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THE ARIANE 5 LAUNCH AND OPERATION FACILITIES

by

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The Ariane 5 Launch and Operation Facilities

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Abstract: The Ariane 5 launch vehicle has a new set of launching operations and procedures. France constructed the third Ariane launch site at the Guiana Space Center in Kourou for the purpose of launching Ariane 5 space launch vehicles. The site consists mainly of a launcher integration building, a final assembly building, a launch control center, a launch zone, and mobile launch platforms.

Key words: Multistage launch vehicle, launch site, France.

1. Foreword

Up to now, two launch sites have been built for the Ariane series of launch vehicles at the European Space Agency's Centre Spatiale Guyanais (Guiana Space Center) in Kourou: the ELA-1 (Ensemble de Lancement Ariane 1) launch site, built between 1979 and 1989, which is used for launching Ariane 1, 2, and 3; and ELA-2, built between 1981 and 1985, which is used for launching Ariane 3 and 4. [ELA-2] has been responsible for launches since 1989.

Today, construction on the third launch site is almost fully completed. [ELA-3] will be used exclusively for launching Ariane 5 launch vehicles. Its major distinguishing feature is that operations at the launch zone are reduced as much as possible and its facilities are simplified to the extent that the mobile launch platform is not used to transport the assembled launch vehicle from the preparation zone to the launch zone until before the countdown.

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According to the requirements of the ESA, the following criteria were set for the Ariane 5 project:

a. A launch rate of eight times per year, with one month between every two launches;

b. A low rate of failure, especially in the preparatory phase and the pre-flight phase. In the event of a launch vehicle explosion, the launch site should be restorable to a normal operational state within six months;

c. Good reliability, maintainability, usability, and safety, with a special emphasis on the latter two items;

d. Optimum launch operation costs;

e. Propellants should be produced locally, to avoid danger (accidents) during transportation.

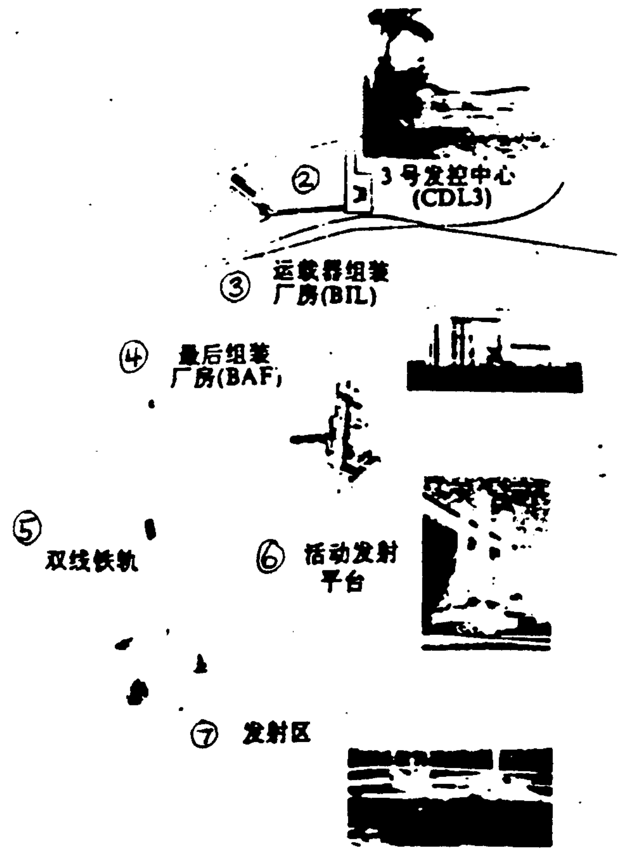
The Ariane 5 ground facilities take up approximately 2100hm^2 [sic] of surface area. The main facilities include:

a. The booster building, including the solid propellant factory, the booster assembly building, the test bed, and the booster recovery and evaluation facilities;

b. Facilities of the third launch site, shown in Figure 1;

c. Other systems, such as fluid production and processing equipment, remote sensing equipment, and ground railways.

The ELA-3 construction project began in 1988, and most of its facilities have already been completed. Some are being used now for development and evaluation of components and substages for the Ariane 5 launch vehicle. For example, booster experiments are being carried out on the already-constructed booster test bed and, between 1993 and 1995, seven to eight of these experiments will have been completed. Also, the finished launch pad is now being used as an engine test bed to carry out "hot test runs." In this way, remanufacturing of substage test beds in Europe can be avoided and, furthermore, ground equipment and operational procedures can be tested and operations personnel can be trained. Development and appraisal are scheduled for 1994-95.



① 图1 第3发射场设施

Key: (1). Figure 1 Facilities at the third Ariane Launch Site (ELA-3). (2). Launch Control Center 3 (CDL-3). (3). Launcher Integration Building (BIL). (4). Final Assembly Building (BAF). (5). Double track railway. (6). Mobile launch platform. (7). Launch zone.

The first two Ariane 5 evaluation flights are scheduled for the latter part of 1995 and the beginning of 1996. It is estimated that [Ariane 5] will be in service until the year 2015.

2. Ensemble de Lancement Ariane [Launch Site] ELA-3

2.1 Characteristics

ELA-3 was designed basically along the same lines as ELA-2, with the preparation zone separate from the launch zone. By simplifying operations at the launch zone, the accident rate can be reduced greatly. For example, to provide passageways and install protective equipment at different heights on the launch vehicle, the fixed final assembly building (BAF), which is in the safety zone far away from the launch platform, is used instead of the mobile service crane used in ELA-2. In this way, it is not necessary to transport the launch vehicle on a mobile launch platform to the launch zone until countdown starts (eight hours before liftoff).

Because the simplified umbilical tower is affixed to the mobile launch platform and is conveyed together with the rocket, the procedure of dropping off and reattaching the umbilical pipeline is avoided. This change was possible because the upper part of Ariane 5 is simpler than that of Ariane 4, and most umbilical pipeline attachment operations can be carried out directly between the mobile launch platform and the lower part of the launch vehicle.

The automated (computerized) ground service testing system (remote control monitoring and command of ground emergency supplies, air conditioning, ignition conditions[1], and other systems) is separate from launch vehicle checkup (rocket filling, pressurization, rocket-borne electricity, and the pre-liftoff countdown).

ELA-3, which is adjacent to ELA-2, is split into two zones: the preparation zone and the launch zone.

Assembly and related operations on the launch vehicle and payload are carried out in the preparation zone. Its main facilities include: the BIL Batiment d'Integration Lanceur (launcher integration building), the BAF Batiment d'Assemblage Final (final assembly building), and the CDL-3 Centre De Lancement 3 (launch control center).

[1] Literal translation of "*huo*^{3}*qing*^{2}."

The launch zone is 1800 meters to the north of the preparation zone. The launcher integration building is about 400 meters away from the launch control center and 600 meters from the final assembly building. These distances were considered from the point of view of safety and determined through calculation and analysis. The two zones and the buildings are connected by double track railways. The railway between the BAF and the BIL is approximately 1200 meters long, and the railway between the BAF and the launch zone (ZL-3) is about 2700 meters long.

2.2 Facilities of the Preparation Area

2.21 Launcher Integration Building (BIL)

The launcher integration building has a steel structure, is 127 meters long, 31 meters wide, 58 meters high, and can be divided into three parts:

a. Rocket storage hall. This hall has a roof, and its outer surfaces have protective measures against the rain. It is 83 meters long by 26 meters wide, and is not air conditioned. There are two cranes inside it. When the 30-meter-long cryogenic core stage, the launch vehicle instrument compartment, and the storable propellant substage are transported here by sea and land, they are directly deposited in the hall along with the transport container.

b. Cryogenic core stage erection hall. The 39-meter-long core stage erection hall is immediately adjacent to the storage hall, and is sealed but not air conditioned. It has a crane inside with lifting power of 30 tons and lifting height of 47 meters. The crane can erect core stages that are transported here horizontally so that they can be easily integrated.

c. Rocket integration hall. This is an air-conditioned hall 43 meters long, 30 meters wide, and 58 meters high adjacent to the erection hall, with a well-sealed sliding door between [the two halls]. This hall also has a door for entry of the solid rocket booster (SRB). The core stage, the rocket instrument compartment, the SRB, and the storable propellant substage are brought together here and are integrated into a whole on the mobile launch platform. Operations require the support of a seven-level fixed-height steel service platform on the upper part of the mobile launch platform [which can] reach every height on the rocket to carry out integration and testing.

On the bottom level of the building (the lower part), in front of the mobile platform, there is a zone 11 meters wide by 30 meters long which is the starting point of the railway to the booster integration building; in other words, it is the terminal point of the railway used when boosters are transported to this hall. In addition, the containers in which the launch vehicle instrument compartment and the storable propellant stage are loaded are transported here by tractor

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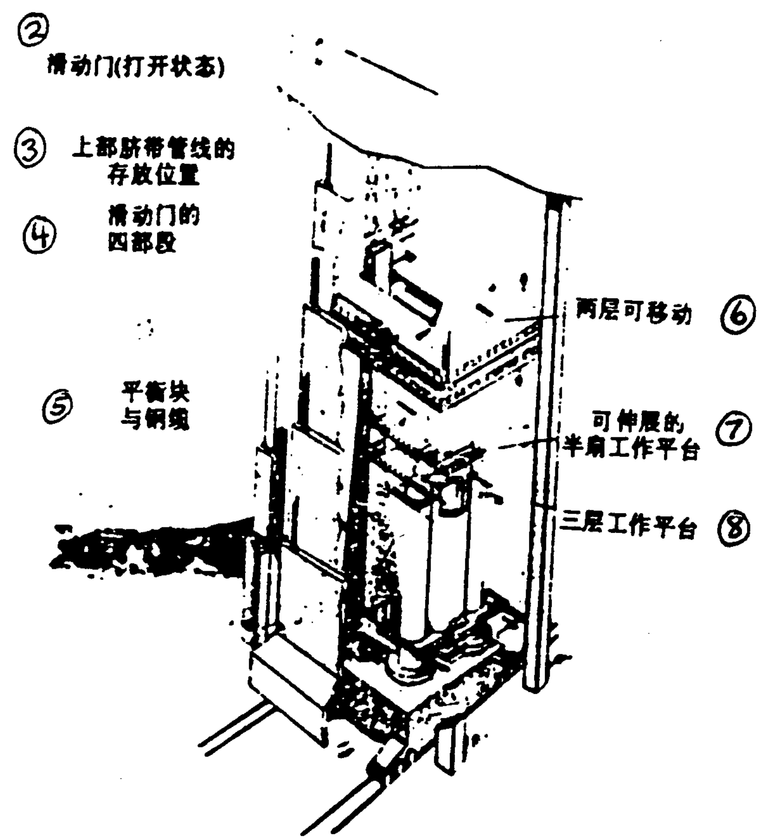
and opened in this zone.

The third door of this hall is for rollout of the launch-ready integrated rocket (including the core stage mated to the upper stage, the rocket instrument compartment, and the boosters) on its mobile launching platform from here to the final assembly building.

2.2.2 Final Assembly Building (BAF)



① 图 2 最后组装厂房里面的三层工作平台

Key: (1). Figure 2 Three-level service platform inside the final assembly building. (2). Sliding door (open). (3). Upper umbilical pipeline in insertion position. (4). Four-section sliding door. (5). Counterbalance and steel cable. (6). Two movable floors. (7). Extendable partial service platform. (8). Three-level service platform.

Construction was begun on this building in 1993 and is projected to be completed in the first quarter of 1995. This building is 85 meters long, 52 meters wide, and 83 meters high, is an air-conditioned all-steel structure, and can be divided into the following parts:

a. Sealed hall. The payload and the fairing are assembled to form the upper composite here. This hall is separated into two rooms, one where the two halves of the fairing are integrated, and the other where the upper composite is assembled. Inside it is a crane with lifting power of 40 tons. The hall is 30 meters long by 30 meters wide, and is a class 100,000 air-conditioned clean room.

Outside the hall and behind the two rooms, there are other facilities such as a storage room (which is connected to the sealed hall through an artificial air lock), an upper stage inspection platform, and two terminal debugging areas for conventional electrical equipment.

b. Assembly hall. This hall is located across from the sealed hall, and can be divided into two parts: the launcher lower section assembly area (the low area)

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and the launcher upper section and payload area (the high area).

The areas have entry facilities similar to those of the BIL, and their elevator mechanisms can stop at any level needed. This hall is 31 meters long by 31 meters wide and is air conditioned.

In the assembly hall, if two payloads (dual satellites) are being mated, the bottom payload must first be mated to the upper section of the launch vehicle before the upper payload is mated. There is a three-tiered service platform 24 meters long by 18 meters wide in the hall. The lower-level service platform is fixed and has an entryway to the rocket instrument compartment and the lower payload. The two upper levels are service platforms that can be raised or lowered and have entryways to the upper payload and the fairing. This hall also has class 100,000 air-conditioned facilities. A crane with 30-ton lifting power can carry out operations in the hall, and fulfills the needs of the service platform from the ground up to all three levels (see Figure 2).

c. Other facilities.

• Main air lock. Located in the middle of the building between the sealed hall and the assembly hall, 30 meters long by 19 meters wide. Equipment and components for the launch vehicle and payload enter the building through this air lock. It is also fitted with a class 100,000 clean air conditioner. A barrel-shaped structure 12 meters high by 8.5 meters wide stands in the middle of the air lock. It is used to raise the launch vehicle's upper composite to the high area. The cranes in the sealed room and the assembly hall can both be driven into this air lock.

• Clean storage room. A class 100,000 air-conditioned clean room behind the main air lock, used for storing clean tools.

• Entrances/exits. The door through which the launch vehicle enters and exits the building is a four-segmented vertical sliding door 62 meters high and 24 meters wide. The door for ingress to the main air lock is also a vertical sliding door, 21 meters high by 12 meters wide.

2.2.3 Launch Control Center 3 (CDL-3)

The launch control center is divided into protected and unprotected facilities:

a. Protected facilities. Three floors are reinforced with concrete, and can withstand 10 tons of force at 120 meters per second. Within these limits, both equipment and personnel can be protected. Inside are two completely independent testing rooms (which can simultaneously monitor two launch vehicles) and three payload control rooms with related operations control equipment.

b. Unprotected facilities. Primarily offices, conference rooms, and computer rooms.

2.3 Launch Zone (ZL)

The launch zone facilities are relatively simple (see Figure 3). Here, operations are only carried out after the countdown is about to begin.

a. A concrete launch platform base, which is affixed to the top of the mobile launch platform by riveting. A water-cooled steel diversion trough in the middle of the base is for directing the flame of the core stage engines, and the two diversion troughs on both sides are used to direct the flames of the solid rocket boosters. Large quantities of flowing water are used to reduce noise at the diversion trough exits. Noise reduction tests were done in Europe using scale models of the Ariane 5 in order to come up with the best noise reduction system at the launch zone.

b. A building next to the launch platform base is used as a shelter for electrical and fluid equipment.

c. A mobile storage tank shed for liquid oxygen, liquid hydrogen, and liquid nitrogen is located about 200 meters from the launching platform.

d. A burning pool for disposal of waste hydrogen.

e. A 90-meter-tall water tower which can store 1500 cubic meters of water. Its primary use is to provide water for cooling operations.

f. Three pylons for lightning protection surround the launch platform base.

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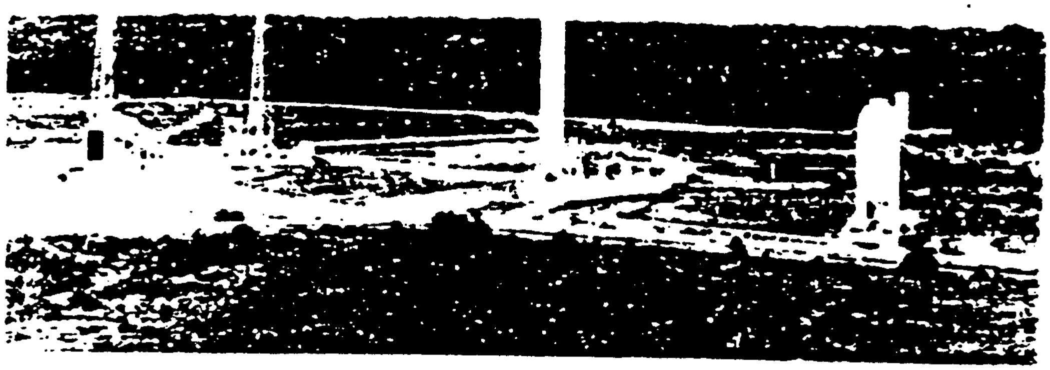

图 3 阿里安 5 的发射区

Key: Figure 3 Ariane 5 launch zone.

2.4 Mobile Launch Platforms (LT)

Two completely identical mobile launch platforms were manufactured for Ariane 5, with the aim of increasing frequency of launches. The mobile launch platforms are 25 meters long by 21 meters wide, have a box-like steel structure, and have an empty weight of 1000 tons and loaded weight of 1500 tons. [They have] 16 dual-axle bogies, move along rails, have a maximum speed of four kilometers per hour, and are towed by two tractors. If one tractor breaks down, the other can continue to carry out the mission.

The mobile launch platforms have three levels: one is for fluid equipment, another for the command and control system, and the remaining one for power sources and air conditioning. All equipment is installed in noise-reducing, positive-pressure, ventilated rooms with air conditioning, and electrical equipment is suspended on shock absorbers.

Associated umbilical pipelines and fluid pipelines are transported along with the rocket on the mobile launch platforms.

2.5 Railway

The buildings and launch zones are all connected by double-track railways. Their gauge is 16 meters, and by using a switching system 376 meters from the BAF, the platforms can be sent directly to the BIL or the launch zone.

2.6 Fluid Processing Equipment

The Ariane 5 core stage will be filled with approximately 130 tons of liquid oxygen. In terms of volume, this is 14 times as much as that used by the third stage of today's Ariane 4. At ELA-2, a plant for production of liquid oxygen (LOX) and liquid nitrogen (LN_2) for Ariane 4 has been modified according to requirements for Ariane 5. Daily production of LOX is 14 cubic meters, and daily production of LN_2 is 60 cubic meters. There are five 140-cubic-meter volume and sixteen 20-cubic-meter volume movable LOX canisters. Production capacity of nitrogen has also doubled and redoubled to meet the ever-increasing needs of the launch positions at the Guiana Space Center. At this position, compressed air and helium are sent to users through a special underground network of pipes.

The Ariane 5 takes on 27 tons of liquid hydrogen (LH_2), 13.5 times as much as Ariane 4, which holds 2 tons. From logistical, economic, and safety

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standpoints, the LH_2 containers that have traditionally been purchased cannot fit the needs of Ariane 5. Thus, a highly automated LH_2 production plant has appeared at the launching position.

Since 1992, a new plant has gone into operation. It produces LH_2 through reclaimed methyl alcohol methods and can produce up to 33 cubic meters per day. There are five 320-cubic-meter volume mobile LH_2 canisters. Three of these are transported 2.5 kilometers along a highway to the launch zone before launching. The specialized canister towing truck is equipped with a hydraulic lifting system and has eight axles and 64 wheels. Following a launch, the canisters are brought back to the production plant to recover the "evaporated" portion, but due to loss during transportation, the amount recovered is very small.

The distribution of fluid processing facilities is as follows: production and storage of compressed air, nitrogen, and helium all take place at the preparation zone. In addition, they are all shared by Ariane 4 and Ariane 5, and [the fluids] are sent to the proper facilities as needed.

Storage of liquid oxygen, liquid hydrogen, and liquid nitrogen is [carried out] at the launch zone, using mobile canisters.

There are special rooms in the mobile launch platform structure for liquid distribution, adjustment, and control systems.

2.7 Command and Control Systems

This part comprises the following four subsystems.

2.7.1 General tracking-telemetry and control[2] system

The general tracking-telemetry and control system can manage, control, and monitor the applications of general equipment that does not have direct contact with the launch vehicle at the launch site, such as power sources, air conditioning, ignition condition examination, and other equipment.

This system is composed of the front-end processors distributed among the BIL, BAF, ZL,

[2] Can also be translated as "measurement and control" or "testing and control."

LT, and the on-line supervisory systems[3] of the control center. This system is driven by the control panel in the launch control center. There is also a complete backup system.

2.7.2 Operations, command, and tracking-telemetry and control system

This system is used to drive and control launch vehicles and launch vehicle/ground facilities interfaces. It is made up of the following components:

a. Front-end processors on line with ground and rocket-borne processing systems. These can be used for obtaining relevant parameters, processing data, transmitting commands, and managing automatic operations. They are all located in the mobile launching platforms, except for one front-end processor in the launch zone building;

b. Processing devices made up of operation execution units (including manual procedures and automatic methods), and data memory filing devices and administrative devices;

c. A network of processing devices and front-end processors;

d. The intercoms at the control panel and in the control station room can act as supplementary equipment to compensate for the operations room.

Backup systems are set up for the operations command and tracking-telemetry and control systems.

A safety system independent of the operation system, which includes the secure front-end processor in the mobile platform, is on line with the control panel in the control room. This system is not connected to the hardware and software states of the functional system, and ensures safety for the launch vehicle and ground equipment through automatic and manual safety command devices.

In the event that the operation command and tracking-telemetry and control system should malfunction, the completely independent manual safety system can return the ground equipment and launch vehicle to a safe condition, especially during the discharge process of the cryogenic

[3] Literally, "*guan*^{3}*li*^{3}*ji*^{1}" means "management machines."

core stage.

Because there are two operations rooms and two mobile launch platforms, there are also two independent sets of operations command and tracking-telemetry and control systems. Each mobile launch platform can go on-line with the operations rooms.

The Ariane 5 launch vehicle adopted a tracking-telemetry and control system for the purpose of being able to express the innovativeness of the Ariane project. Today, a series of tracking-telemetry and control systems with identical specifications, which are suited for tracking-telemetry and control of all stages and can be used in Europe or Guiana, is being developed for general use. Its goals are to reduce development costs and to assure tracking-telemetry and control standards for different tracking-telemetry and control systems, so that, during the course of the launch in Guiana, tests of the same stage can be repeated in exactly the same way at the European production sources.

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2.7.3 Upper portion tracking-telemetry and control system

This system is used for tracking-telemetry and control of the hot/cold state[4] electrical system and corresponding electrical cables of the launch vehicle upper composite before the launch vehicle is assembled, and is also used to test Speltra [Structure porteuse externe pour lancements triples Ariane] satellites, fairings, and payload adapters. The upper portion tracking-telemetry and control system is located in the BAF, near the sealed hall.

2.7.4 Payload tracking-telemetry and control

After the payload arrives in Guiana, it is sent to the payload preparation and testing building (that is, the S_1 building where the main testing system is located), 20 kilometers from ELA-3.

Afterwards, the payload is sent to the S_3 building next to ELA-3, [engines are] filled with propellant, and the apogee engines, which carry solid propellant, are installed. During this time,

[4] Literal translation of "*leng³re⁴tai⁴*."

each payload is connected to the nearby testing terminal equipment (COTE) so that it can be charged [with electricity], transmit commands, and measure data obtained. Testing terminal equipment is controlled by the remote control panel in the S_3 building and is connected to the testing system in the S_1 building.

When the upper payload is sent to the BAF for encapsulation, testing terminal equipment should be set up at a certain position near the encapsulation hall. The remote control and testing panel should also be sent to the launch control center.

After the two payloads are mated with the carrier vehicle, the testing terminal equipment is installed at the mobile launch platforms.

While the carrier vehicle is being transported between the BAF and ZL, a radio frequency network provides communication between the payload and the tracking-telemetry and control system in S_1. The radio network also provides communication between the remote control and testing panel and the terminal equipment.

At the launch zone, communication with the payload and the S_1 building's tracking-telemetry and control is [carried out] through radio frequencies (RF), while communication with the remote control panel (RCS) and the testing terminal equipment is [carried out] through fixed networks.

3. Design and Operation Requirements

The purpose of the Ariane 5 ground operations facilities is close correspondence with the design of the launch site. The principles abided by [at the facilities] are:

a. All mechanical integration is carried out in the launch vehicle integration building. There is no intermediate function testing; function testing is carried out on each part in parallel when each part is in a semi-assembled state.

b. Because the electrical testing equipment and testing procedures used for all stages of the carrier vehicle at ELA-3 are basically the same as those used by manufacturers in Europe, comparisons and choices can be made.

c. Operations and testing should be highly automated, to improve reproducibility and assure safety.

d. All tests on the launch vehicle should be completed in the integration building before mating with the payload.

e. According to requirements, the launch vehicle is not transported to the launching zone for filling of the main stage until before the countdown, because the amount of time the launch vehicle is exposed to the outside environment should be limited.

f. If the launch must be delayed, or if the launch vehicle or payload malfunction, the launch vehicle can stay at the launch zone.

3.1 Operations at the Launcher Integration Building

Relevant operations at the launcher integration building take 13 days, and include mechanical integration (such as core stage erection, instrument module and storable propellant substage integration, and SRB integration) and electric and pneumatic operations, as well as function testing.

Operations after the launch vehicle enters the final assembly building take eight days. They comprise a series of assemblies and cleanings of the payload, as well as integration and testing of the launch vehicle and the payload, and last until the launch vehicle and the payload are prepared to be sent to the launch zone.

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3.2 Transportation from the Final Assembly Building to the Launch Zone

The launch vehicle is not transported from the final assembly building to the launch zone until the day of the launch. It takes about four hours from disconnection from the platform to completion of connection operations in the launch zone. Transportation of the uncharged launch vehicle to the launch zone takes approximately one hour. At this time, the cryogenic core stage's automatic safety device goes into operation and the payload is provided with electricity from the power supply. The payload is controlled by the launch control center and the S_1 tracking-telemetry and control system, while simultaneously its batteries are charged.

The payload and certain sections of the launch vehicle require ventilation to reduce as much as possible the effects of heat and component contamination which is caused by propellant leakage.

During transportation, platform general-equipment control units are connected to the launch platform, the power sources, the electrical equipment, and the ventilation installations, in order to ventilate or air-condition the mobile launch platform.

3.3 Countdown to Launch

During the final preparation phase at the launch zone, all operations that were not carried out at the final assembly building must be completed. These operations are carried out by the launch control center through automatic methods. At this time, personnel must leave the launch zone. Primary operations include:

a. Cleaning of the cryogenic core stage engines;

b. Filling the cryogenic core stage with LN_2 and LOX;

c. Pre-launch adding of LN_2 and LOX;

d. Pressurizing the high-pressure containers of the cryogenic core stage and the solid rocket boosters to liftoff levels;

e. Activating and inspecting launch vehicle circuits.

Countdown procedures last six hours, until synchronized procedures begin.

3.4 Synchronized Procedures

This is a set of fully automatic procedures carried out by the operations command and control system It is synchronous with the launch base's overall countdown system. It makes preparations for entry ignition state for the launch vehicle until liftoff. The procedures last six minutes altogether. During this period of time, if a test is abnormal, or if the launch base equipment should malfunction and the countdown is aborted, the synchronized procedures can be stopped through the operations command and control system.

If the synchronized procedures cease functioning, similar to the above-mentioned situation, the countdown procedures resume. This is analogous to the state of affairs before the first synchronized procedures begin. Therefore, if [the synchronized procedures] always start over again in the same way, the countdown procedures will be suspended.

The main operations carried out in these procedures are:

a. Cessation of LOX and LN_2 addition;

b. Removal of igniter safety shield;

c. Pressurization of cryogenic main stage to liftoff levels;

d. On-board cooling of main stage's cryogenic engines;

e. Turning-on of ground and on-board power source switches;

f. Inspection of ground and rocket-borne interfaces;

g. Supplying water to flame diverters;

h. Turning-on of ground and rocket communication management systems;

i. Entry of inertial reference system into launch state.

There is a three hour launch window during each countdown. In this period, it is possible to repeatedly implement synchronized procedures.

If it has not been possible to carry out the launch by the end of the three hour launch window, the countdown procedure should be aborted, and the launch vehicle should return to its pre-countdown state.

4. Firing Range[5] Modernization

Besides investing in Ariane 5 installations, the French space center (CNES) in Guiana is also renovating or replacing its safeguard system with more modern and reliable systems. It is implementing this simultaneously with the Ariane 5 project itself. The ESA provides funds for this project, and CNES carries out the engineering tasks and takes charge of purchases and administering the project.

A modernization project called Centre Spatiale Guyanais 2000 (Guiana Space Center 2000) began in 1991 and includes the following:

a. Rapid display of tracking and flight paths. Radar and data processing systems are being renovated to ensure their longevity up to the year 2010 or 2015, to improve liftoff safety performance and reduce experimental costs.

b. The ground communications system, including the operation communications system and the business communications system, are being changed over to optical cable networks. Telephones, facsimile machines, intercoms, data processing, and video terminals have already been renovated.

c. Telemetry and flight terminal systems, including ground processing systems and the adaptation, antenna, data storage, and data transmission of the Ariane 5 telemetry data processing program, as well as ground telemetry stations, have all been renovated or expanded. In order to better carry out launches and to better understand the needs of entry into synchronous transfer orbits, there are ground stations in the Kourou area, the Natal region of Brazil, Ascension Island, South Africa, and other places.

d. Coordination between weather forecasts and safety and operation systems, to improve meteorological observation and provide favorable conditions for better completing all relevant

[5] Probably should be "Launch Site."

tasks.

e. There are investments in other items such as photography, video recording, and launch observation bases.

The above projects are being put into effect under the premise that they will not impede the present Ariane 4 launch missions. Certain parts of the projects have been completed and certified, and now provide safeguards for the Ariane 4 launch mission.

5. Testing and Appraisal (Acceptance) of Ground Facilities

By using the launch platform as a testing stand, it is possible to save the costs of specially building a testing stand in Europe. Before transportation to Kourou, tests of every subsystem must be carried out in accordance with the requirements of the European firms. After installation in the Kourou region, other tests must be carried out according to the grade of each subsystem (this is called phase 1); afterwards, another series of tests must be carried out (in phases 2 through 5). In these tests, more and more subsystems and more and more automatic control and command systems are added. Before implementation, tests of the overall system must be completed, such as hot tests of the cryogenic main stage on the launching platform.

In 1991, the "general testing system" was installed and tested. It has been used in operations since October of that year. In 1992 and 1993, the first filling test of a model of the main stage on the launching platform (called the "battleship project") was completed. The ground systems and manual procedures for filling of liquid oxygen, liquid hydrogen, liquid nitrogen, and liquid helium were also tested and certified. Several other related systems were also tested, such as emissions and combustion, extinguishing, and drainage of the Vulcain engine cooling [system] and related control and command systems.

In 1994, the first operations, control, and command system (CCO) was installed and tested, and the first main stage hot test was conducted in the same year. From the end of 1994 to the beginning of 1995, a series of relevant experiments and spare part performance tests were conducted in the launcher integration building and the final assembly building, as well as on the mobile launch platforms and the launching platform.

Before the first launch at the end of 1995, modernized management and operations will be realized at Ariane 5's ground facilities and launch site, and the static ignition facilities of the solid rocket boosters and cryogenic main engines will be used. Two launch tests will be carried out.

Total investment is one billion ECUs, including the cost of operations before the first civil launch in 1996. The life span of these facilities is estimated to be at least 100 launches. The goal of Ariane 5 is to occupy 50 percent of the present Ariane 4 launch market.

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6. Conclusions

In view of the present situation, the Ariane 5 ground facilities conform to all design requirements. A launch rate of eight times per year will be easy to achieve, because two launch vehicles can be prepared simultaneously. For example, when one launch vehicle has entered the final assembly building or is about to be transported to the launch zone, a second launch vehicle can be integrated in the launcher integration building at the same time. [This is possible] because ELA-3 has two operations rooms, two mobile launch platforms, and two functioning tracking-telemetry and control systems.

Other aspects, such as low rate of failure, high reliability, a high degree of automation, and reduced costs can all satisfy requirements. At present, the cost of launching Ariane 5 is ten percent less than that of Ariane 4 (model 44L).

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