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Paper Session II-A - Current Status of the Ariane 4 Program and of the Ariane 5 Development

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Current Status of the Ariane 4 Program and of the Ariane 5 Development

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Abstract

This paper provides an overview of the commercial situation of Arianespace, a general update regarding its technical and operational activities and its near and medium term prospects.

A summary of the Ariane 4 "track record" is given and the latest improvement to its third stage, the H10 III, is presented. Operational improvements that reduce the interval between two consecutive launches are also addressed.

The rationale for going to Ariane 5 is discussed and the current status of the Ariane 5 development program is reviewed. The Ariane 4 to Ariane 5 transition is outlined.

The Ariane 4 "track record"

Since the so-called 401 maiden flight in June 1988, 34 Ariane 4 vehicles in various configurations have flown, successfully injecting 52 satellites and 20 auxiliary payloads into orbit (Figure 1). Two failures, V36 in February 1990, a quality-related failure, and V63, last January have marred its record.

Operational buildup of the Ariane 4 was gradual with 2 launches in 1988, 4 in 1989, 6 in 1990 (in spite of the failure) and finally 8 in 1991: Arianespace managed to make up the lost ground due to V36 in just 18 months. Subsequent slow down in the launch rhythm to 7 in both 1992 and 1993 was mostly a consequence of Payloads availability. This was particularly true last year in 1993 when the first launch of the year only occurred in May: Galaxy IV had to be sent back to California for rework 2 weeks only before it was due for launch in January. The forced interruption of launches was however put to profit to carry out all the necessary heavy maintenance of the launch facilities and in particular of the pad. Another delay occurred in September when Spot experienced a problem during launch site check out operations, postponing the launch from the end of August to the end of September. In spite of those setbacks, Arianespace was able to meet its contractual commitments as set forth in its published Manifest, securing the last 4 launches of the year in less than 3 months (September 25 through December 17, 1993).

May 1993 also saw the maiden flight of the last version of the Ariane 4 that had not yet been used: the Ariane 42L, featuring two liquid strap-on boosters.

¹ Director of Engineering
² President
Figure 1. The 6 versions of Ariane 4 with number of flights and of payloads injected.

<table>
<thead>
<tr>
<th></th>
<th>AR40</th>
<th>AR42P</th>
<th>AR44P</th>
<th>AR42L</th>
<th>AR44LP</th>
<th>AR44L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flights</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>10</td>
<td>14</td>
</tr>
<tr>
<td>S/C</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>17</td>
<td>23</td>
</tr>
<tr>
<td>Aux.</td>
<td>16</td>
<td>2</td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Launch delays induced by V63 in January 1994 are expected to be made up by the end of 1994. The general Ariane space objective of achieving 30 launches in the 1994-95-96 time frame remains.

Orbit Injection Flight Data

Figures 2 & 3 provide the orbit injection accuracy figures that have been recorded for all Ariane 4 launches. They clearly show the quality and the consistency of orbit deliveries of the vehicle.
The Ariane 4 standard Geostationary Transfer Orbit (GTO) is 35,975 km (apogee) x 200 km (perigee) x 7° inclination. Associated standard deviations are 52 km, 1.0 km and 0.018° respectively. Standard deviations for sun-synchronous orbits are 0.7 km for altitude and 0.032° for inclination (V35, V44 and V59). They are similar for the high inclination circular orbit used on V52 to launch Topex-Poseidon, a joint US/French oceanography mission.

Operational Performance of the Ariane Launch System

As important to our Customers as the technical quality of the Arianespace launch services is the timeliness with which it is delivered. Figure 5 is a measure of the maturity the Ariane 4 launch system operations have reached; it shows that most launches go on time (Reference for those statistics is the beginning of the countdown, i.e., the morning of J-1 (Launch Day - 1) when the storable propellants are loaded into first and second stages and liquid strap-on boosters if any).

The causes for those launch delays are broken down in the following pie chart (Figure 4).

Note: Flights delayed by one day or more are accounted for twice in these statistics.
Availibility of ELA2 Launch pad since March 86

Figure 5. Operational performance of the Ariane Launch system

Ariane 4 improvements

The Ariane 4 launch vehicle is the result of a progressive evolution of the European launcher from the original Ariane 1 to Ariane 2 & 3 and finally Ariane 4 with successive stretches and performance improvements of all stages, addition of solid and/or liquid strap-on boosters, development of multiple launch structures and fairings.

In parallel with actual vehicle development and improvements Ariane launch operations evolved from a conventional "build-on-pad" concept to the currently used Integrate, Test and Launch concept.

Vehicle Performances:

The current performances of the Ariane 4 to Geostationary Transfer Orbit (200 km x 35800 km, 7° degree inclination) are those documented in the User's Manual and are recalled in Table 1.

<table>
<thead>
<tr>
<th>Ariane Model</th>
<th>Baseline Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ariane 40</td>
<td>2,050 kg</td>
</tr>
<tr>
<td>Ariane 42P</td>
<td>2,840 kg</td>
</tr>
<tr>
<td>Ariane 44P</td>
<td>3,320 kg</td>
</tr>
<tr>
<td>Ariane 42L</td>
<td>3,380 kg</td>
</tr>
<tr>
<td>Ariane 44LP</td>
<td>4,060 kg</td>
</tr>
<tr>
<td>Ariane 44L</td>
<td>4,520 kg</td>
</tr>
</tbody>
</table>

Coefficients to be applied to the previous figures in case of a non-standard, subsynchronous, GTO orbit are also provided. (In that case, the Payload would carry out Perigee Velocity Augmentation type maneuvers to reach synchronous altitude - the Galaxy satellites thus gained almost a year and a half by filling their propellant tanks to capacity at liftoff).
Table 2. Coefficients to be applied to standard GTO performance figures as a function of apogee altitude (km)

<table>
<thead>
<tr>
<th>Version</th>
<th>34,000</th>
<th>32,000</th>
<th>30,000</th>
<th>25,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR42P</td>
<td>1.012</td>
<td>1.030</td>
<td>1.049</td>
<td>1.105</td>
</tr>
<tr>
<td>AR44P</td>
<td>1.012</td>
<td>1.029</td>
<td>1.048</td>
<td>1.102</td>
</tr>
<tr>
<td>AR42L</td>
<td>1.017</td>
<td>1.036</td>
<td>1.056</td>
<td>1.112</td>
</tr>
<tr>
<td>AR44LP</td>
<td>1.010</td>
<td>1.024</td>
<td>1.040</td>
<td>1.092</td>
</tr>
<tr>
<td>AR44L</td>
<td>1.017</td>
<td>1.036</td>
<td>1.056</td>
<td>1.112</td>
</tr>
</tbody>
</table>

Launcher improvement

A new and final improvement of the third stage, the so-called H10 III, is currently under development and qualification. It will fly at the end of this year for the first time (Flight V70 or Y71).

Whereas the previous improvement (the H10+) had led to a fairly substantial development program (both the LO₂ and the LH₂ cylindrical parts of the tanks were lengthened and the tank manufacturing process changed), this latest evolution is remarkably simple considering the benefits it will provide in terms of performance.

The common bulkhead has been slightly moved upward and the LH₂ top bulkhead was raised by 5 cm without changing the interfaces of the stage itself: the LO₂ loading capacity has thus been increased by 700 kg and the LO₂/LH₂ mixture ratio changed with a slight decrease (1.7 sec.) in the Iₚ of the engine. The corresponding burn time of the third stage engine now attains a duration of 780 seconds (over 30 additional seconds).

The following performance figures are expected:

Table 3. Expected Ariane 4 performance with the H10 III third stage

<table>
<thead>
<tr>
<th>Version</th>
<th>Load (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ariane 40</td>
<td>2,070 kg</td>
</tr>
<tr>
<td>Ariane 42P</td>
<td>2,920 kg</td>
</tr>
<tr>
<td>Ariane 44P</td>
<td>3,380 kg</td>
</tr>
<tr>
<td>Ariane 42L</td>
<td>3,450 kg</td>
</tr>
<tr>
<td>Ariane 44LP</td>
<td>4,170 kg</td>
</tr>
<tr>
<td>Ariane 44L</td>
<td>4,700 kg</td>
</tr>
</tbody>
</table>

Operational Improvements

In anticipation of an increase in launch rates, an internal review had been initiated in 1990 by Arianespace management to seek improvements to the launch preparation activities in Kourou.

The scope of this review was broadened and the implementation of its recommendations accelerated in the aftermath of the V36 accident. All launch operations procedures were revisited and most rewritten. The actual number of operations was significantly reduced (from 1,200 to 700 approximately). At the same time, a powerful, specially-developed real-time scheduling tool became available (Planops). This allows managers to stay abreast of the operations being conducted on the launch vehicle with a 30-minute accuracy. It also enables them to reschedule in real time and at any time any or all operations to react to a problem on a specific operation, the unavailability of an operator or of a ground means or to safety constraints. (Ref. 1)

Tangible evidence of these improvements can be seen in the minimum necessary interval between launches that has been steadily decreasing from 5 to 4 and now to 3.5 to 3 weeks.
Commercial status

In 1993, Arianespace played a significant role in the emergence of new business in the US by launching:
- the first of the latest generation of Intelsat satellites, Intelsat 7 (Space Systems/Loral-built),
- the first of the new generation of Mexican satellites (Solidaridad 1),
- the first national Spacecraft for Thailand (Thai com 1) and
- the first US-domestic direct broadcast satellite, DBS-1 for DirecTV and USSB.

The three latter satellites were built by Hughes Space & Communications.

In 1994, all but the first launch (V63), i.e., 9 launches, feature at least one US-built satellite and 7 launches feature Hughes-built satellites.

Arianespace's current backlog (March 1994) stands as 39 contracts, 6 of which are with American customers and 9 with International Organizations. 26 of these 39 satellites are US-built.

Why Ariane 5?

One must bear in mind that the original development of the Ariane 1, 2, 3 and 4 family stemmed from the political will of Europe to ensure their autonomous access to Space (recalling that the US originally would only orbit foreign or European payloads under the provision they would not be used commercially).

The commercial success of the Ariane program was thus an indirect but welcome fallout of these initial political and strategic stakes; it was helped along by some shrewd technical choices in the early 80's and some farsighted commercial vision: the Ariane launch vehicle was a product that was adapted to and evolved with the market. Arianespace, created in 1980, remains a very efficient commercial organization that has captured and secured over 50% of the worldwide commercial market.

This commercial success has now become an intrinsic condition for the autonomous and economical access of Europe to Space:

- The high launch rates have helped establish a very strong and organized industrial basis for the production of the launch vehicle. Competent and stable teams have been set up and contribute to an efficient system, responsive in case of problems.

- Reliability and productivity improvements have been achieved. They would never have been reached by relying solely on Governmental missions (these only represent around two launches a year).

- The launch rate increase and a continuous policy of dual launches have led to a decrease of launch costs for all missions, commercial and governmental: it is therefore in Europe's best interest that Arianespace captures as large a share of the market and launches as often as possible to diminish its own cost of access to Space.

This significance of the commercial market in attaining purely governmental goals is specific to Europe. Both the US and Russia, formerly the USSR, can rely on a governmental market that is sufficiently important to reach the above objectives: 70 to 80% of American launches are governmental. For instance launch rates for noncommercial purposes are around 8 to 10 per year for Delta.
Reliability and cost of access to Space for Europe are thus contingent on the existence of a strong vehicle on the commercial market.

1987: Go-ahead for Ariane 5

The evolution of satellite characteristics, the need to improve the European stance vis a vis of the competition, the need for significantly improved performances into low earth orbit and the mere fact that Ariane 4 had reached the end of possible development were the main drivers that led Europe to go forward with the development of Ariane 5: a completely new, cost-driven launch vehicle with a reliability goal of 0.985. Seven years later, it seems that Ariane 5 will indeed be the vehicle adapted to the needs of the next decades.

Brief Vehicle Description

The bottom part of the launcher, common to all missions, consists of a main cryotechnic core stage and of two large solid boosters. The upper part is tailored to the mission and will feature for GTO missions a reignitable conventional MMH/N₂O₄ upper stage, a vehicle equipment bay and the payload composite.

Each of the P230 solid boosters, 10 ft in diameter and 98 ft high, contains 230 metric tons (over 500,000 lb) of propellant in three segments, providing 550 metric tons of thrust (at sea level) during the first 123 seconds of flight. Cost, logistics and safety considerations led to locate the production site of the two main segments and the booster test stand in Kourou. The production facilities are today fully operational (Ref.2)

The main core stage, the H155, is propelled during a 10-minute single burn by a single Vulcain engine, ignited and checked out on ground.

The L9 upper stage fits within the inner volume of the Vehicle Equipment Bay (VEB), above the interstage skirt.

Various Payload configurations are shown in Figure 7.
Performance of the vehicle to GTO (with a perigee of 640 km, higher than the Ariane 4 200 km) is 6.8 tons or 5.9 tons in dual launch configuration.

The first two flights, 501 and 502, will be qualification flights under the responsibility of the European Space Agency. Arianespace will "take over" from the third flight, 503, currently planned at the end of 1996.

**Current development status**

The current program master schedule, shown in figure 8, targets a late 1995 maiden flight for Ariane 5, 6 months only behind the April 1995 originally planned at the inception of the program in 1987.

![Figure 8. Ariane 5 Program schedule](image)

- **System:**
  Significant progress was made in 1993 concerning system and major subsystems testing: Cryotechnic stage and Upper part structural models and Guidance system in particular. The System CDR was completed in January 1994.

- **Vulcain engine:**
  By the end of 1993, 163 firing tests had been completed with a total cumulative duration of over 36,000 seconds (with one engine seeing more than 10,000 seconds). These tests also covered the vectoring system and tolerance to failure cases.

- **Cryotechnical stage:**
  Following completion of vibration testing, the structural model was shipped to Guiana, integrated to two solid booster mockups and the launch table and served as the first operational verification tool for the ELA3 facilities. Preparations are under way for the first stage-level testing to take place in Kourou by the summer of 1994.

- **Solid boosters:**
  Two firing tests took place in 1993 with satisfactory results: the first one on February 16 (with a battleship-type casing) and the second on June 25 (with a flight-type structure).

- **Upper stage:**
  The first L9 upper stage has been integrated and accepted. It will undergo firing tests in 1994.

- **Fairing:**
  The fairing was modified following the first separation test in vacuum. A subsequent test last October was successful. Qualification testing of the Speltra (Multiple launch bearing structure) is about to begin.

- **ELA3 facilities:**
  The construction of the final assembly building, or BAF, is under way. All the other buildings have been completed and accepted. The launch vehicle operational command and control system has been accepted on site.

1994, even more so than 1993, is going to be the year of the verification of the overall consistency of the Ariane 5 launch system and associated ground facilities. System qualification of the guidance and flight program will take place and the final cycle of verification of general loads and dynamic environment will be run. Coupled loads analyses with all the major spacecraft platforms will be performed.
Validation of the ground facilities and of the automated filling, firing and control procedures are to be carried out by this summer to allow for cryotechnic stage level testing in battleship and flight standard configurations. Three more solid booster development tests are planned in 1994.

The L9 upper stage will undergo development and qualification tests in Germany. 1994 will also see the beginning of the production phase of Ariane 5 with the negotiation and implementation of contracts to Arianespace’s industrial partners for the manufacturing of an initial batch of fourteen vehicles.

Figure 9. Ariane 4 to Ariane 5 Transition (Typical)

Ariane 4 to Ariane 5 transition

36 Ariane 4 vehicles remain to be flown, 29 of them by the end of 1996 when the first commercial Ariane 5 is to be launched. The 1997 to 1999 period will be a transition phase where Ariane 4 will be gradually phased out as Ariane 5 gains momentum and its launch rate builds up.

This transition will be costly to Arianespace as two production lines and launch pads will have to be maintained and operated during that time. However this smooth transition is essential to provide our Customers with the best possible guarantee of service and maintain our strong position in an increasingly competitive international market.

Ref 1.: "Ariane launcher real-time operational planning"
Fifth Space Logistics Symposium, May 24-26, 1993, Huntsville, Alabama

Ref 2: "The Ariane 5 Booster Facilities" by P. Sartini & J. de Dalmau, ESA, Paris & Kourou
ESA Bulletin No 75, August 1993.