H-IIA launcher. Photo courtesy of JAXA.

Improving Asia's launch capabilities

We do not talk enough about the Asian launch market but there is a great deal of activity in this sector. Helen Jameson looks at the past, present and future capabilities of the Asian launch vehicle sector and the things we should be taking into account for the future.

We are very familiar with the activities of the European, United States and Russian launch service providers such as Starsem, ILS, Sea Launch and Arianespace, and the launch vehicles that they use on a regular basis but Asia has its own impressive launch capabilities as well. There are exciting developments taking place in Asia in terms of futuristic launchers and a move towards further offering their services to the rest of the world.

Asserting independence

Asia has gained an enormous amount of confidence in its space capabilities of late and it is displaying these to the rest of the world. In terms of satellite communications, Asia is seeing significant growth and continues to be a hub of the industry. Demand for satellites with capabilities such as DTH and new applications such as HD and Mobile TV is growing so more manufacturing means more satellites need to travel into orbit.

Since the beginning of the century, the case for a new generation of launch vehicles has been put forward. Leading the way are the US, Europe and Japan. China is also working on the development of a range of next generation launch vehicles (NGLVs). Concerns have been raised that these next generation launch vehicles need to be accessible to emerging regions such as Asia and Africa who require lower cost launch services to enter the market. However, there is question over the degradation of quality if the emphasis is placed on developing lower cost launch vehicles. New launch vehicles such as the Angara, will emerge in the middle of next decade. The principal points to be addressed in the development of new launch vehicles are:

- Cost Effective;
- Environmentally Friendly;
- Sustainable;
- Reliable; and
- Re-usable.

But Asia is already making its own way in the development of new launch vehicles that take into consideration these points. In this article I would like to take each region of Asia that is developing launchers – Japan, China, Korea and India – and find what their launch capabilities are.

Japan

Japan has been developing its own launch vehicles, based upon various research projects and experiments. Among those vehicles is the H-IIA launch vehicle which has been supporting major, large-scale satellite launch missions and has proved itself to be highly reliable.

The Japanese H-IIB launch vehicle is an upgraded version of the current H-IIA launch capacity and will be expected to open the door to new possibilities for future missions, including cargo transport to the International Space Station (ISS) and, one day, to the Moon.

The H-IIB launch vehicle has two major purposes. One is to launch the H-II Transfer Vehicle (HTV) to the ISS. The HTV will carry the necessary daily commodities for the crew, but will also transport experimental devices, samples, spare parts and other research items for the ISS. The other purpose will be to respond to broader launch needs by making combined use of both H-IIA and H-IIB launch vehicles. In addition, H-IIB's larger launch capacity will make it possible to perform a simultaneous launch of more than one satellite, therefore reducing the cost. This will contribute to ensuring continued invigoration of the Japanese space industry.

Keycapacity improvement

The H-IIB launch vehicle is a two-stage rocket that uses liquid oxygen and liquid hydrogen as propellant and has four strap-on solid rocket boosters (SRB-A) powered by polibutadiene.

The H-IIB has two liquid rocket engines (LE-7A) in the first-stage, instead of the one found in the H-IIA. It has four SRB-As attached to the body, while the standard version of H-IIA had two SRB-As. In addition, the H-IIB's first-stage body has expanded to 5.2m in diameter from the 4m of H-IIA. It has also extended the total length of the first stage by 1m from that of H-IIA. As a result of such enhancement, the H-IIB needs propellant 1.7 times more powerful than the HII-A. Clustering several engines, whose performance is already fixed, has the advantage in shortening the period and reducing the cost for its development.

For effective development

At the time of launching the HTV, the H-IIB will use a special fairing. However, in other areas, it will use most of the specifications and structures of on-board equipments and ground systems already used for the H-IIA. This is designed to reduce development risk and cost. Moreover, it will share the launch facility with the H-IIA and be launched from Yoshinobu Launch Pad of the Tanegashima Space Centre.

As part of the Japanese Aerospace Exploration Agency's (JAXA) research on the next-generation solid propellant rocket they plan to reduce the cost by a third of that for their former M-V Launch Vehicle. However, JAXA's ultimate goal is to lower hurdles to space by developing a futuristic space transportation system and by making rocket launches much simpler. Additionally, they will be able to meet the wide range of demands for rocket launches by operating their H-11A and H-11B Launch Vehicles as well.

Simplifying the launch

For the next-generation solid fuel rocket, JAXA plans to reform the launch system and improve the operation performance to the highest global standard by utilising innovative ideas beyond a simple combination of existing technologies. For example, they hope to reduce the time needed for the operation of ground facilities and launches to about one fourth of the time required for the M-V Launch Vehicle. To do this, they will make the vehicle perform checks onboard autonomously and reduce the time required for operations on the ground. Ultimately, through the Internet, JAXA will be able to check and control rockets anywhere in the world simply by using a laptop computer. JAXA hopes to develop a launch control system that does not necessarily have to be located at the launch site. Such an innovative concept for a new solid propellant rocket will become a good model for future launch systems involving a liquid fuel rocket. JAXA hope to simplify the launch procedure so that it could conceivably be a daily event.

Currently, onboard equipment is custom made to suit each rocket. Assuming that the rocket was a personal computer, onboard equipment for the rocket would correspond to the computer peripherals that are unique to that specific rocket. For the new rocket, JAXA is aiming as much as possible to develop onboard equipment that can be shared with a family of rockets. For example, they are hoping to connect onboard equipment through a high-speed network. If common interfaces are used, the operator could freely add or change equipment, or even put them on a different rocket just like computer peripherals. In other words, launching the rocket would become the same as using a computer.

JAXA are also developing a new propulsion system using liquid oxygen and liquefied natural gas. A launch vehicle is propelled by hot gases spewed from the engine, generated by the combustion of the fuel. Unlike jet planes, which utilise atmospheric oxygen for combustion, a launch vehicle must carry its own oxygen supply or other oxidising reagent in addition to the fuel. The propellant package, including fuel and oxidising agent, makes up the majority of the weight of the launch vehicle. Thus any new developments in the efficiency and design of engine and propulsion technology will have a significant impact on the development of space transportation overall.

Hydrogen propellants, consisting of liquid oxygen as an oxidising reagent and liquid hydrogen as the fuel are used for the world's best rocket engines. This hydrogen-oxygen combination has the advantage of non-toxicity and high performance, but it also requires a large tank because of the low density of hydrogen. Use of liquid natural gas (LNG) can reduce the weight, size and cost of the propellant package. JAXA is pursuing research into the use of an LNG propulsion system using LNG and liquid oxygen.

The further development of hydrogen and LNG propulsion systems, in response to the increasing diversification and growing demands of space activities, will contribute greatly to further improvements in space transportation. The LNG Engine Flight Demonstration Research Project continues to develop this new technology for space transportation. The goals of the LNG Engine Flight Demonstration Project include development of the LNG engine and cryogenic propellant tanks, and a flight demonstration on a two-stage GX launch vehicle to be developed by private companies. Test firings and other experiments are leading steadily toward the world's first LNG-fired engine application.

China

The Long March family of expendable launch vehicles are operated by the People's Republic of China. Named after the 'Long March' of Chinese communist history, they are abbreviated to LM (in English), and CZ (in China). The Long March vehicles are descendents of the

Dongfeng ballistic missiles that were originally developed by China in the 1960s.

China's Launch provider is the Great Wall Industry Corporation. In the mid-1990s the united States stopped issuing export licenses to allow companies to launch on the Chinese launch vehicles. However, Chinasat-6B was built with no involvement at all from US components by Thales Alenia Space and was successfully launched in July 1997 on a Long March rocket.

Pre-1990, Long March launched only Chinese satellites. However, they entered the international market in 1990 but endured several failures and tragedy occurred in 1995 when a Long March rocket killed several people on the ground after veering of course. This was followed by a similar failure in 1996 when, during the launch of the intelsat 708 satellite, again the rocket veered of course and landed in a village. However, after the investigation that followed and the improvements made, the Long March rocket has been extremely reliable and has had no failures since.

China launched its first astronaut into space in 2003 and two further astronauts in 2005 on Shenzou 6. This made China the third nation to send a man into space. Long March's centenary launch was completed on June 1 2007 and has since completed further successful missions.

The Long March vehicles comprise three generations

The first generation launch vehicle was developed from the DF-3 missile which was never built. It was 29.5 metres long and comprised of three stages. The first two stages used a liquid propellant and the third stage was solid rocket propellant. This vehicle launched the first two Chinese satellites between 1970 and 1971.

The second generation vehicles were the FB-1, CZ-2A, CZ-2B and CZ-2C. Most is known about the CZ-2C which was a successful LEO rocket with a payload of 2,800kg and was derived from the DF-5 ICBM which formed the basis for future launch vehicles. It launched a Swedish satellite, Freja, in 1992. Then in 1993, the Chinese Great Wall Industrial Corporation and Motorola signed a contract for the multiple launch of Iridium satellites using the CZ-2C/SD (a 2C variant with a smart dispenser and improved second stage tanks and engines). First deployment launches for Iridium went ahead in 1987-8.

The third generation the CZ-3 was a three stage launch vehicle specifically designed to place spacecraft into Geosynchronous Transfer Orbit (GTO) and was a development on the Cz-2C proven technology. A new third stage contained liquid oxygen and liquid hydrogen and a cryogenic engine. The GTO payload was 1,500kg.

Following the CZ-3 was the CZ-3A. Similar to the CZ-3, the CZ-3A had a more powerful third stage and could take a 2,700kg payload. The rocket boasted a more capable attitude control systems and was offered to international customers in 1998. Later, the CZ-3B emerged as the most powerful launch vehicle created yet. With a payload capacity of 5,000kg the vehicle was based on the CZ-3A but featured enlarged propellant tanks, a larger fairing and four boosters strapped to the core stage.

Next came the CZ-3C that combined the CZ-3B core with two boosters from the CZ-2E and finally the CZ-4 was developed. This three stage rocket uses storable propellants and is intended for launching satellites into polar or sun-synchronous orbit. It differs from the CZ-3 rocket due to its third stage that features a thin wall tankage and two gimballed engines.

Next generation

Since 2003, China has been working on the development of a new launch vehicle. China continues to work towards the goal of a manned

H-IIB launch vehicle. Photo courtesy of JAXA.

lunar mission in the future but, as it stands, their existing launch vehicle is not powerful enough. However, their launch of a moon probe has cemented their very real intention to make this a reality. Therefore, Chinese scientists have been working on a powerful, non-toxic, pollution-free launch vehicle to enable China to eventually get to the moon. The research and development project has been approved by central government and the project is based on existing launch vehicle technology with 14 varieties of LV with the launch capability of 1.2-25 tonnes in Low Earth Orbit and 1.8-14 tonnes in Geo Synchronous Earth transfer Orbit. Liquid hydrogen is to be used as a propellant.

A new launch site in Hainan Province is being investigated and China hopes to have the space resources to compete with Europe, the USA and Japan in the near future.

India

Developed by the Indian Space Research Organisation (ISRO), India's launch vehicle programme can be divided into four different phases: the learning phase (1960s and 70s), the experimental phase (1980s), the operational phase (1990s) and the expansion phase (2000 and beyond).

SLV

The learning phase took India into low earth orbit with the Space Launch Vehicle (SLV). This was India's first satellite launch vehicle (SLV-3). It was capable of placing a 40kg payload into LEO. The SLV-3 was a four stage vehicle, all of which used solid propellants. It's features included fins for extra stability, a heatshield to protect the satellite from aerodynamic heating, an analogue autopilot, on-board event programmer, inertial attitude measurement system and telemetry, tracking and tele-command avionics. The SLV programme was an incredibly important step in the development of Indian launch vehicles. The SLV laid positive foundations in terms of procedures for designing a space vehicle and ensuring its readiness for flight. Between 1980 and 1983 three successful launches of the SLV-3 occurred and led to the subsequent development of the ASLV.

ASLV

The ASLV was developed as a response to the need for higher payload capacity. Based upon the SLV-3, the ASLV had two added strap on motors on the first stage enabling a payload of 150kg to be inserted into LEO. Developments to the ASLV included a bulbous payload fairing, closed loop guidance, inertial navigation system, new digital avionics, and the development of the launch complex facilities required for vertical integration. There were two failures but lessons were quickly learned form these incidents in terms of the actual regime of flight. After two consecutive launches of the ASLV, ISRO was able to master the critical mission management of launching vehicles into space.

PSLV

The Polar Satellite Launch Vehicle was the next developmental phase for ISRO and was developed for the purpose of inserting remote sensing satellites into orbit and represented a huge stride forward in launch vehicle development both in size and complexity. There are four stages to the PSLV:

- Large solid motor with 139 tonne propellant loading;
- Earth storable liquid propellant main stage with 37 tonne propellant loading;
- High performance solid propellant motor with composite motor case in upper stage; and
- Final stage twin engines with 2.5 tonne liquid propellant loading.

New technologies introduced into the PSLV include digital autopilot and all digital avionics. The first PSLV flight in 1993 failed to inject the satellite into orbit but this only meant that ISRO worked on developing and strengthening ground simulations and testing before launch. The PSLV has been adapted over the years to carry two satellites of around 5-600kg and more work has been carried out on propulsion and re-entry technologies. The PSLV is still being further developed.

GSLV

The GLSV is a launch vehicle configured of only three stages. This is in order to improve the reliability and maximise payload capability. The GSLV retains many of the features found in the PSLV in order to reduce time to manufacture and production cost. However, the third stage of GSLV is cryogenic, originally sourced from Russia but developed with Indian industry. GSLV has completed developmental and operational flights with communications satellites. The payload capacity stands at up to 2000kg and this has been enabled through increased propellant loading, a high pressure engine for the liquid stages and trajectory shaping, for example. And it doesn't stop here. The developmental flight for GSLV Mk-III is expected soon.

As a result of the strides forward that ISRO has made, on April 28, 2008 a PSLV-C9 rocket launched a multiple payload of ten satellites in a single mission. The rocket had a payload of an Indian remote sensing satellite and also nine smaller satellites, eight of them foreign. This was an historic milestone for ISRO and means that India has marked its place in no uncertain terms, as a major player in the space market.

South Korea

South Korea is currently developing a launch vehicle to be known as the Korea Space Launch Vehicle or KSLV-1 – the first launcher that South Korea has ever produced. It is being built under the authority of the Korea Aerospace Research Institute and is based upon the first stage of the Russian Angara rocket. In fact, the rocket will be constructed in Russia. It will eventually be capable of launching a payload of 100 kilogrammes in to low earth orbit. The future of South Korea's launcher programme is not yet certain but here is a brief summary of where each programme is at:

- KSLV-1
Stage 1: Angara UM (Lox/Kerosene Propellant)
Stage 2: KSR-1 (Solid Propellant)
Payload: 100 kg (LEO)
Launch date: delayed until 2009
- KSLV-2
Payload: 1,000 kg
Original Launch date: 2010 Cancelled
- KSLV-3
Stage 1: Angara UM (Lox/Kerosene Propellant)
Stage 2: Angara UM (Lox/Kerosene Propellant)
Stage 3: KSR-1 (Solid Propellant)
Payload: 1,500 kg
Launch date: 2017

Re-usable launch vehicles – the next, next generation

Asia and the rest of the world are all conscious that part of their next generation launch vehicle specification will involve a re-usable rocket. The need for re-usable launch vehicles or RLVs will become necessary in future years. The point must be made that the commercial transportation industry here on earth is re-usable. We see it everyday with aeroplanes and helicopters, for example. However, there is no re-usable space transportation system in use at present aside from the space shuttle which will soon be de-commissioned. RLVs are believed to be the answer to lower cost, highly reliable access to space. However, these systems are still very much in development and technical complexities make this process highly challenging due to the need for an incredibly strong structure and to survive re-entry into the earth's atmosphere. The demands placed on an RLV will be much increased. Whether the lower costs and reliability can be proved remains to be seen. However, with issues such as the environment and the huge costs involved with the manufacture of expendable rockets, surely there must be a way in which modifications can be made without affecting performance.

The European Space Agency is highly engaged in the development of a future launcher that can meet all these requirements. The ESA Future Launchers Preparatory Programme began in February 2004 with aim of building a next generation launch vehicle by 2020. The first two phases of development are to be completed by 2009. The programme was launched with the intention of improving the present launchers and taking them to a more competitive level through analysing new technologies.

Studies carried out by various institutions and companies will look at the type of launcher systems that will determine the architecture of the launcher, they will provide in-flight experimentation and an insight into rocket propulsion, materials and structures, aerothermodynamics, launcher health management and avionics.

It is hoped that the development of an Intermediate Experimentation Vehicle (IXV) will make its first orbital flight on 2010, to be launched by Vega. This vehicle will be used to validate re-entry technologies and will make a controlled earth re-entry flight using aerodynamic control surfaces. The flight will help ESA investigate advanced thermal protection systems and hot structure in-flight performance, key aerothermodynamics phenomena, innovative materials, structural health monitoring and navigation and control issues.

The issue of propulsion is also critical. The propulsion system must be able to interact with the overall launcher performance and is also extremely complex. Studies are currently being carried out on engine systems and potential trade-offs with propulsion cycles and propellants (e.g. liquid oxygen oxidiser and hydrogen or hydrocarbon fuels) and are also taken into the context of the entire launcher system.

The rigorous testing of all these technologies will follow. By 2009, technology demonstrations will be developed to test the engines. This will be the next key event in propulsion development.

New structures and materials will be necessary for a Next Generation Launcher. Testing and designing work on advanced structural concepts are happening as we speak. The main challenges facing the team will be to reduce the structural mass of the launcher but increase the structural margins for robustness, to contain cryogenic hydrogen and oxygen propellants, to develop a reusable thermal protection system in support of the IXV, to reduce operational costs but ensure sustainability and to provide optimum performance at a cost that is affordable.

In addition, the research and development that is being undertaken on the NGL programme will contain many elements that may be used to enhance life on earth.

Continued evolution

Asia's launcher programmes are looking very healthy indeed and the scope for development is huge, as it is in other areas of the world. The days of re-usuable launch vehicles may seem far away but with plans to launch demonstration vehicles next year in Europe, perhaps these changes will be realised in the not-too-distant future. From the 1960s, Asian launch vehicle technology has evolved impressively and rapidly and there is an air of deserved optimism in the Asian space market at present.

Asia can proudly stand up and be counted as a major player in the launch market and will continue to evolve and strengthen and tick off the milestones as time goes by. ■

Advanced solid rocket. Photo courtesy of JAXA.