SPACE TRANSPORTATION SYSTEMS – SYSTEM CONCEPTS

J. Kauffmann
ESA Launcher Directorate, 8-10 rue Mario Nikis, 75738 Paris Cedex 15, France

ABSTRACT

The paper will provide a short overview of the current European launcher family, constituted by the operative Ariane 5 which will be complemented in the next near future with the European Vega launcher and Soyuz from CSG.

Possible future developments will be described which are ongoing in Europe in the frame of the ESA FLPP (Future Launcher Preparatory Programme). In general these activities are currently focussing on launch vehicle options for three different scenarios addressing the short 2013, mid (2015) and long term (2020+) timeframe.

The paper will provide an overview of the launch system concepts which are being conceived for the different scenarios.

INTRODUCTION

The DGLR S4.1 Working Group on Space Transportation Systems (Fachausschuss S4.1 Raumtransportsysteme) is a forum for members from agencies, institutions, industry and universities. Gathering and analysing information and argumentation on space transportation systems' past, status and future is the objective of the group. The analysis and documentation is coordinated around the topics

- Demand / Market, [1]
- System Concepts
- Propulsion, Structures & Subsystems (System related aspects), [2]
- Missions & Operations (incl. Ground infrastructure), [3]
- Cost (Development, Production & Operation), [4]
- Projects / Programmatics (Development & Demonstration), [5]

In line with the above mentioned organisation of the working group this paper presents the DGLR-FAS S4.1 status of discussion of the current situation regarding European launch system activities.

1. EUROPE'S FAMILY OF LAUNCHERS

Europe's family of launchers consists of Ariane 5 in 3 versions plus Vega and Soyuz from CSG, out of which currently only the Ariane 5 in the ECA and GS version are operational. All launch systems are or will be operated by Arianespace from the European spaceport (CSG) in Kourou, French-Guyana. The main features of the different launch system are described in the following.

FIG 1: The European Launcher Family

1.1. Ariane 5

Ariane 5 is since 1997 the main element of European space transportation, optimized for commercial missions to GTO. Currently three different versions exist:

- Ariane 5 ECA
- Ariane 5 GS
- Ariane 5 ES ATV

FIG 2: Ariane 5 Versions

The current workhorse is since early 2005 the latest version of the Ariane-5 launcher, the Ariane 5 ECA with its new cryogenic ESC-A upper stage. In this version the Ariane performance into GTO is about 9.6 Mg, into an 800 km SSO about 10 MG and into the ISS orbit around 20

Mg. Like the other Ariane versions, with the exception of the ES ATV, the Ariane 5 ECA features a double launch capacity.

The Ariane 5 GS is the latest evolution of the Ariane-5 Generic launcher, produced after the end of the Ariane 5 G+ series. This version integrates more recent elements produced in the frame of the Ariane 5 ECA and Ariane 5 ES ATV developments. The GS has a performance of around 6.7 MG into GTO. Only A limited number of Ariane 5 GS have been produced and will have been launched in the coming one or two years.

The ES ATV version of the Ariane 5 has been designed to place ESA's Automated Transfer Vehicle (ATV) into a 260 km circular low Earth orbit inclined to 51.6˚. The Ariane 5 ES ATV is derived from the Ariane 5 G+ and Ariane 5 ECA versions. It consists of the same lower composite as Ariane 5 ECA and will use the EAP boosters identical to those of the Ariane 5 ECA version and the same cryogenic main stage equipped with the Vulcain 2 improved engine. The upper composite is composed of a new reinforced vehicle equipment bay (VEB) to withstand flight loads with the ATV and a re-ignitable storable propulsion stage (EPS). EPS re-ignition capability has been incorporated to maximise the launcher's performance into the target orbit and to fulfil the mission requirements. The first flight of the Ariane 5 ES ATV to the ISS is planned for 2007.

1.2. Vega

The Vega launch system, which is under development since 1998 in the frame of the ESA Vega Small Launcher Development Programme, will cover the performance range on the lower end being tailored for small to medium sized satellite payloads (300 to 2000 kg) for missions to LEO and SSO.

It features a four-stage design using three solid propulsion stages and one additional liquid propulsion upper module used for attitude and orbit control as well as satellite deployment. The targeted payload capacity into a 700 km circular polar orbit is 1.5 Mg. The first flight is foreseen for 2008.

FIG 3: Vega

1.3. Soyuz

Ariane 5 and Vega will be complemented in CSG with the Russian Soyuz launcher, the world's most launched vehicle, with over 1685 manned and unmanned missions performed by the Soyuz family to date. The Soyuz is a highly versatile launch system allowing for medium GTO payloads, MEO, LEO and SSO satellites, as well as Earth escape missions.

The Soyuz 2-1-b, which includes upgrades to its propulsion system, will have its payload capability to geostationary orbit increased by 300 kg to 3000 kg, while the performance to medium Earth orbit is 1579 kg, and the Sun synchronous capacity is 4900 kg. The first flight of Soyuz from CSG is foreseen for late 2008.

FIG 4: Soyuz

1.4. Evolutions

Evolutions that are currently being considered are focussed on the European Ariane 5 and Vega launchers. A major element for the evolutions of the latter launch systems is the investigation of new upper stages reflecting the requirements for either more payload performance and/or higher mission flexibility. In general such evolutions are mainly driven by the interest to

- Increase the performance
- Increase versatility
- Maintain the industrial competences
- Reduction of cost

For Ariane possible evolutions are being investigated in the frame of the "Ariane 5 Mid-Life Evolution" line of the ESA ACEP [5] programme. The investigated possible evolutions cover improvements on sub-system and system level. For the latter an improvement of the system performance by about 2 MG into GTO over the current ECA version is targeted while allowing also for higher mission flexibility. An essential part of the performance and flexibility improvement shall be realised via the upper compound. Here different options of cryogenic upper stages either reignitable or in combination with a storable kick-stage are under investigation.

For Vega possible evolutions aim at a performance increase up to 2Mg into 700km polar orbit and 1 Mg in MEO direct. The considerations how to achieve the performance targets are still in an early state. An increase of performance of any or all of the all three SRB can be conceived as well as changes o the upper compound (Z9/Avum) with a liquid reignitable stage either cryogenic or storable.

It is worthwhile to note that the maturation of enabling technologies for future reignitable cryogenic upper stages addressing the needs of Ariane, Vega and future launchers (see below) is being performed in the CUST (Cryogenic Upper Stage Technologies) line of the ESA FLPP-2.

The numerous configurations resulting from the above listed elements will be screened first according their ability to meet the performance and technology maturity requirements. Afterwards, some selected configuration will enter into a detailed design phase aiming at establishing the technical and programmatic data required to assess the pros and cons of such a development scenario.

2. FUTURE LAUNCHERS ACTIVITIES IN ESA

The investigation of possible future launch systems for Europe is being performed in the frame of the ESA FLPP. The programme, running since 2004 and currently in its second period, is structured in the following main elements:

- System activities
- In-Flight Experimentation (IXV)
- Technology
    - Liquid Rocket Propulsion
    - Upper Stage Engine System and Technologies
    - Main Stage Engine System and Technologies
    - Solid Rocket Propulsion
    - Upper Cryogenic Stage Technologies
    - Materials and Structures
    - Other Technologies

For further details see [5]. The system concept activities within the FLPP are focussed on launcher options for two different scenarios:

- A “Long Term” scenario, addressing expendable and reusable launch system options for an NGL (Next Generation Launcher) system to be operative around 2020.
- A “Short Term” scenario addressing expendable launch system options based on existing elements or “Building Blocks” which could be operative around 2015. This scenario assumes a need for an immediate launcher development to replace Ariane 5.

The launch system concepts which are currently being considered for the two scenarios are described below.

2.1.1. Mission Requirements

As described above the main distinction between the two scenarios lies within the different timeframes for the beginning of the exploitation of the new launch systems, driving the needs for technology development. Yet, the basic mission requirements are the same.

Today, the definition of the mission requirements for these future launch system developments are characterised by the expressed interest to focus on the European institutional prior to the commercial needs with the potential to address the commercial market as an opportunity to support a cost efficient exploitation (as stated e.g. during the 2005 Council on Ministerial Level in Berlin). These institutional needs cover a wide range of missions and performances stretching from earth observation, telecommunication, science, navigation, meteorology, exploration and so forth, requiring a flexibility which is strongly affecting the launch system design.

The reference mission for both scenarios is to address European institutional needs, for LEO, MEO and GTO missions as follows:

- Single launch
- Reference performance: 5 t in GTO (performance equivalent) institutional
- Enhanced performance for commercial missions: 8 Mg in GTO for a single pay-load
- Versatility through upper stage restart capability
- Performance modulation preferably through the lower composite architecture (use of different combinations of solid propellant strap-on boosters)

2.2. NGL

A number of launch system concepts, summarized under the term NGL (Next Generation Launcher), is currently being investigated consisting of expendable and semi-reusable system concepts. Both ELV and RLV concepts are being investigated with the same time horizon and technology maturity requirements.

2.2.1. Next Generation Expendable Launcher Concepts

One driving requirement for the Next Generation ELV concepts design is the fact that the main objective is to satisfy the institutional needs, as mentioned earlier. The commercial market segment is supposed to addressed by performance enhanced versions of the basic launch concept (e.g. by means of solid propellant strap-on boosters).

Based on a two-stage architecture approach the following configuration options are being considered for the lower and the upper composite of such NGL concepts:

Lower Composite

- Solid propellant + solid Boosters
- LOX/Methane propellant + solid Boosters
- LOX/LH2 propellant + solid Boosters

For the LOX/LH2 propellant lower composite the following engine system options are addressed:

- LOX/LH2 with gas generator cycle, performance optimized engine
- LOX/LH2 with gas generator, low-cost engine
- LOX/LH2 with staged combustion engine

Upper Composite

- Cryogenic restartable (based on expander cycle)
- Storable restartable (based on Aestus/Aestus-2)
- Cryogenic + storable kick-stage
- Methane restartable (based on e.g. MIRA)
- Innovative low thrust upper stage concepts like:
  - Low thrust pressure-fed upper stage
  - Cryogenic orbital propulsion (use of fuel cells)
  - Solar thermal with solar concentrators or solar arrays
  - Electric propulsion

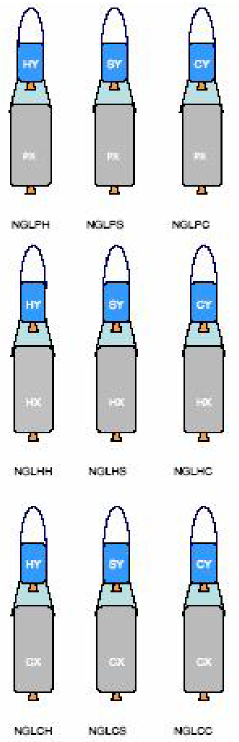

FIG 5: NG-ELV Schemes

The numerous configurations resulting from the above listed elements will be screened first according their ability to meet the performance and technology maturity requirements. Afterwards, some selected configuration will be investigated further in the course of the programme.

2.2.2. Next Generation Reusable Launcher Concepts

The RLV concepts under investigation in FLPP are focussed only on the commercial market only, being in comparison to the institutional market the only segment which can possibly allow the launch rates that could justify the development of such a launch system.

To fulfil the objective of an initial operational capability of the NGL in or about 2020 with controlled development risks, the required technologies for a given NGL concept must fulfil a defined level of maturity around 2013. The results obtained in various national and European RLV studies such as the ESA-FESTIP allow to reasonably limiting the number of categories of RLV concepts. Therefore, Single-Stage-To-Orbit (SSTO) concepts and the concepts using new air- breathing ascent propulsion systems (e.g. Scramjet) are not being regarded, as they will not meet the above mentioned technology maturity requirement.

Still, the number of possible concept candidates that could match the FLPP requirements is quite high. Accordingly, one of the first tasks during the first phase of the activity was to perform a critical re-view of existing RLV concepts and to de-fine initial design features for selected promising concepts, including the definition of system derived requirements towards the related propulsion activities. Another important task was to establish a set of RLV design guidelines so to ensure a consistent design approach. Last but not least a first version of the FLPP Technology Testing and Development Roadmap was established.

The results obtained led to consider the following categories of RLV concepts that are currently undergoing further analyses in the frame of the FLPP program:

- Sub Orbital Hopper (down-range landing)
- Semi-reusable RFS
- Semi-reusable LFBB

For further details on the concepts see [6].

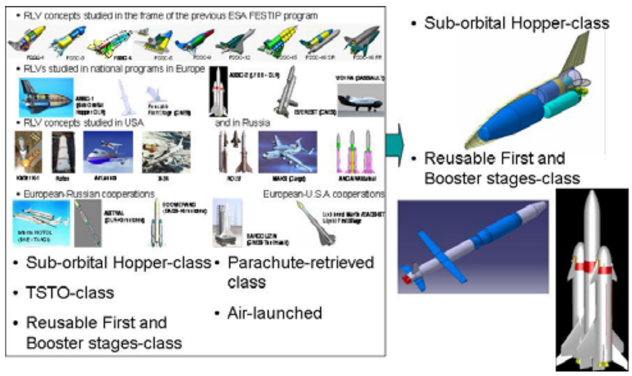

FIG 6: NG-RLV Concepts

2.3. "Building Block" Launcher Concepts

The "Building Block" launcher scenario is built on the assumption that the need for a short term development of a new launcher, replacing Ariane 5, may occur. Consequently, such a development would have to based only on existing elements and mature technologies from the Ariane 5 and Vega launch systems. These elements consist of e.g. stages, engines, motors, structures so called "Building Blocks" and possible derivatives with limited changes (with low risks and mastered technology needs).

Based on a two-stage architecture approach and considering the above mentioned constraints the following configuration options are being considered for the lower and the upper composite of such launcher concepts:

Lower Composite

- P240/P240-FW + P80 + strap-on boosters
- 1 Vulcain2 + strap-on boosters
- 2 Vulcain2 + strap-on boosters

Upper Composite

- Cryogenic restartable (based on expander cycle)
- Storable restartable (based on Aestus / Aestus-2)
- Cryogenic + storable kick-stage
- Methane restartable (based on e.g. MIRA)

The numerous configurations resulting from the above listed elements will be screened first according their ability to meet the performance and technology maturity requirements. Afterwards, some selected configuration will enter into a detailed design phase aiming at establishing the technical and programmatic data required to assess the pros and cons of such a development scenario.

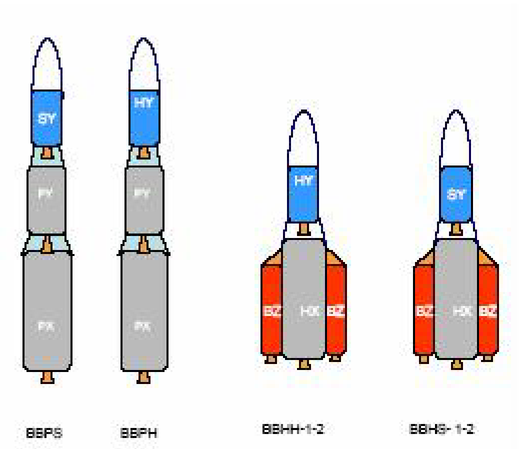

FIG 7: Building Block Launcher Schemes

3. SYNTHESIS

Europe has with Ariane, Vega and Soyuz a launch vehicle family covering a broad range of different missions and performances, especially for the commercial and institutional market of today and the near future. Some flexibility maybe added in the mid-term future perhaps to cover new missions with different satellite injection schemes requiring re-ignition capability (e.g. direct MEO and GEO).

For the long term, activities devoted to future launch systems of 2020 and beyond, such as the NGL, are concentrated more on expendable rather than reusable options. The interest in RLV as a means to reduce recurring cost for classical unmanned space transportation missions is declining in Europe. This is not at least driven by the expressed interest of the ESA member states to focus, as to what regards the NGL, on the fulfilment of the European institutional mission needs in the first place.

One important part of these institutional needs will be the European involvement in space exploration. One can expect that such mission will induce new design requirements on future launcher developments.

4. REFERENCES

[1] Ch. Gritzner, U. Block, M. Obersteiner; Space Transportation Systems - Demand / Market, 1st DGLR/CEAS European Air and Space Conference, September 2007, Berlin
[2] R. Lo, H. Adirim, W. Zinner, R. Pernpeintner; Space Transportation Systems - Propulsion, Structures & Subsystems (System related aspects), 1st DGLR/CEAS European Air and Space Conference, September 2007, Berlin
[3] O. Kalden, M.H. Gräßlin; Space Transportation Systems - Missions & Operations and Ground Infrastructure), 1st DGLR/CEAS European Air and Space Conference, September 2007, Berlin
[4] D. E. Koelle, R. Janovsky; Space Transportation Systems - Cost (Development, Production & Operation) 1st DGLR/CEAS European Air and Space Conference, September 2007, Berlin
[5] R. Pernpeintner, D. Sygulla; Survey Of Programmes And Budgets Dedicated To Demonstration And Development Available For German Space Industry, 1st DGLR/CEAS European Air and Space Conference, September 2007, Berlin
[6] C. Tomatis et al.; RLV candidates for European Future Launchers Preparatory Programme, IAC-06-D2.2.07