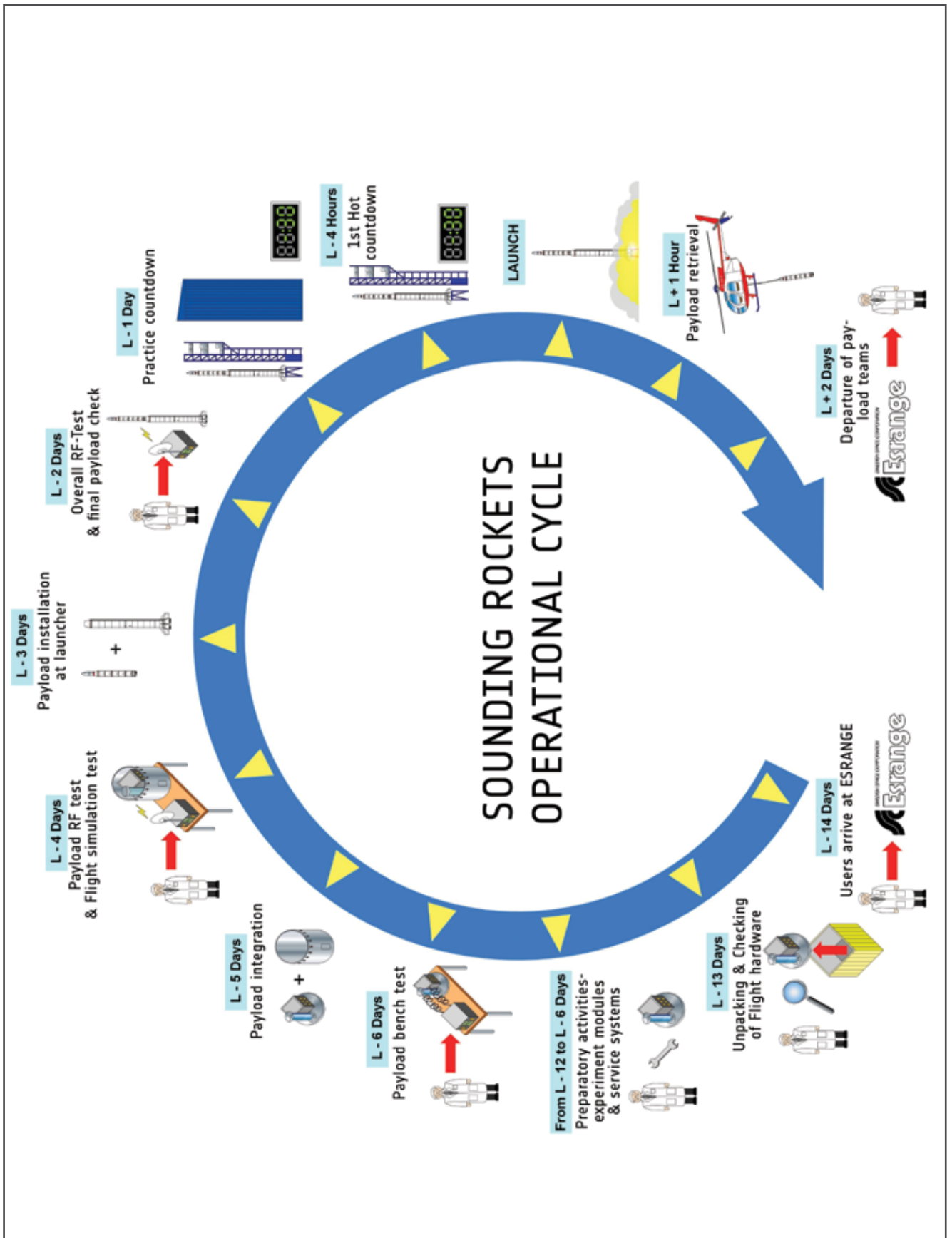


Figure 6-13: Sounding rocket campaign operational cycle

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