Developments in space policies, programmes and technologies throughout the world and in Europe

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1. Space policies and programmes

All major space policy developments worldwide were presented in the previous section of part one, in an attempt to clarify the principal space faring nations' strategies in 2009 and 2010. In the section bellow, there will be a biref discussion on developments in technology related areas, including access to space technologies and policies. The aim of this section is to clarify how the strategies already presented above interact with and influence specific space programmes and related research and development projects.

2. Space transportation

2.1. Europe

The most important development in European space transportation programmes in 2009 and 2010 was related to the deployment of GNSS, for which the European Commission opted for a two launcher scheme to lift the satellites: out of the 14 initial spacecrafts ten would be launched onboard 5 Soyuz rockets, whereas the last four would be carried to orbit on a single Ariane 5 ECA launch. Launching costs however were thought to be considerably higher than expected and their budget override could exceed €1 billion. A third €85 million contract for system support and validation was awarded to ThalesAleniaSpace. Further contracts on ground control and mission segments were anticipated in mid-2010.[408] Eventually, the first three contracts for the Galileo full operational capability system were signed in the premises of ESA's European Space Research and Technology Centre (ESTEC) in the Netherlands, on 27 January 2010.[409]

In a related development, the European Commission also announced on 7 January 2010 that the Galileo satellite navigation system's launching campaign

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was facing a 59% budget override, mostly due to the Soyuz rocket's unexpectedly high cost. In July 2008 the European Commission had announced that launching the 28 satellite constellation would cost €700 million, or approximately €25 million per spacecraft. The new figure announced in January for lifting only the first ten satellites to orbit mounted to €397 million, or €39.7 million per satellite (with each rocket carrying two spacecraft). This substantial budget increase was attributed by the European Space Agency's (ESA) Director General J.J. Dordain in a 14 January interview to higher Russian launchers' prices, as well as to initially underestimating the costs of adapting the Soyuz rocket for the Galileo mission.[410]

In conclusion, it can be noted the the deployment of the Galileo system is a major driver behind the development of European space transportation capabilities, making full use of both Ariane 5 and the European Soyuz rockets. Since the GNSS deployment campaign is expected to continue and intensify in the medium term, it can be stated that any future developments regarding these two vectors would have to take into account their ability to satisfy the system's operational needs. At the same time, ESA's small launcher VEGA continued its development, with a first flight expected in 2011. This rocket would complement operationally and commercially the heavier launchers, consequently improving the European launcher family's adaptability and affordability. It would also contribute to increasing European independent launch capabilities in the small payload category in an efficient way instead of relying on the use of Russian small launchers, which is the case today.

2.2. United States

The most significant change in U.S. Space transportation programme during the period in question was the adoption by the Obama Administration of a new NASA orientation that included the cancellation of the Constellation programme and the development of private Human space flight services providers as a possible long-term substitute. Indeed, on 1 February 2010, U.S. President Barack Obama surprised policy and industry officials alike with his NASA budget proposal for 2011. The new budget constituted in fact a major change in the U.S. civil space programme and a radical departure from the previous administration's NASA policy. The new policy's corner stone was the cancellation of the Constellation human spaceflight programme, including all of its components (namely the Orion spacecraft, the Ares heavy rocket and the Altair lunar lander). Instead, the new policy called for funding the development of radically new human space flight technologies that would enable NASA to venture not only to the moon, but to more distant destinations as well. While waiting for the development of these new

technologies, NASA would increase funding to the private space flight industry, effectively outsourcing the entire U.S. programme for manned space flight to Low Earth Orbit. At the same time, a considerably increased budget was foreseen for the American participation to the International Space Station (ISS) so as to maintain the country's current LEO space flight capabilities. For the purposes of the new civil space programme, the White House requested a slightly increased budget for 2011 ($19 billion, 1.5% higher than in the previous year). Furthermore, total funding through 2015 was now estimated at $45.5 billion or $6 billion more than in the 2010 proposed medium term spending plan.[411]

The key plank of the new policy has been the change in NASA's orientation from a mission-focused organisation to a technology development one. According to this doctrine, NASA would be responsible for related research and development, bringing about ground braking innovations that would ultimately revolutionise human spaceflight. As far as specific missions were concerned, it would only maintain authority over ISS operations and it would continue to promote international cooperation in future manned space exploration projects. All other manned space flights to low Earth orbit short of the ISS would be outsourced to private companies. NASA would thus become the driving motor for the development of a flourishing commercial spaceflight industry in the U.S. The agency would support private sector endeavors in two ways. On the one hand, it would conduct the necessary R&D to develop future space transportation technologies that private companies would then be able to commercialise. On the other hand, NASA itself would be a client for commercial spaceflight services, for instance in order to secure independent access to the ISS. In this fashion, NASA would become the industry's partner and client, instead of its competitor.[412]

It should be noted that the new paradigm for developing human spaceflight in the U.S. bares significant resemblance to the way the country's Department of Defence has handled its relations with the commercial satellite industry. U.S. armed forces have been increasingly relying on a balanced mixture of developing their own space assets while punctually procuring commercial space applications products on an ad hoc basis. This dual approach has allowed for the simultaneous development of dedicated high performance military satellites on the one hand, and for outsourcing demand for less sophisticated products to the commercial satellite communications and Earth observation industry. With the proposed NASA space budget, a similar approach seems to be adopted in regard to the U.S. civil space flight programme as well. As we saw above, according to this new scheme NASA would be conducting the advanced R&D required for manned space exploration missions outside the Earth's orbit, while commercial companies would take over the technologically less demanding task of launching people to Earth orbit.

The proposed Obama space policy seems to have been developed exclusively within the White House Office of Science and Technology, and it was admittedly loosely inspired by the Augustine Report on the future of the Constellation programme. However, although it was endorsed by NASA's Administrator Charles Bolden, it met with considerable resistance from lawmakers and NASA officials alike, including some skepticism expressed from Bolden's predecessor Mike Griffin. Criticism on the proposed course of action focused mainly on three issues. First, the Constellation programme cancellation would nullify the $9 billion investment already made in the project and it would jeopardise the thousands of jobs depending on it. Second, outsourcing human space flight even to LEO could prove a lot more complicated than expected and in the end NASA might not be able to disengage itself from LEO spaceflight completely (for example, it would have to certify that commercial spacecraft are safe for humans). Third, changing the nature of NASA's objectives in relation to human spaceflight (from missions to R&D) and passing some of its mission areas to the private sector could jeopardise U.S. national capabilities in this field during the transition period from one policy model to the other.[413]

Finally, the announcement of the new policy was closely followed on 23 February by changes in NASA's administrative structure. More precisely, the agency's ten regional field centres and four mission directorates would be reporting directly to Administrator's C. Bolden office instead of the Associate Administrator's office, as it was the case previously. This decision clearly increased the grip of NASA's Administrator on the agency's day to day activities and made its decision-making process more top-heavy. Furthermore, the restructuring also put additional focus on the agency's R&D activities by reestablishing the offices of the agency's Chief Technologist and Chief Scientist. In fact one could argue that the changes clearly reflected NASA's new R&D oriented direction, while at the same time ensuring a pivotal role of the agency's head in managing these activities.[414]

Understandably, the principal contractors for the Constellation programme were the first to contest the President's new space policy. Representatives of Alliant Techsystems Inc. (ATK) of Minneapolis, the programme's principal rocket subcontractor, expressed their disappointment with the administration's decision and their hope that it would be overruled by Congress, which should have the final word in approving the project's termination. They also voiced concern over whether commercial spaceflight companies would be capable to develop man-rated spacecrafts within the foreseeable future. The company was expected to lose at least $650 million in backlog orders related to the Constellation programme. At the same time, it was unclear how much of the NASA's $2.5 billion budget slated for wrapping up Constellation-related work ATK would receive. The decision to terminate the project could weight heavily on the company's future,

as it was already trying to cope with the phase-out of the Space Shuttle, as well as the cancellation of USAF's Minuteman 3 ballistic missile programme. Maryland based Lockheed Martin, the contractor for the building of Constellation's Orion capsule, also questioned the wisdom of the administration's new policy.[415]

Another concern voiced by many opponents of the new NASA policy was that it could corrode the U.S. solid rocket motor industrial base. In an interview on 11 February, NASA Deputy Administrator Lori Garver revealed that long high level discussions were held between NASA and Defence Department officials prior to the new policy's announcement. The Pentagon's concern was that after cancelling the Constellation programme there would be no solid fuel rocket development project left in the U.S. This situation could jeopardise the very existence of the only two companies that currently make these motors, Alliant Techsystems Inc. of Minneapolis and Aerojet of Sacramento. If these two companies seized their production, their important know-how would be irreversibly lost. Since the same motor type is also used in ballistic missiles, the U.S. could loose the industrial capability to replenish their strategic missile reserves. In order to tackle this issue, the U.S. military has set up a joint working group, mandated by Congress to deliver by June 2010 a strategic plan to preserve the U.S. industrial base in this field. In the mean time, the U.S. Air Force, Navy and Missile Defence Agency have decided to pool their solid motor rocket demands so as to sustain a very low rate production of the motors for as long as possible.[416]

Concern over loosing skilled workforce and critical industrial know-how as a result of the new policy was even expressed by officials who endorsed it, such as the president of the Aerospace Industries Association Marion Blakey. Although the potential of the new policy to create jobs in the private sector is acknowledged by the industry, there are also worries that a part of the skilled workforce currently employed in government programmes might loose its job. In that case, manufacturing know-how on several critical technologies could be irreversibly lost. On the other hand, NASA officials argued that commercial space had the potential to create a lot more jobs than those lost. Consequently, there is consensus in the U.S. that the space industrial base would benefit from the new policy on the long term. Nevertheless, coherent strategic industrial planning on a nation wide scale would be necessary to preserve critical manufacturing capabilities during the transition period. In an attempt to increase awareness of this problem, the NASA Administrator himself urged private space firms to make better use of existing labour force and industrial infrastructure.[417]

In an effort to prevent further reaction from industrial and policy officials, NASA Administrator Charles Bolden confirmed on 6 February that development work on heavy-lift rocket technology would not stop under the new U.S. space policy. In fact, he said that NASA would conduct an evaluation of all

technologies related to Ares 5, the heavy-lift launcher of the Constellation programme, in order to choose the most promising ones for further development regardless of the programme's cancellation. The objective of this decision would be to maintain R&D relating to key heavy launcher technologies in order to start the manufacturing of such a rocket by 2020 at the latest. In this respect, the Obama administration space policy seemed to adhere to the Augustin Report's key policy recommendation known as the Flexible Path. Under this policy NASA was to perform only unmanned missions to the Moon and rather concentrate on Mars as the principal destination of future U.S. human exploration missions. Furthermore, NASA officials pointed out that the new policy would actually speed up the development of new space transportation technologies through its provisions for larger R&D budgets and increased international cooperation. As far as research was concerned, it was clear that the new policy called for an approximately $500 million annual budget for R&D on new space exploration technologies through 2016, whereas the Bush administration planning only foresaw $100 million.[418]

2.3. Russia

One of the major preoccupations of the Russian space programme has been to secure an independent space launch capability. In this regard, the construction of the new space centre will enable launches from national territory, providing Russia with the desired unrestricted access to space. Furthermore, Roscosmos has resumed the development of the Angara, its first entirely new post-soviet era rocket, which is expected to make its debut in 2011. The new rocket will use predominantly Russian made components and it should therefore decrease the country's dependence on foreign suppliers. At the same time, Soyuz launches from French Guiana are scheduled to begin in 2010 and its Russian manufacturers have already secured 14 orders from the system's operator Arianespace. This development should help Russian companies to expand their global market share and provide them with the necessary starting funds to develop their next generation of rockets.

In the framework of this dual strategy to reduce its dependence on third countries, Russia moved to secure the future use of the Baikonur Cosmodrome in Kazakhstan and to consolidate its plans to build a new spaceport in Vostochny, in the Russian Far East. Indeed, after years of disputes the Kazakh Parliament officially ratified on 9 April 2010 a 2004 agreement between the two countries, granting Russia access to the site until 2050. The agreement followed the general terms of the lease contract currently applied, under which Russia pays an annual

fee of $165 million for the use of the Cosmodrome. After this development, the road opened for the joint construction by the two countries of a new space launch facility in Baikonur, known as the Baiterek, in order to accommodate the new Angara heavy rocket currently under development.[419]

Furthermore, during a meeting with Russian Prime Minister Vladimir Putin in July, the Head of Russia's Roskosmos space agency Anatoly Perminov promised that delays in constructing the Soyuz launch pad in Europe's Guiana Space Centre would be completed in time for its first launch in February 2010. Soyuz rockets launched from Guiana are scheduled to lift two spacecraft for Europe's Galileo satellite navigation system in 2010.[420]

On the other hand, Russia also continued its engagement in international cooperation in the field of Human space flight. In fact, on 28 May 2009 the Russian space agency Roskosmos announced a $360 million extension to its long-running space transportation contract with NASA. Under this contract modification, Roskosmos would launch an additional six U.S. astronauts on board four Soyuz capsule missions, scheduled for 2012. The same capsules will return their crews to Earth by spring 2013.[421]

At the same time, Russian officials confirmed that preliminary work for the creation of a new spaceport in Vostochny were proceeding according to plans and that its construction would begin in 2011. The new launching site would be operational by 2015 and certified for manned spacecraft missions by 2018. The project's total budget was expected to exceed 400 billion Rubles ($13.5 billion). Government officials accorded great importance to the new spaceport, which is hoped to boost the Russian space launch industry's overall competitiveness. In fact, the site is expected to become a space industry hub, generating more than 20,000 jobs on a long term basis.[422]

2.4. Japan

Key developments in the field of space transportation in Japan included the completion of the development of a new variant of the H-2 rocket family, capable of lifting the HTV-1 spacecraft to the ISS. But the period under examination also saw the development of Japan's future launcher system fall victim to its budget overrides. As far as the first one was concerned, on 11 July the Japan Aerospace Exploration Agency (JAXA) and Mitsubishi Heavy Industries Ltd announced the completion of ground tests for the H-2B rocket.[423] This is a more powerful version of the H-2A rocket, designed to lift the H-2 Transfer Vehicle 1 (HTV-1) cargo spacecraft to the International Space Station (ISS). HTV-1 is a solar-powered cylinder-shaped spacecraft approximately 10 metres long and 4.4 metres wide.[424]

It can carry 6 tons of pressurised and/or unpressurised cargo. Its development started in 1997 and cost about $680 million.[425]

At the same time however, the country's future launcher development came under scrutiny because of budgetary issues. On 17 November the Government Administration Reform Committee, an advisory committee to the Japanese government set up to eliminate wasteful budget spending, proposed the cancellation of the future GX rocket. GX has been under development since 2003 and was originally scheduled to fly in 2006. However, development of the rocket's second-stage liquid gas engine was not expected to be completed before 2011 and at a cost that was double the originally estimated budget (¥35 billion instead of an estimated ¥15 billion).[426] The final decision on the GX's fate was taken 16 December 2009, when the Japanese government opted to cancel the programme, but continue development work on its intended eliquified natural gas-powered engine. As it was announced, the principal reasons behind the programme's cancallation were its budget overrides and an increase in its expected launching cost that was bound to compromise any future commercial prospects.[427]

2.5. China

The Chinese space transportation prpgramme in 2009 and 2010 evolved around the improvement of the Long March rocket family's reliability and consequently also of its commercial prospects. Nevertheless, this effort suffered a set back when the Chinese Long March 3B rocket failed to place Indonesian commercial communications satellite Palapa-D into Geosynchronous transfer orbit on 31 August, due to an engine malfunction in its third stage. This was the launcher's second failure in 12 flights, the last one being during its maiden flight in 1996. Long March 3B is China's principal communications satellite launcher. The incident also grounded Long March 3A and 3 C rockets, as they all share the same engine. The launch services provider China Great Wall Industry Corp. declined to comment on the causes of the failure, but later in September it appointed an independent enquiry board to investigate them. Palapa-D was eventually salvaged, when satellite constructor ThalesAlenia was able to propel it into a geosynchronous orbit using its own propulsion module.[428]

On 19 November the enquiry board, comprising of officials from the China Academy of Launch Vehicle Technology (CALT) and the Academy of Aerospace Propulsion Technology, published its findings. It had reached the conclusion that the upper stage's engine had delivered 38% less thrust than expected for 43% of its total working time. The cause of this underperformance was determined to be

a burn-through of its gas generator, caused by foreign matter or icing in the engine's liquid hydrogen injectors. To prevent any future similar accidents, the rocket's manufacturer China Great Wall Industry Corp. of Beijing decided to install a filter to the liquid hydrogen gas feed system. The company also stated it would flight test the new system before the end of 2009.[429]

2.6. India

Launch vehicle development absorbs the largest share of India's space budget, illustrating that rocket development is at the top of the list of the country's space programme priorities. As it was indicated in previous chapters, the country's future rocket development plans include the Mk 3 version of the Geosynchronous Satellite Launch Vehicle (GSLV), with a lift capability of four tons, which was expected to fly in 2010 or 2011, soon after a new indigenous cryogenic upper stage engine has been tested. However, its development has met serious problems, including a catastrophic failure at its very first launch that destroyed its GSAT-4 communications satellite payload on 15 April 2010. According to ISRO's first statements, the failure was due to two vernuer control motors igniting. However, it is not certain whether the cryogenic stage started to fire. While the cryogenic engine had been tested by ISRO and other experts, it was not tested in conditions that simulate high altitude, according to Nambi Narayanan. This failure also had repercussions on the timetable of the Chandrayaan-2 lunar orbiter mission in 2012 and launches of communication satellites.[430]

2.7. Emerging actors

The second half of 2009 and the first half of 2010 was a challenging and somewhat frustrating year for South Korea and its attempts to launch a satellite onboard the country's first national space launching vehicle. The first attempt, which was made on 25 August 2009, failed when the Korea Space Launch Vehicle (KSLV-1) did not put its payload (the meteorological satellite STSAT-2) into orbit. The vehicle, built with considerable help from the Russian rocket engine manufacturing company Khrunitsev, was presumed to have suffered an upper stage malfunction.[431] At the same time, Korea proceeded with its plans to acquire a completely independent launching capability by 2018.

In another development, on 3 February Iran unveiled the country's latest rocket, Simorgh. A full-scale mock-up of the vehicle was demonstrated to the public during the Iranian national Space Day ceremonies, which also included the

launch of the Kavoshgar-3 rocket that carried small animals to space. According to the published pictures of the Simorgh, the vehicle seems to be 27 m long with a maximum diameter of at least two metres. It has two stages, with four engines for the first and one for the second one. Iranian officials claimed that it had the capacity to lift 100 kg into orbit, but western analysts claimed this could be upgraded in the medium term. The same analysts noted that if it was used as a ballistic missile, Simorgh could propel a one ton warhead to a range of 4,000 km. U.S. and Israeli experts were surprised to see an entirely new launcher developed by Iran, as they predicted Iran would focus on evolving its existing rockets, namely the liquid-fuelled Safir-2 and the solid-fuelled Sejil-2. It appears that Shehab 3B engines were used in the rocket's clustered first stage. Some observers also noticed similarities with the first stage of North Korea's Taepodong-2 three-stage launcher. In spite of its size, Simorgh apparently lacked a thrust-to-weight ratio capable of an intercontinental range. Its radically new first stage design however, could eventually be used in a future Iranian ICBM.[432]

Finally, Brazil has been increasingly focusing during our reporting period on the development of its national space rocket VLS-1, capable of carrying satellites to LEO. This project has been managed in close cooperation with Ukrainian and Russian companies. In April 2010, Brazil's space agency AEB announced a schedule for the programme, which foresaw the first launch of a version of the VLS-1 capable of lifting small satellites into LEO by 2014 at the latest. This mission would be the first since 2003, when an explosion of the rocket on its launching pad cost the lives of 21 people and put a halt to its further operational testing. Reportedly, this improved version has been developed with the assistance of Russian companies.[433]

3. Space sciences and exploration

Space exploration continues to attracting people imagination and governmental attention. In spite of the financial crisis which has entailed reassessment of certain projects or cooperation in this field, a lot of missions are ongoing or under development.

3.1. Human spaceflight activities

The human spaceflight activities are off courses largely dominated by the ISS events which are quite numerous between mid 2009 and mid 2010. The period

covered has been mainly marked by the successive retirements of American shuttles while a new generations of commercial ones is under development and more described in the propulsion and launcher section. NASA has launched the first human-like robot to join the ISS team in 2010. A new fellow for the crew which could be particularly useful in the future especially for risky missions. In any case, "R-2" will be the base for development of next generations of robots which could be crucial to support human spaceflight activities. Its functioning within the particular gravitational environment of the ISS will be especially studied. The dexterous robot not only looks like a human but also is designed to work like one. With human-like hands and arms, R2 is able to use the same tools station crew members use. R2 will constantly updated by software to handle different kind of tasks and test its adaptability. It is therefore a crucial step in the ling term space exploration in which robots are due to play a significant role.[434]

The new tranquillity node attached to the ISS allow the astronauts to have a breathtaking view on earth and thus alleviating the sensation of confinement. The STS-130 astronauts delivered the two new space station pieces, the final components of the U.S. segment of the station, aboard space shuttle Endeavour during the first mission of the year. Throughout the mission, supplies and new equipment delivered by Endeavour were stowed, and work to outfit Tranquillity and cupola was the focus of the combined crews. The new segments added 2,600 cubic feet to the station's interior. An intense episode of the assembly of the ISS was thus achieved.[435]U.S. seems to look for another impulsion in its way to yield the advantages provided by the ISS after having invested so much effort. Several hundred leaders in space and science met in Cape Canaveral, Fla. on Nov. 16 and 17 2010 to explore ways to open the vast and exciting research capabilities of the space station to a wide array of uses. The setting for the discussion was the national conference of the American Astronautical Society. An occasion to present the capabilities of the achieved station and their hope for the upcoming decade.[436]

In April 2010 the STS-131 mission operated by the space shuttle Discovery to the International Space Station has been successfully fulfilled. Discovery delivered supplies and equipment to the station stowed inside the Italian-built multi-purpose logistics module Leonardo. The payload included new crew sleeping quarters, an ammonia tank, gyroscope and experiments.[437] It was the last flight for the shuttle Atlantis in May. The STS-132 delivered to the International Space Station the Russian Rassvet Mini-Research Module-1, only the second Russian module to ever be carried into space by a space shuttle. It's a fitting final payload for the orbiter that not only launched the first into space, but also was the first shuttle to dock to the Russian Space Station Mir. Atlantis was the shuttle behind seven of the 11 shuttle missions to Mir and this vehicle has visited

10 times the ISS. An historical page in spaceflight is thus turned while there are still a lot of questions unsettled about the news spacecrafts able to replace it.[438] Russia is therefore taking the lead to resupply the ISS affirming itself as an indisputable partner in this venture while the shuttle retirement is approaching. Numerous flights have been successfully undertaken by Russian to sustain the ISS as in april 2010 with the Progress 36 unpiloted spacecraft.[439] The station's 37th Progress unpiloted cargo craft docked also successfully to the International Space Station despite the failure of the automated rendezvous system, the cargo was manually flew to the dock by Russian crew resupplying successfully the ISS.[440] In July, the ISS Progress 38 cargo has also resupplied the ISS successfully without failure this time of the automated rendezvous system. It was also the last flight for Discovery. Among other noticeable tasks, it had delivered the Japanese Kibo laboratory to the International Space Station.[441] A new project of cooperation has been also settled between NASA and Roscosmos. A special lab may be installed in the International Space Station devoted to growing crystals for solar arrays in the nearest future. The lab to be initiated in 2013, is intended for growing up crystals of a brand new type. The lab is due to improve the crystals's properties thanks to the conditions not available on the ground. It is so expected to enhance their efficiency by around 60%. The project includes NASA and Roscosmos.[442]

The solution to assure the resupply of the ISS is coming up between Japan and Europe. Germany has committed to paying a 38 percent share of an estimated 3.8 billion euros that European governments will need to continue their work on the international space station (ISS) in the next 10 years. Germany confirms thus its strong support to the pursuit of the project until 2020. The discussions are rather fierce between the European partners concerning the possibility to develop an autonomous Automated Transfer Vehicle (ATV) to permit it to return station cargo to Earth. Indeed, France and Italy which currently pay about 27 percent and 19 percent of Europe's space station costs, respectively, have not come out in favor of the ATV upgrade. ESA has engaged talks with the Japan Aerospace Exploration Agency to determine whether Japan's plans to upgrade its current throwaway H-2 Transfer Vehicle cargo tug could be merged with ESA's vehicle into a single program. In order to develop a vehicle with payload-return capabilities, what could save money rather than developing alone a major hardware project such as an ATV. Two options are thus under studying and the European position should be cleared in 2012. But it is obvious that such a vehicle would be an asset that would serve Europe's future space-exploration plans beyond the space station.[443]

Indeed, Japan is currently developing an ambitious programme to enhance its role on the ISS, announcing its intentions to better utilize the Kibo laboratory and build a variant of the H-2 Transfer Vehicle (HTV) that would be capable of

bringing cargo back to Earth. The project intends to add human capability after 2020 to assure Japan space flight operation in the future. A long term mission which has been started in the 1990s while it was seen as a necessity that Japan develop basic technologies for independent human space capabilities. The present-generation HTV, which was launched for the first time in September 2009 by Japan's heavy-lift H-2B rocket, is set to play a major role in keeping the ISS in service, ferrying roughly 6 tons of cargo on each of the six space station resupply missions planned between next January and 2015. Not less than 650 Japanese companies are involved in the space station and this project could be a crucial step for the Japan space programme which could become in the nearest future both more present in the international cooperation and autonomous trough its own exploration programmes.[444]

3.2. Lunar exploration

The moon still seems to spark international vocations. The perspective of finding water to establish a base and resource to eventually exploit attracts the international attention. This discovery makes utopian lunar bases closer to reality. Water provides the way to obtain propellant and oxygen supplies for the cosmonauts in the future bases.

In Europe a new step has been achieved for the ESA's first Moon lander. The mission foresees to land autonomously with pinpoint precision near the Moon's south pole, a region full of dangerous boulders and high ridges by 2018. The aim is to probe the moonscape's unknowns and test new technologies to prepare future human landings. A new contract has been signed between EADS-Astrium in Berlin, Germany. The region envisaged is particularly important because it concentrates continuous sunlight for power and potential access to vital resources such as water-ice. A milestone in the ESA's spaceflight programme to prepare a future human landing by accumulating data on this area as poorly understood as crucial for the upcoming lunar exploration.[445] Projects which could be helped by the recent discoveries of a new type of solar wind interaction with airless bodies in our solar system. Magnetized regions called magnetic anomalies, mostly on the far side of the Moon, were found to strongly deflect the solar wind, shielding the Moon's surface. This crucial element will help understand the solar wind behaviour near the lunar surface and how water may be generated in its upper layer. Evidences of this phenomenon have been presented at the European Planetary Science Congress in Rome, on 24 September 2010. The study of Atmosphere-less bodies being particularly interesting in their way of interact with the solar wind quite differently than the Earth. Indeed, surface of such bodies are exposed without

any shielding by a dense atmosphere or magnetosphere forming a very rough and chaotic surface called "regolith". A significant flux of high energy particles was found to originate from the lunar surface, and the information collected will be particularly useful understand the role that solar wind can have as potential source of water on the Moon. Another studies presented by searchers from NASA suggest that the moon has cooled since its formation it has contracted and could still be tectonically active today. Indeed, the moon is smaller than it used to be and could continue shrinking.[446]

China has announced that lunar exploration would be its main priority with the aim of returning lunar samples by 2017. Without being an absolute priority for China, the space exploration sector has seen steadily increased its funding through several new scientific initiatives. Reflecting these new ambitions, China's space science budget is estimated to have increased substantially over the past five years, from about 800 million Yuan in 2006 (€69 million) to 1.88 billion Yuan ($194 million) in 2010. The first lunar orbiter probe was launched in 2007. The lunar program is divided in three phases consisting of landing on and returning samples from the lunar surface. China's ultimate objective is for a manned mission to the moon in the 2020s.[447] Besides the China's new Moon probe reached its destination Oct. 6 after firing braking thrusters to enter into lunar orbit. There are still two manoeuvres to execute in order to bring the probe to orbit desired allowing this one to map the Moon from an altitude of 100 kilometers.[448]

Two missions to the Moon are planned by Russia for 2013, one of them exclusively Russian and the other one devoted to studying the lunar resource on the poles is the result of a Russian-Indian agreement The Russian Luna-Glob will apply seismic methods instead of complicated penetrators to better figure out the composition of the lunar underground.[449] This new comes after the chunks of frozen water detected, within the moon's perennially shadowed polar craters. The data provided by the Indian probe Chandrayaan suggest a massive presence of water which could the result of a comet which would have smashed into the moon eons ago. It would have enough water to supply a human expedition. In addition to this important finding the probe has also mapped most of the area near the north pole of the moon.[450]

3.3. Mars exploration

Some questions about Mars still attract the international scientific awareness. This is particularly true concerning any form of life which could have or could exist on the Red planet. An obsessing question which explains the numerous missions

undertaken to respond to this quest. Another matter often raised concerns the atmosphere which would have been disappeared. The ghosts of Mars seem to all the more haunt the Terrian inspirations as that could somehow be the destiny of our planet.

ESA and NASA have selected the scientific instruments to install for their first joint Mars mission scheduled for 2016.[451] This mission will study chemical makeup of the Martian atmosphere included previously methane important for life. An unprecedented alliance which is only due to begin because the ExoMars Trace Gas Orbiter is the first in a planned series of joint missions leading to the return of a sample from the surface of Mars. Scientists worldwide were invited to propose the spacecraft's instruments. Among its objectives, one is to characterise the planet's atmosphere, and in particular search for trace gases like methane. Discoveries could bring about crucial information about the eternal question, namely has Mars ever hosted any form of life. The selected materials are an infrared spectrometer to detect very low concentrations of molecular constituents of the atmosphere, An infrared spectrometer to detect trace constituents in the atmosphere and to map their location on the surface, An infrared radiometer to provide daily global measurements of dust, water vapour and chemical species in the atmosphere to aid the analysis of the spectrometer data, A camera to provide 4-colour stereo imaging over an 8.5 km swathe and finally A wide-angle multi-spectral camera to provide global images in support of the other instruments. U.S., ESA and a lot of European national agencies and Canada are coopering under the present agreement to develop jointly these equipments.[452]

Since July 2010, the German Aerospace Centre (Deutsches Zentrum für Luft- und Raumfahrt DLR) is currently studying the existence of liquid salt solutions on Mars which could host a form of life in spite of the extremely low temperatures. The previous modelling has showed that the conditions required were met. Triggered by the findings of NASA's Phoenix Mars mission these study could bring crucial information on this fluid medium that supports life because there is no water. This liquid solution could allow flow processes, known as rheological processes, on the Martian surface. In the context of possible biological processes, this could also be a life-sustaining transport of nutrition and waste. The characteristics of this fluid are therefore rather close to water and so favourable to form of life. This is all the more true since U.S. scientists have found that a form of life was partially composed of arsenic.[453] Recent observations made by Mars Express could help German scientists. Indeed, A small crater called Schiaparelli embedded in the north western rim of the Schiaparelli impact attracts the attention of scientists. The images provided by ESA's Mars Express would show evidences for past water and the great Martian winds that periodically blow. However, other

astronomers thought he meant canals, meaning artificial irrigation and transportation routes, which led to a few astronomers, and a large number of the general public, believing that they had been created by intelligent Martians. No doubt that the future missions will enlighten this enigma.[454]

The NASA's Mars Reconnaissance Orbiter resumed observing Mars after having recovered from an unplanned reboot which has plunged the probe in a safe mode waiting for plenty recovery. The spacecraft appeared to finally operate normally, making science observations and returning data. It has already completed its primary science phase of operations in November 2008.[455] It continues to observe Mars both for science and was used by NASA to try to reach Phoenix but NASA has finally abandoned hopes to recontact the NASA's Mars Lander[456] which had studied by digging up during six months the Martian soil. Indeed, Mars Reconnaissance Orbiter shows signs of severe ice damage to the lander's solar panels and has tried unsuccessfully to catch any radio signal. However there are still possibilities to Phoenix to survive and it could try later to recontact the Orbiter. During its mission, Phoenix confirmed and examined patches of the widespread deposits of underground water ice detected by Odyssey and identified a mineral called calcium carbonate that suggested occasional presence of thawed water. The lander also found soil chemistry with significant implications for life and observed falling snow. The mission's biggest surprise was the discovery of perchlorate, an oxidizing chemical on Earth that is food for some microbes and potentially toxic for others.[457] In the same way, The NASA's Spirit Mars Rover had hold evidence of a wet, non-acidic ancient environment that may have been favorable for life. However additional information put into perspectives these discoveries because the rover has also found that the environment may have been acidic and so much less favourable to any form of life. The core of the questions arisen by these discoveries is to determine where most of the carbon dioxide went which could bring crucial element to respond why the Martian's atmosphere had disappeared.[458] A new project concerning Mars is on the verge of being carried out since NASA gave the green light Oct. 4 to what is expected to be the last of its Mars Scout missions, a $438 million probe that could help one more time scientists to understand how the red planet lost much of its atmosphere. The 2,500-kilogram spacecraft is due to be launched by 2013. The yearlong mission is designed to sample the planet's upper atmosphere in an effort to understand a dramatic climate change that left Mars unable to support the presence of liquid water on its surface. Earlier this year, however, NASA decided to discontinue the Scout program and join the European Space Agency in 2016 on the first of several proposed joint Mars missions.[459]

In a statement in October 2010 The Chinese Academy of Space Technology has expressed its plan to independently conduct a Mars orbiting exploration by

as early as the year 2013. The objective is to use the same platform as the unmanned lunar orbiter Chang'e I successfully launched in 2007. Meanwhile, China's first Mars probe "Yinghuo-1" is expected to be launched on a Russian carrier rocket in November 2011. The Chinese Mars probe, designed for a two-year life span, will try to discover why water disappeared from the planet and explain other environmental changes on Mars.[460]

3.4. Saturn exploration

The ESA and NASA's Cassini spacecraft has successfully returned images of Enceladus and the nearby moon Dione.[461] The Cassini-Huygens mission is a cooperative project of NASA, the European Space Agency and the Italian Space Agency. Several pictures show Enceladus backlit, with the dark outline of the moon crowned by glowing jets from the south polar region. The images show several separate jets, or sets of jets, emanating from the fissures known as "tiger stripes". Scientists will use the images to pinpoint the jet source locations on the surface and learn more about their shape and variability. The Enceladus flyby took Cassini within about 48 kilometers of the moon's northern hemisphere. Cassini's fields and particles instruments worked on searching for particles that may form a tenuous atmosphere around Enceladus. They also hope to learn whether those particles may be similar to the faint oxygen and carbon-dioxide atmosphere detected recently around Rhea, another Saturnian moon. The scientists were particularly interested in the Enceladus environment away from the jets emanating from the south polar region. Scientists also hope this flyby will help them understand the rate of micrometeoroid bombardment in the Saturn system and get at the age of Saturn's main rings.[462] An experiment also designed to probe the moon's interior composition. The instruments are designed to measure the gravitational pull of Enceladus against the steady radio link to NASA's Deep Space Network on Earth. Detecting any wiggle will help scientists understand what is under the famous "tiger stripe" fractures that spew water vapor and organic particles from the south polar region.

3.5. Venus exploration

Europe has taken the lead in the Venus exploration with its orbiter. ESA's Venus Express which has returned the clearest indications proving that Venus is still geologically active. Indeed, relatively young lava flows have been identified by the way they emit infrared radiation. The finding suggests the planet remains capable

of volcanic eruptions. The data were collected by the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) on ESA's Venus Express spacecraft, which has been orbiting the planet since April 2006. Venus still keeps jealously certain of her secret as explained Dr Smrekar : "There are some intriguing models of how Venus could have completely covered itself in kilometres of volcanic lava in a short time, but they require that the interior of Venus behaves very differently from Earth. If volcanism is more gradual, this implies that the interior may behave more like Earth, though without plate tectonics."[463] The orbiter has also permitted to detect high density of Sulfur dioxide has been detected as well by special equipment developed by the French space agency (CNES).[464] Moreover, Venus express has successfully studied the Venus's atmosphere. The polar atmosphere of Venus is thinner than expected, Venus Express has flown through the upper reaches of its poisonous atmosphere. The orbiter went diving into the alien atmosphere during a series of low passes in July August 2008, October 2009, and February and April 2010 which was unprecedented. The results suggest that unanticipated natural processes be at work in the atmosphere as 10 measurements so far and shown that the atmosphere high above the poles is a surprising 60% thinner than predicted. Unfortunately, Venus Express had not been foreseen to sample atmosphere and use radio tracking stations on Earth watch for the drag on the spacecraft as it dips into the atmosphere and is decelerated by the Venusian equivalent of air resistance. The resistance and longevity of the orbiter are however remarkable and promises other interesting data.[465]

From their side, Russian are preparing a mission to Venus planned to 2016. The main objectives are to study the planet's turbulent atmosphere and surface, and find out why it has no water. A leading Russian firm specializing in automated probes would be in charge of designing the hardware but no contract has been signed so far. The orbiter should reach its target by 2017 and will be carried by a heavy Proton-M or Angara-A5 rocket. The lander and probes will work for up to several days before harsh corrosion damages them. The orbiter's life is expected to be much longer.[466] It has been also announced that France should participate significantly to the project[467] Japan's Akatsuki spacecraft has unfortunately failed to enter into Venus orbit but mission planners hope to attempt orbital insertion again in six years. Whereas it was about to be injected into the Venus orbit, the Venus Climate Orbiter switched itself into safe mode for unknown reasons. A painful failure which recalls the Japan's Nozomi Mars mission. This one suffered in 1998 a thruster failure that delayed the orbiter's arrival at the red planet by more than four years. The Orbiter will be back in position between December 2016 and January 2017 to make a second attempt to enter orbit around Venus. It is however not clear whether the spacecraft will have enough battery and fuel at this date.[468]

3.6. Neptune exploration

New measurements provided by a European space telescope suggest that a comet may have crashed into the gas giant about 200 years ago in July 2010. Composition of Neptune's atmosphere is currently analyzed from data furnished by the Herschel space observatory. The scientists examined the atmosphere of Neptune, which mainly consists of hydrogen and helium with traces of water, carbon dioxide and carbon monoxide. They detected an unusual distribution of carbon monoxide in Neptune's atmosphere, with much higher concentrations in the upper layer, called the stratosphere, compared to the troposphere layer beneath. They also found higher concentration of Methane than expected which operates in a similar ways to water vapor on Earth. The European Space Agency launched the Herschel infrared space telescope in May 2009 and is the largest and most powerful infrared telescope in orbit today.[469]

3.7. Jupiter exploration

In June 2010 the NASA/ESA Hubble Space Telescope has provided insights of two recent events on Jupiter: the mysterious flash of light on 3 June and the disappearance of the planet's dark Southern Equatorial Belt. Another flash has been noticed by an amateur astronomer. However there is no sign of debris above Jupiter's cloud tops. The flash is thought to have come from a giant meteor burning up high above Jupiter's cloud tops. An interesting occasion to observe how Jupiter's atmosphere is going to react to such extremely violent event.[470]

3.8. Solar observation

The Sun vitally linked to our liveable environment on earth is subject to many studies to better understand its nature and functioning. This all the more true as it can show unforeseen phenomenon which can entail huge consequences on Earth concerning as much as the climate or technological aspect particularly vulnerable. In Europe, ESA has begun to exploit the probe Proba-2. Launched in the end of 2009, Proba-2 is a small but innovative experimental technologies. In June 2010, after only eight months of life, it has already returned more than 90 000 images of the Sun. It embodies this new generation of miniaturised science instruments, focused on the Sun and space weather, as well as 17 state-of-the-art technology payloads. Moreover Proba-2 constitutes a technological stepping stone to future missions which will be used onboard of BepiColombo mission to Mercury.

An ideal Platform of test for material such as credit-card-sized magnetometer or among others experimental solar panel produced in Belgium. The scientific payload of Proba-2 is equally innovative with a Sun camera (SWAP) that is the first solar physics instrument with Active Pixel Sensor (APS) detectors. The data provided are satisfactory and allow operational application related to the risk entailed by space weather on satellite.[471] In July 2010 the French satellite Picard has provided its first images from the Sun. An opportunity for the ground teams to operate the last adjustments before the beginning of the mission. The functioning of the satellite launched has been successfully achieved and it can now start its scientific mission. The satellite is to stay several years to study in detail the Sun's activity by taking one photo each minute and measuring regularly its power during several years.[472] These experiences take place at a cornerstone of the Sun understanding. A lot of questions are raised all around the world such as a recent study published by researchers from Stanford and Purdue University that shows that the decay rates of radioactive elements are changing. An explanation put forward would explain this phenomenon. The celestial body would emit a previously unknown particle that is meddling with the decay rates of matter. The issue appears to be particularly tricky for the searchers and could even bring us to rethink our way of understanding the true nature of these subatomic particles.[473] As herein explained, the solar activity has been provoking great concern among the scientist community given its erratic and sometimes volatile behaviour with potential heavy damages. For this reason, representatives from more than 25 of the world's most technologically-advanced nations were gathered in July 2010 for the International Living with a Star (ILWS) meeting in Bremen, Germany, to discuss the importance of developing better methods for forecasting space weather. Indeed, Streams of charged particles that fly off the sun can interfere with electronics on Earth and satellites orbiting our planet. The dependence of technology on earth being more and more important it appears as a necessity to face the risk entailed by the unforeseeable nature of the Sun.[474]

On the other side of the Atlantic, many efforts are deployed in the same way. In February 2010, the space-based Solar Dynamics Observatory (SDO) was launched successfully from Cape Canaveral on an Atlas V. A project carried out by the DLR supporting NASA-led mission with the SDO Data Center at the Max-Planck-Institute for Solar System Research (MPS) in Katlenburg-Lindau. The data provided by the observatory are due to improve our ability to forecast space weather significantly. From its geosynchronous orbit (36,000 kilometres) SDO should observe the Sun during five years. It is particularly expected from this mission to better understand the negative effects of the Sun. These adverse factors are caused by massive explosions in the Sun's atmosphere, known as "flares" which expel billions of tons of solar material into interplanetary space.

Some of these electrically-charged particles can travel at the speed of light as well as solar radiation. The areas most affected by these harmful solar outputs are near-Earth space and Earth's polar regions. The system will improve the forecasting of solar radiation also known as "space weather". Foreseen more efficiently the threats from space enable satellite operators, to switch their equipment to a secure mode whenever danger threatens, thereby protecting sensitive devices from damaging overloads and surges. When danger looms, astronauts in the ISS take shelter in a specially-protected room. A significant step in the understanding of our Sun achieved to better adjust our behaviour to him.[475] NASA is envisaging devising a Solar Probe intended to plunge directly into the Sun as well.The probe must be launched by 2018 and is due to bring crucial information about solar physics. The announcement means that researchers can begin building sensors for unprecedented in situ measurements of the solar system's innermost frontier. A very stimulating experience in an unexplored territory which will demand cutting-edge technologies given the extreme conditions that the probe is due to encounter.[476] The awareness of the potential damages entailed by the Sun activity has been spreading among the politicians in the U.S., especially the changes in the solar magnetic field which can have a number of effects on Earth, some of which can be disruptive to critical technologies such as GPS and the electric power grid. The congress has subsequently decided to add $5 million to NASA's 2010 budget to refurbish and launch the Deep Space Climate Observatory, which had been shelved since 2001, to replace ACE. NASA and the National Oceanic and Atmospheric Administration will be responsible for getting the satellite ready for launch, and the Air Force will provide the launch vehicle in 2013. The system should dramatically improve the quality of space weather forecasts.[477]

3.9. Outer solar system exploration and observation

A couple of projects are ongoing in Europe, one of the most excitant technology speaking is surely the ESA's Rosetta probe which has returned the first close-up images of the asteroid Lutecia defining it as most probably a primitive survivor from the violent birth of the Solar System. The pictures taken are provided by Rosetta's OSIRIS instrument. Rosetta has successfully completed its flyby and transmitted the data corresponding to Earth. The Lutecia asteroid is due to be a fragment of the cores of much larger objects. The next step for the probe is to meet its primary target, namely the comet Churyumov-Gerasimenko scheduled in 2014. A successful and informative first step in its mission which announces others in the future. An event that also symbolizes a real achievement in term of

know-how for the European industry and scientist community.[478] The French's space telescope Corot has discovered an alien planet orbiting another star and which could host potentially water in its atmosphere. The suspected temperate nature of the planet whose surface temperature is between minus-20 degrees and 160 degrees Celsius could mean that it could harbour liquid water. But this water would not be in the form of Earth-like oceans; more likely it would be only in the form of clouds with water droplets reports scientists. The study of the planet's composition is ongoing and should enlighten our knowledge of similar ones already observed.[479] From its part, the powerful Herschel space telescope enlarges our horizons thanks to the effects called "gravitational lensing" or "cosmic magnifying glass". The European satellite Herschel has been able to detect and characterize galaxies how they are used to be 10 milliards years ago. Herschel is particularly adapted to take advantage of this kind of phenomenon. Indeed, a massive object tends to amplify the visibility of a target located behind it. That allows to observe much more farther than using only its own capacities providing an insight of galaxies never studied before.[480]

A great achievement has been also reached with the return of the Hayabusa capsule in Australia on 13 June 2010. Launched in 2003 the capsule has successfully delivered its sample from the near-Earth asteroid, Itokawa. JAXA concludes with this success a remarkable step in exploration of celestial bodies in partnership with their US's fellows. It was the occasion for Japanese engineers to deepen their knowledge in information on electrical propulsion and autonomous navigation and obtain useful asteroid samples. It is worthy to note that was only the second time in history a spacecraft descended to the surface of an asteroid. A preliminary cataloguing and analysis of the capsule's contents is ongoing by scientist from JAXA in cooperation with Australian ones. The sample should be then distributed to scientists worldwide for more detailed analysis. This return concludes thus a successful cooperation between NASA and JAXA which will be surely pursued in other projects.[481] A short time after JAXA has announced to find minute particles in the capsule of the space probe Hayabusa which returned to Earth. Scientists hope that could help them to better understand the solar system's origin.[482]

In the U.S., the period has been particularly busy in outerspace discoveries. The first is the detection of the youngest nearby black hole by the NASA's Chandra X-ray observatory. The 30-year-old black hole provides a unique opportunity to watch this type of object develop from infancy. The subject would be a remnant of a supernova in the galaxy M100 approximately 50 million light years from Earth. That could constitute an decisive opportunity to enlarge our understanding about mysterious and fascinating black holes.[483] Secondly, a team of planet hunters from the University of California (UC) Santa Cruz, and

the Carnegie Institution of Washington has announced the discovery of a planet with three times the mass of Earth orbiting a nearby star at a distance that places it squarely in the middle of the star's "habitable zone". The W. M. Keck Observatory in Hawaii, one of the world's largest optical telescopes has been used to detect the body. It could host form of life and constitute the most Earth-like exoplanet yet discovered representing the first strong case for a potentially habitable one.[484] Then, NASA has made another discovery thank to its Kepler spacecraft with the first confirmed planetary system with more than one planet crossing in front of, or transiting the same star. The Kepler's ultra-precise camera measures tiny decreases in the stars' brightness that occur when a planet transits them. The size of the planet can be derived from these temporary dips. This discovery would be the first clear detection of significant changes in the intervals from one planetary transit to the next, what we call transit timing variations according to the scientists in charge of the project. There is thus evidence of gravitational interaction between the two planets as seen by the Kepler spacecraft.[485] NASA has also discovered a crucial element which could answer the long-standing question of how massive stars are. Kraus' team whom is known to be at the origin of the discovery used the Very Large Telescope Interferometer of the European Southern Observatory in Chile to observe of a massive disk of dust and gas encircling the giant young star. The presence of the disk is strong evidence that even the very largest stars in the galaxy form by the same process as smaller ones growing out of the dense accumulation of vast quantities of gas and dust, rather than the merging of smaller stars, as had been previously suggested by some scientists. This could be a major step towards a better understanding of Space and development of celestial bodies such as Earth around this kind of stars.[486] Still in the U.S scientists from the California Institute of Technology and UCLA have discovered evidence of "universal ubiquitous magnetic fields" that have permeated deep space between galaxies since the time of the Big Bang. The images provide an insight of the most powerful objects in the universe supermassive black holes that emit high-energy radiation obtained by NASA's Fermi Gamma-ray Space Telescope. There would be signs of primordial magnetic fields in deep space between galaxies. The universal magnetic fields may have formed in the early universe shortly after the Big Bang, long before stars and galaxies formed report scientists in charge of the programme.[487] Finally, Wide-field Infrared Survey Explorer, or WISE has completed its first survey of the entire sky on July 2010. The mission has generated more than one million images so far, of everything from asteroids to distant galaxies. This infrared view highlights the region's expansive dust cloud, through which the Seven Sisters and other stars in the cluster are passing. Infrared light also reveals the smaller and cooler stars of the family.[488]

3.10. International cooperation in space exploration

Rather more than concluding new agreements, NASA has reinforced the previous ones between 2009 and 2010. More explained in the part concerning Mars the cooperation between NASA and ESA has reached another steptstone with the selection of the five science instruments for the first mission. The ExoMars Trace Gas Orbiter, scheduled to launch in 2016 and will be one of the joined robotic mission among in series planned. The second one scheduled for 2018 consists of a European rover with a drilling capability, a NASA rover capable of caching selected samples for potential future return to Earth, a NASA landing system, and a NASA launch vehicle. A crucial experience might constitute the base for further common space exploration mission.[489] Another cutting edge project concerns the common telescope whose new components are under development for the Webb Space Telescope destined to that focus the attention of the infrared camera on specific targets to the exclusion of others. They can therefore concentrate themselves on objects like very distant stars and galaxies. The microshutters will enable scientists to block unwanted light from objects closer to the camera in space, like light from stars in our Galaxy, letting the light from faraway objects shine through. This is a technical challenge and a big step in the cooperation between ESA and NASA to assembly the future most powerful space telescope. Constructed in the U.S. the pieces are installed by the European Space Agency.[490] With national agencies, NASA and the DLR concluded a framework agreement for bilateral cooperation in Washington D.C. on December 2010. The partners have also agreed to cooperate on lunar research, through the Lunar Science Institute Agreement. The NASA-DLR framework agreement encompasses cooperation in all relevant aspects of aerospace research. In terms of space, the emphasis will be on Earth observation and conducting research in the space environment, as well as space operations and planetary research. In addition, the agreement also covers the exchange of research staff and scientific data. There will also be even closer cooperation in encouraging the development of young researchers.[491] NASA and SLR have also concluded an agreement on June 2010 to extent the Gravity Recovery and Climate Experiment (GRACE) mission through the end of its on-orbit life, expected in 2015.[492] NASA and the Israel Space Agency have also signed a joint statement of intent on August 2010 to expand the agencies' cooperation in civil space activities. Several key sectors of cooperation have been identified such as space science, life sciences, space exploration and other areas of mutual interest. An agreement might announce several projects in common in the upcoming years.[493]

Meanwhile, Russia is strengthening its links with Europe and a good many of others countries. An agreement has been indeed concluded on September 2010

between ESA and the Russian Ministry of Foreign Affairs in order to facilitate continuation and evolution of fruitful cooperation between Roscosmos and ESA.[494] The cooperation with ESA member's states is also developing. A complex series of plasmas physics experiments have been carried out by a Russian-German team in January 2010 on the ISS. The German DLR has funded both the development of the experimental equipment and the research itself. The development of the equipment for space and the experiments themselves has resulted in a surprising spin-off in the field of medicine, known as a "cold plasma torch". This is a small medical tool that uses cold plasma to sterilise chronic, antibiotic-resistant wounds. It has already been used with success in clinical trials on more than 100 subjects. A successful cooperation leaded by the DLR which shows just once will not hurt that ISS can provide useful result.[495] Common Scientifics experiences which follow a frame agreement between Roscosmos and the DLR signed in Berlin in June 2010. The agreement which covers long-term cooperation on scientific microgravity research in Photon-M and Bion-M spacecraft. The document defines the framework and general principles of the long-term cooperation program.[496]

Vladimir Putin has emphasized mutual advantages that could obtain Russia and France by uniting their space technological potentials at the meeting of the Russian-French Bilateral Cooperation in December 2010. According to him "Speaking about aviation and space, France and Russia have cumulated essential heritage her". A declaration which follows a clear will to strengthen their relation in the future.[497] Meanwhile, Roscosmos and NASA have begun talks about the possibility of signing a protocol in order to define and implement different space programs. The protocol could include missions to asteroids and the moon.[498] In July 2010 an important agreement was concluded between Russia and the UK to enhance and develop their mutual cooperation in particular concerning space exploration, the Memorandum of Understanding highlights the new step in relations between the UK Space Agency and Roscosmos.[499]

Prime Minister Vladimir Putin has also reiterated its commitment to strengthening Russia and Ukraine cooperation in space exploration. The two countries are devoted to modernizing their economy by creating high-paying jobs and new technologies clusters. The areas concerned are nuclear power industry but also aircraft industry and space exploration. [500] Russia has also been sustaining a dialog with India especially to develop several project related to space exploration such as the successful lunar exploration projects (Chandrayan-2) which could be the fisrt to a serie of common project.[501]

Egypt and Saudi Arabia have signed a memorandum of understanding on remote sensing and space sciences cooperation. The agreement is aimed at promoting joint action in the domain of space sciences and remote sensing research and exchanging expertise and information on this score, he added.[502]

4. Satellite applications

4.1. Space-based communications

Apart from development in government programmes and industrial activities presented above, one of the most prssing issues that preoccupied global satellite communicatios was the issue of interference. On 27-29 October the Satellite Users Interference Reduction Group (SUIRG) met in Cannes, France. The Group has been trying for years to raise industry awareness of the importance of interference for commercial communication satellites operators. During the meeting, Intelsat, SES and Inmarsat decided to create a voluntary satellite database named Space Data Association (SDA) and based on the Isle of Man. Its mission will be to collect voluntary data contributions from commercial operators on their respective satellites, such as satellite location, broadcast frequencies and power, signal polarisation and coverage areas. Using this database should shorten the time needed to localise interference sources. Other commercial operators were expected to join in the effort, but questions remained on whether they would be willing to distribute such sensitive information. Furthermore, although this initiative is expected to contribute to limiting unintentional interference, it will still have to overcome the absence of a legal framework that would oblige operators to cease activities that create interference.[503]

In November, SDA begun to take form as its three founding companies issued a Request for Proposals (RfP) for a contract to design and build the database. The RfP called for the creation of a central Space Data Centre on the Isle of Man, as well as two more backup data storage servers on different continents. These would probably operate from within SDA member companies. The centre would provide accurate and timely information on commercial satellites and would also act as a registry of interference incidents and sources. SDA's members also signalled their future intention to link the database to the U.S. Space Surveillance Network and to invite operators from Russia, China and India to participate as well.[504]

4.2. Space-based positioning, navigation and timing systems

The European GNSS programme has withnessed considerable progress during the period in question. Apart from its progrees in contracting its first spacecraft mentioned above, the programme has also matured in its purpose, ellevated to a strategic asset fo Europe. For example, in March 2010 the European Commission announced that it was considering the removal of

all non-European built components from the Galileo satellites currently under final assembly. This decision, mainly affecting Chinese-built parts of the spacecrafts for which European-made substitutes would have to be found, reflected the EC's view of the system as a strategic asset for Europe, in which a cetain degree of manufacturing independence should be achieved. However, if this this decision were to materialise it might also impede the procurement of the Canadian-built search and rescue terminals currently envisaged for the system. This significant change in the programme's procurement policy could also be seen as a result of its change from a private-public partnership to a 100% public financed project.[505]

In any case, this decision was reinforced by China's own step towards the development of its own national satellite navigation system called Beidou (Compass). The system was originally planned to provide only regional coverage, with China relying on Galileo for global wide use. However, this policy is now changed and China is developing Beidou as a global system, directly competitive to Galileo. This development has also created friction between European and Chinese authorities over radio frequencies reserved for each system's government-only use, known in Europe as the Public Regulated Service (PRS) and in China as the Authorised Service. Although these systems should in principal emit in different frequencies, negotiations over allocating them between Galileo and Beidou have been fruitless up to now. On the contrary, a similar agreement between Europe and the U.S. was signed already in 2004 and similar negotiations with Russia on cooperation with its Glonass system also saw progress in 2010.[506]

Another important developmnet concerning Galileo was the preliminary agreement reached among EU membern states in March 2010 on the service use policy of the PRS. Negotiations were expected to conclude by the end of 2010, but it appeared that EU governments would be granted direct and unconstrained access to Galileo's encrypted military signal. This arrangement would imply that EU member-states would all create their own national points of contact with the system's two Galileo Security Monitoring Centres (GSMC) in France and the UK and they would be solely responsible for the service's use by their authorities. Furthermore, officials from the Galileo Supervisory Authority (GSA) disclosed that all member-states would have unrestrained access to the service and no prior approval by EU institutions or authorities would be required for its military use. However, according to the same sources, the question of whether the PRS would be completely free of charge like its GPS counterpart or if its use would entail a certain fee was not yet decided. Needless to say that any charge related to PRS could damage Galileo's competitiveness to its U.S. counterpart.[507]

Finally, in a related development the European GPS Navigation Overlay Service Egnos was declared ready for use for its freely accessible service on

1 October 2010. Higher reliability versions, as well as an Egnos Commercial Service were expected to become operational in 2010. The system uses two Inmarsat and ESA's Artemis satellites to augment GPS performance. The programme's budget was €350 million. A French-based consortium of seven European air-navigation agencies, called ESSP, is under contract to the European Commission to manage Egnos until 2013.[508]

Another country that paid particular attention to the development of its satellite navigation capabilities in 2009 and 2010 was Russia. The Glonass constellation is expected to be completed by the end of 2010, with the launch of 7 spacecraft, bringing their total number to 28 satellites, of which 23 fully operational.[509] Nevertheless, the constellation would have to include at least 24 spacecraft to provide global coverage.[510] The development of a new generation of satellites (Glonass-K) has already matured and the first spacecraft are expected to fly by 2011. The programme's budget reached 2.5 billion Rubles in 2009 and it was expected to rise to 3.7 billion Rubles through 2011.[511] The first three of the Glonass satellites scheduled for 2010 were put into orbit on 2 March onboard a Proton-M rocket launched from the Baikonur Cosmodrome.[512]

Further steps for the programme include improving its performance and accuracy, as well as giving it an international dimension by providing services outside Russia. In this respect the Russian government has launched a high political level effort to convince neighbouring countries and emerging space powers to subscribe to the system's services. The issue was discussed during the Russian Prime Minister's visit to India in March. According to Russian officials, the two countries would establish a joint venture in India to produce Glonass-compatible navigation equipment. According to the same sources Indian authorities would use the system's civilian signal at first, but negotiations were underway to allow them to access its more accurate military signal as well. All navigation equipment made in India would also be GPS compatible.[513] Finally, in order to improve the system's commercial prospects Russian authorities announced that the next generation satellites' civilian use signal would be compatible with the GPS and Galileo systems.

In a similar fasion, Russian officials discussed with their Ukrainian counterparts the possibility of creating a joint venture for the supply of Glonass services to that country as well. Although Ukraine has previously opted for using the GPS satellite positioning system, the recently elected government seemed to prefer the simultaneous use of both the U.S. and Russian systems, but no final decision had been made yet. Finally, broader negotiations between the two countries on possible cooperative ventures in the field of communications, including Satcom's, were expected to start in the second half of 2010.[514]

4.3. Space-based Earth observation

In the field of Earth observation, 2009 and 2010 saw considerable advances in the European GMES EO programme. The European Commission also had a number of decisions to make during the period in question, including defining a data-access policy and securing future funding. GMES would consist of three dedicated Sentinel surveillance satellites and two payloads on other satellites, for which the European Commission has secured a €2.3 billion budget while most of the hardware will be paid for by ESA's 18 Member States. In addition to this, the programme will utilise national satellites built by Member States. However, funding of the future generation Sentinels after 2013 still remained unclear. Although European Commission officials were previously leaning towards a user-defined/user-paid approach, press reports indicated that longer operating cost recoupment methods were also considered.[515]

The question of the future funding of the GMES space segment preoccupied the European Commission and Member States throughout the year, as the European Commission budget line for the programme would expire in 2013 and further funding would be needed to develop the next generation of its Sentinel satellites. For the time being, six Sentinel satellites and two dedicated payloads onboard EUMETSAT satellites are planned. However, with an expected satellite operational life-span of seven years, the next generation of Sentinels will have to enter into development soon, in order to sustain operations after 2020.[516]

As far as future funding is concerned, all possible options were investigated by the European Commission. The conclusion was that only an adequate long-term budget for GMES operations after 2013 would guarantee a profitable return for the investment already made on the programme. In other words, backing away form the project now would defeat its declared objective of a sustainable Earth observation capability for Europe. Furthermore, without additional future funding the programme would not reach its full research and development potential and it would not produce any significant technological returns for the European space industry.[517] An independent ESA long-term analysis of the programme also reached the same conclusion. According to this, a €600 million annual budget between 2014 and 2020 would be required, including €470 million for operational activities and €170 million for future research and development, (R&D).[518]

Several other issues concerning GMES also remained open, including ownership of the system, data policy, procurement policy and governance arrangements. The most probable scenario contemplated would be for the transfer of the Sentinels' ownership from ESA to the European Commission (EC). Such an arrangement would make the EC the operator of the system's space segment,

thus assuring a free and open access policy to its data. It would also normalise the project's governance, with the EC acting as the programme manager deciding on system upgrades, ESA working as the development and procurement agent on behalf of the EC, and EUMETSAT operating oceanographic and meteorological components onboard its satellites.[519] Finally, another milestone for the programme's governance was accomplished on 5 February 2010, with the European Commission's decision to set up the GMES Partners Board. The 27 member board (one from each EU member country) would function as a panel of experts, monitoring the GMES project's implementation and providing strategic guidance for its future development.[520]

ESA, on the other hand, launched on 1 November 2009 its Soil Moisture and Ocean Salinity (SMOS) Earth observation satellite and the Proba-2 technology demonstration spacecraft, aboard a Russian Rockot vehicle operated from the Plesetsk Cosmodrome. The 658 kg SMOS was put into a near-polar sun-synchronous orbit at an altitude of 760 km. It is equipped with a Spanish Microwave Imaging Radiometer using Aperture Synthesis (MIRAS) instrument, the first major satellite instrument built for ESA in that country. The device is using L-wave microwave frequencies to derive information about soil moisture and ocean salinity levels based on their reflection. Proba-2 is an ESA spacecraft that is set to test future satellite systems and instruments currently under development. Total costs of the programme reached €333 million.[521]

5. Technology developments

5.1. Propulsion

The period 2010–2010 has seen the emergence of a lot of new technologies and improvements while questions arise concerning the technological challenges to take up, brought by the prospective of Mars exploration. The main cutting-edge evolutions ongoing come predominantly from Europe, the U.S., Russia and Japan. It is worthy to note that almost each country or region have its own programme in this field particularly strategic. This is not astonishing because it affects directly the weight that the launcher can lift and so the profitability of the system. Europe has made significant progress especially concerning its IXV (Intermediate eXperimental Vehicle). It is now in a transitory period of its FLPP (Future Launchers Preparatory Programme) between the step two (2009–2012) which includes Completion of systems studies on expendable launch configurations, progression through ground demonstrators, in particular for high

thrust engine, in-flight experiments and cryogenic upper stage technologies, and the step three (2012–2015) with the flight of the IXV on an ESA Vega Launcher. These tests are necessary to prepare the development of next generation launcher and begin to design the future vehicle.[522] This movement was particularly noticeable with the signature of an agreement between ThalesAleniaSpace and ESA for the development of the IXV.[523] A new step was reached with the workshop hold in Paris in September 2010 which came within the scope of developing a European re-entry flight module. The main industrials involved in the development of the next ESA's Intermediate experimental Vehicle had the opportunity to discuss and suggest their hardware development and issues. The event was the occasion to share technical achievement and to envisage the short and long term perspectives concerning this crucial project. The IXV project objectives are the design, development, manufacture, ground and flight verification of an autonomous European lifting and aerodynamically controlled re-entry system. Three sides of the project have been particularly studied namely, advanced instrumentation for aerodynamics and aerothermodynamics, thermal protection and hot-structure solutions, guidance, navigation and flight control through a combination of thrusters and aerodynamic flaps: It is foreseen that the IXV be launched in 2013 on Vega Europe's new small launcher, as part of the "VERTA" (Vega Research and Technology Accompaniment) programme. After re-entering Earth's atmosphere and being slowed by friction from 7.5 km/s, it will descend by parachute and land in the Pacific Ocean to await recovery and analysis.

A High-thrust engine demonstrator industrial day has been also hosted in Germany during February. It has confirmed the commitment to develop a liquid propulsion system for first stage propulsion providing flexibility and efficiency. The demonstrator is due to be definitely chosen by mid 2010 and will undergo firing test around 2015. The activities were presented by the Joint Propulsion Team, a contractor consortium composed of Astrium GmbH (D), Avio SpA (I) and SNECMA (F). It is a critical endeavour in the will to equip Europe with a new generation of launcher able to continue the "success-story" of our continent in this strategic domain.[524]

Concerning propellant itself a great step has been achieved to overtake hydrazine. This one is a high-performing storable propellant, given its characteristics and remains the main source of fuel for satellite. Unfortunately hydrazine is also highly toxic and ground personnel have to wear protective gear in all procedures dealing with this substance. This situation is due to change as ESA and a Swedish company called ECAPS, part of the Swedish Space Corporation Group develop a new propellant officially called LMP-103 S, this new fuel is a blend of ammonium dinitramide (ADN) with water, methanol and ammonia. The AND is not only

due to give better performance (around 30%) but it will be much less toxic for humans and their environment as well. That would facilitate and reduce the cost of satellite handling as they would not have to be fuelled at the last moment as this is done now due to safety reasons.[525]

Concerning engine more particularly, the development of the new Vulcain equipping currently Ariane 5 has known a new step with the test of a new nozzle design (codenamed NE-X) for the first time. The nozzle is built by the Swedish company Volvo. The innovative design consists of a sandwich system construction "an external metal cone is laser-welded to an inner one, doing away with the numerous cooling ducts of the current design. The result is a construction that is considerably cheaper to produce than the existing Vulcain nozzles, as well as lighter than more powerful, thus increasing the payload capacity and cost-efficiency of the Ariane 5. Numerous of tests have been carried out so far to gauge the viability of the system and adapt it in order to enhance the global performances of the engine and so Ariane 5 itself.[526]

In the other side of the ocean Atlantic is not outdone with a couple of significant innovations in this field. The NASA's ion-propelled Dawn spacecraft has eclipsed the record for velocity change produced by a spacecraft's engines, deep in the heart of the asteroid belt, on its way to the first of the belt's two most massive inhabitants. The Dawn mission to Vesta and Ceres is managed by JPL, a division of the California Institute of Technology in Pasadena, for NASA's Science Mission Directorate, Washington[527] Then, NASA has achieved a milestone in its preparation for a third major rocket engine test project concerning the next generation J-2X rocket engine.[528] The transition work from the space shuttle main engine project to the J-2X test project included structural, electrical and plumbing modifications to accommodate the different geometry of the J-2X engine, and included the installation of a new J-2X engine start system. Liquid oxygen and liquid hydrogen transfer lines that dated back to the 1960s also were replaced, as was other piping on the stand. Control systems also were upgraded on the stand. The J-2X engine is being developed by Pratt & Whitney Rocketdyne for NASA as a next-generation engine that can carry humans beyond low-Earth orbit to deep space. These crucial improvements announce thus future and maybe more daring missions.

Another field explored by the U.S. agency consists of a new kind of manoeuvre without any fuel depending only on the power of Earth's magnetic field to move satellite and spacecraft in orbit.[529] This particular force could be employed to compensate the degradation of their orbits due to friction from colliding with atmospheric particles that have escaped into space. This technology would considerably reduce the need of propellant and could prolong the satellite's life expectancy. This would be useful as well to make them re-entry into the atmosphere when they will have accomplished their mission.

Japan has also undertaken research to develop a new kind of solid propellant for its rockets. The main objectives are to facilitate the operations in the grounds facilities and save about one fourth of the time previously needed. The new system expected should improve the liquid propellant consumption and simplify the procedures making them meanwhile safer.[530]

Another major Japan's space propulsion project is to launch a "space yacht" propelled by solar particles that bounce off its kite-shaped sails. The ikaros is a prototype of interplanetary Kite-craft accelerated by radiation of the Sun, the system is a "space yacht" that gets propulsion from the pressure of sunlight particles bouncing off its sail. The flexible sails, which are thinner than a human hair, are also equipped with thin-film solar cells to generate electricity to create an hybrid technology of electricity and pressure.

Nuclear energy seems to particularly interest the Russian which would like to take advantage from their know-how in this field. A lot of events have underpinned this will during 2010–2011. For instance, Russian President Dmitry Medvedev defined Keldysh R&D Center as a sole designer of the megawatt nuclear propulsion system.[531] This event took place before the statement of Roscosmos Head. According to him, attempts to improve parameters of the existing rocket propulsion systems are unreasonable. Indeed, the improvement of actual fuel propellant would be only measurebable in fraction of percentage, far from the power necessary to furnish reliable propulsion to reach Mars. Nuclear would impose itself as sole realistic alternative especially for large scale manned mission.[532]

This affirmation has been backed by Russian scientists from the Moscow Physical institute[533] which currently study the opportunity offered by powerful plasma engines in nuclear propulsion systems which could provide according to prof. Oleg Gorshkov the necessary technology to build a new generation of spacecraft. One more time this conclusion supports the idea that nuclear energy would be much more effective for long term and human mission, these kind of Ionic engines are featured by 5-year life-time. By this way the Russian authorities could prepare their participation to an eventual future mission towards Mars which would probably necessitate a nuclear propulsion system much more light and powerful than classic propellant.

5.2. Information technology

An important step has been made with the ESA's SMOS satellite which includes the use of fibre optic in the micro satellite.[534] It represents thus a historic step forward "photonics" in space. Proba-2's experimental payload includes a fibre-

optic sensor system which monitors its propulsion, while SMOS's triple-armed MIRAS (Microwave Imaging Radiometer using Aperture Synthesis) is entirely reliant on an optical fibre-based communication harness. This represents a historical turning point for the use of lightwave technologies in space, there are more than 500 metres of optical fibres embedded within the MIRAS instrument. Through this project ESA extends the use and network of optical fiber to Space. This system allows not to produce electromagnetic radiation to transmit information which could be polluted among other electrical signals, indeed Any electrical noise leaking out from the electronic boxes in the arms can influence the correlation measured and blur the resulting images and optical fibres relay information with light pulses rather than electrical signals, so they do not produce any. But MIRAS's optical fibre harness turned out to bring other advantages. Their lower weight meant that the instrument's long arms could be unfolded in orbit using relatively light spring-loaded motors, and the fibres' mechanical flexibility meant their performance was unaffected by this movement. This is therefore a crucial step ahead which will probably lead to other applications on other future satellites. Another important advance has been done with Hylas-1, the first satellite created specifically to deliver broadband access to European consumers, is very much a commercial undertaking. It is also a significant technological achievement, encapsulating a decade of research and development by ESA and European industry. This satellite has also the specificity to be a successful public private partnership through UK operator Avanti Communications and ESA. The satellite is particularly adaptable and is due to enter in service very quickly contrary to its counterparts. It has also the capability to reuse its given allocation of radio frequencies between spot beams. The operator can fine-tune how much bandwidth and power to put in each beam so it is possible to match changes in data demand as they happen in order to be more reactive to the market.

The satellite is the result of an intense cooperation between ESA and Atrium for the development of a Modular Microwave Hybrid Technology' (MMHT). A successful relation which has produced this Generic Flexible Payload making the Hylas satellite so efficient. The flexibility that the GFP delivers to Hylas-1 is increased by another pioneering piece of technology, developed with ESA support by Tesat-Spacecom in Germany: the In-Orbit Adjustable Microwave Power Module (IOA-MPM) allows the transmit power signal to be adjusted to match demand while maintaining near-constant efficiency, preventing power being wasted in the form of heat. One last innovation is the most visible: Hylas-1's larger, double-sized antenna, which had to be carefully optimised for high-frequency Ka-band operations, the responsibility of EADS Casa Espacio in Spain. Hyas project is thus the vibrant example that we can associate in a PPP the needs of profitability and science.

5.3. Spacecraft operations and design

This subject has brought an intense reflexion in various areas such as Europe, Russia, U.S. and Japan to find solution or arise the future challenge that the future Spacecrafts will have to take on.

It is such a defy to fly multiple satellites in formation, separate multi-million-euro pieces of hardware, each one moving through space at several kilometres per second through an hostile environment. Lose the control even momentarily can entail dramatic consequences that a cutting-edge software try to avoid. To respond to this challenge ESA and industrial have developed a new software to get to grips with multiple-satellite missions to come. This one is a generic simulator for formation flying mission no matter how many spacecraft are concerned. Of course this system needs several CPU in order to calculate the different trajectories so the software is distributed among several machines without affecting the users of them. This new technology will be used to address crucial operational factors for formation flying, including mission and vehicle management, guidance navigation and control, fault detection, isolation and recovery and inter-satellite links.[535] A test is ongoing on Proba-3 and already announces itself has a great step in Spacecraft management.

In Russia, a constellation of nano-satellites is to be launched by Russian scientists in the coming two years.[536] It is another development of nano-tehnology in Russia which started 5 years ago when Russia launched its first nano-satellite. Russia is firmly committed to investing in this new branch particularly crucial in space application. The only national micro-satellite was launched manually from the ISS by cosmonauts Salidzhan Sharipov. Another ground of reflexion in Russia is symbolised by the CIS programme called Cosmos-NT which is aimed at reducing duration and expenses on development of new space technologies in order to achieve the goals of space programs for the benefits of Russia and Belorussia.[537]The program will include a multifunctional space system which is an integrated part of Russian and Belorussian ground and orbital systems. The system will provide space monitoring data to the users, maintain acquisition of navigation data and remote education on the basis of communication and relay satellite systems. Cosmos-NT includes development and verification of space data display systems, design of a unified micro-satellite platform, development of advanced propulsion systems and power supplies, etc, BELTA informs.

Russia has also undertaken the development of a new vehicle which will be capable of docking to the orbital station on the day of its launch.[538] The decision has not been definitively made yet and the convenience for the crew and the cost-effectiveness of this solution must be verified.

This vehicle would be multifunctional with several types of mission such as to LEO and LLO, spacecraft orbital maintenance, deorbiting big space debris and it could be also used to fly space tourists. The configuration expected for the vehicule is a capability to fly autonomously for 5 days, and in the lunar modification 4 cosmonauts shall fly in the vehicle for 14 days.

Japan is pressing forward with ambitious plans to enhance its role on the international space station (ISS), announcing its intentions to better utilize the Kibo laboratory and build a variant of the H-2 Transfer Vehicle (HTV) that would be capable of bringing cargo back to Earth.[539] JAXA officials have presented two enhancements which would allow the HTV to return cargo from the space station before 2020 and put the automated cargo supply ship on the path to eventually carrying humans. The Japanese government is particularly committed to improving the current HTV since a statement in which he has firmly expressed its will to procure to Japan its own human space capabilities. The main aim is to provide an alternative way to resupply the ISS while that would also allow to maintain the nation's space industrial base, and also its participation in the ISS which constitutes an important part of Japan's soft diplomacy and power projection.

5.4. Suborbital activities

The suborbital news are mainly dominated by the U.S. which extends important investments to foster the private activity in this field. However a significant English technology could soon reestablish the balance between Europe and the U.S. in term of reusable and suborbital spacecraft.

2010 is a milestone for suborbital activity, Masten Space Systems of Mojave has signed a letter of intent with space florida to explore conducting demonstration launches of Masten's suborbital reusable launch vehicle from Cape Canaveral.[540] A crucial step in space tourism has been also reached by virgingalactic. Though SpaceShipTwo did not reach space, the flight was a major step for the private suborbital spacecraft, which flew in glide mode for 11 minutes after being released from its WhiteKnightTwo carrier plane at an altitude of 13,700 meters. Accomplished on the 13 October 2010 this successful flight allows Virgin Galactic to go ahead in this non explored field.[541] Virgin Galactic is resolutely on the roll. Indeed, a new law has been enacted in New Mexico and saluted by the company. This legislation reduces significantly the risk that space tourism operators will face crippling lawsuits brought by surviving family members of a participant injured or killed during flight.[542] The performances targeted are quite similar in term of thrust and efficiency, but the real objective is to develop rather more an engine that could be dropped into existing stages. The real challenge is thus to make it much

cheaper and adapt the existing engine to the XCOR's spacecraft Lynx. The suborbital spacecraft is designed to carry tourists along with research payloads. Those recent developments bring about analyst to foresee a global fall of the suborbital tickets for the next years.[543] Indeed hundreds or even thousands or flights could be soon operated once the technical aspects have been solved. The question of the future of this market is however a crucial question given the huge investments which have been made so far. It is expected that the markets growth as the price by seat drop but that does not mean necessarily that could become a sustainable activity. An important topic particularly treated during July 2010 at the Space Frontier Foundation's annual conference in Sunnyvale.

The development of commercial suborbital flights is kindly watched over by NASA which tries hard to encourage this activity through programmes such as the Commercial Reusable Suborbital Research (CRuSR) under which the agency proposes to spend $75 million over the next five years to make use of commercial suborbital vehicles. According to the U.S. agency those flights would constitute a real opportunity to carry out there scientific experimentations at a lower price.[544] Other scientific and independent entities have decided to invest this field by investing or booking pre-ticket. A lot of disciplines are concerned such as astronomy, life sciences, and microgravity physics. There are no less than five companies which are due to propose suborbital flights, namely These firms, led in some cases by technology industry pioneers, include Virgin Galactic, Armadillo Aerospace, Blue Origin, Masten Space Systems and XCOR Aerospace. That could be a crucial asset in order to rend the market profitable and competitive enough by maintaining several operators in course allowing thus lower prices.

The race for the NASA awards concerning the development of commercial launchers and spacecraft that would transport astronauts to and from low Earth orbit is particularly fierce. While Sierra Nevada Corp is the big winner in NASA's first round of Commercial Crew Development awards, Orbital Team could take the lead by proposing a new lifting-body spacecraft capable of carrying at least four passengers to orbit by 2015.[545]

The spacecraft, designed to launch atop an Atlas 5 rocket and dock with the international space station, could be ready for test flights as early as 2014. The remotely piloted spacecraft would be able to carry four passengers initially, including three astronauts and one paying ticketholder.

JAXA undertook scientific research with several releases of balloons from the Taiki Aerospace Research Field.[546] The release experiment, called BS10-06, aimed at testing the high-altitude thin film balloon flight performance and observing the ozone and atmospheric gravitational waves. The balloon that was expanded to its full capacity of 60,000 m^3 was made of a thin film for high altitude

with a thickness of 3.4 micrometers, and it ascended about 300 meters per minute. In this experiment, we achieved the scheduled objectives of flight verification for a thin-film high-altitude balloon using the polyethylene thin film that is wider than conventional films, and the balloon's tearing mechanism for a thin-film balloon. At the same time, the balloon carried out precise observations on the ozone, wind velocity, temperature and air pressure using two kinds of ozone measurement devices, namely an optical type, and electrochemical type.

5.5. Other technologies

The 2009–2010 period has been particularly rich in technological and science progresses and advances in the current major programmes. First of all, Astrophysics and space observation have experienced significant progresses.

Dark matter has interested scientists for many years, two researches carried out could improve our knowledge about this crucial topic. Astronomers from NASA have created one of the most accurate map of dark matter in the universe thank to Hubble space Telescope.[547] An important step to better understand this crucial element of the universe functioning. The researches are particularly focused on the massive Galaxy Abell 1689 which could explain the particular role of this substance. Astronomers have devised a new method for measuring the dark matter through cosmic lens for this purpose.[548] The AMS (Alpha Magnetic Spectrometer) launched by endeavour on 16 April 2011, it should provide other crucial information about dark matter and black holes. It has been assembled in the CERN (European Center of Nuclear Research) based in Geneva and is the result of cooperation between ESA, NASA and the CERN.[549]

In Europe, the magnetic tests are ongoing to check if the spacecraft LISA Pathfinder is magnetically clean,[550] The project among the most difficult challenge treated by ESA is due to be launched in 2013 and concerns gravitational wave detection. To succeed, the mission has extremely stringent requirements to limit any disturbance of the test masses by magnetic materials or effects. Having first characterised these effects, designers sought to minimise them. Any magnetic disturbances could condemn the entire mission to failure.

Astrium is due to supervise the development of an atomic clock using two new-generation atomic clocks to be operated aboard the international space station under a contract with the European Space Agency (ESA).[551] The system will be launched by 2013 aboard a Japanese HTV. The first, called Pharao, was developed by the French space agency, CNES. It is a laser-cooled cesium clock designed specifically for use in a microgravity environment. The second, developed by the Observatory of Neuchatel, Switzerland, is a hydrogen maser clock. Ground based

atomic clocks through a microwave network will be used as comparison with the two ACES clocks to measure the differences.

The ESA's Herschel infrared space observatory has discovered the key ingredient for making water in space-ultraviolet starlight.[552] A crucial finding which explains why a dying star is surrounded by a gigantic cloud of hot water vapour. Herschel's PACS and SPIRE instruments have revealed that the secret ingredient is ultraviolet light, because the water is too hot to have come from the destruction of icy celestial bodies. The Herschel water detection made the astronomers realise that ultraviolet light from surrounding stars could reach deep into the envelope between the clumps and break up molecules such as carbon monoxide and silicon monoxide, releasing oxygen atoms. The oxygen atoms then attach themselves to hydrogen molecules, forming water.

Concerning rather more life in space and medicine. In 2010 NASA had announced a capital discovery concerning other form of life,[553] if a lot of people have been finally disappointed by the new it was however an important step. Indeed, NASA astrobiology research has changed the fundamental knowledge about what comprises all known life on Earth. The first micro organism on earth capable to use Arsenic in its reproduction process has been observed. These researches allow us to rethink what we had previously considered as the necessary basis of all form of life. In the future this kind of discoveries could allow us to detect more easily and better understand extraterrestrial form of life.

ESA coordinates a project made of French companies MEDES Magellium and the CNES designed to use Ultrasound as medical technique.[554] This system is particularly useful for remote operation by distant specialists which could be crucial in case of operation aboard a spacecraft. ESA tests currently this new robotic ultrasound system within a project expected to last two years.

Medicine is a domain in which ESA has already shown its capacity to transform a scientific discovery into a successful innovative and commercial project as it has been recently illustrated with the telemedicine system telemedicine system adapted to answer to a potential onboard medical emergency.[555]

In a more practical view numbers of important programmes have been carried out. Experiment concerning nanotechnologies have been engaged to better understand the creation process of carbon nanotube,[556] and especially how carbon gets recycled in the regions of space that spawn stars and planets. Lead in cooperation between NASA and a Japanese university, this crucial study could bring about some cutting edge progress which could find application in various sectors and even enhance our understanding of certain supernova for instance. The first human-like robot Initially developed by NASA and General Motor the so called R2 is due to join the ISS crew and become a permanent resident of the ISS.[557] Its operational functions will be being studied on weightlessness.

It announces future enhancement in order to make it sufficiently autonomous to move inside and outside the complex executing tasks more and more complex. The current model is not yet equipped with system resisting to the extreme temperature of outer space but it is just a matter of time.

NASA experiences new tank dome technology[558] in partnership with Lockheed Martin Space Systems and MT Aerospace in Augsburg, Germany. This new development should reduce the weight of future liquid propellant tanks by 25 percent, compared to current tank designs that use a lower-strength aluminum alloy that weighs more. The concave net shape forming process patented by MT Aerospace simplifies the manufacturing and reduces thus considerably the costs Beyond the technological feat it is a good example of international cooperation between Europe and the U.S:. This project has been funded by the Exploration Technology Development Program for NASA's Exploration Systems Mission.

The study of earth and particularly its weather provokes concerns and thus a lot of innovative solutions to deal with the upheavals brought about by the climate change.

NASA has carried out an experiment using a new prototype designed to surveying the impacts of aerosols and clouds on global climate change.[559] The successful test is the first step to equip weather and scientific satellite with this instrument. NASA has also revealed its new tool for weather forecast called iSWA[560] (Integrated Space Weather Analysis) which gathers information from spacecraft including the National Oceanic and Atmospheric Administration's (NOAA) Geostationary Operational Environmental Satellites (GOES), NASA's Solar Terrestrial Relations Observatory (STEREO), the joint European Space Agency and NASA mission Solar and Heliospheric Observatory (SOHO), and NASA's Advanced Composition Explorer (ACE). It is expected that this new system in constant evolution allows to improve weather forecast and global understanding of it by making information more available to the scientific community.

Earthcare a satellite jointly developed by Japan and ESA is undergone vacuum test[561] before its launch scheduled for 2013. Equipped with four sensors (Cloud Profiling Radar, Backscatter Lidar, Multi-Spectral Imager and Broadband Radiometer) it will permit to improve the accuracy of climate change predictions. It is know that the effects from clouds and aerosols make sometimes current predictions unreliable. This phenomenon between radiation in interaction with clouds and aerosols can be studied and solved enhancing the reliability of the data collected to study the weather.

ESA is working on a largely ground-based project: designing the Agency's Space Situational Awareness infrastructure, which will allow Europe to track potential hazards in space. This system will permit Europe to predict, detect and

assess the risk to life, property and in particular space assets due to natural or man-made space hazards. A contract was recently awarded to ThalesAleniaSpace (France) supported by Spanish, French, German and Belgian companies.[562] The network of computers organizes will allow to constitute an efficient and coordinate tools to detect any risky situation from space. This allows for iterative design at a fast pace, with customer and designers agreeing requirements and taking decisions in real time to ensure the best design for the right cost and an acceptable risk. New navsat sensors developed within the scope of the ESA Business Incubation Centre in the Netherlands allow to improve electricity production from a hydroelectric plant on Lake Laja in Chile by using navigation satellite signals to measure water levels and wave heights in real time.[563] The device provides a very accurate of the water level reducing drastically the maintenance needed to check the water sensors.

The burning topic of space debris has brought about some interesting development. Especially in Russia where tracking space debris has been becoming a real concern for Russian authorities which have planned to tackle this crucial issue for the benefit of the worldwide space activities. We have seen a great involvement and significant progress to develop adapted technologies. To achieve this purpose, a group of scientists from Lebedev Physical Institute (FIAN) have developed a unique special tracker and SW which can be used to search for small space debris from 1 to 10 cm.[564] The tracker could be installed on any spacecraft especially concerning those located in risky orbit such as GEO. A more ambitious programme in Russia again is devoted to launching a special orbital pod that would sweep up satellite debris.[565] The system whose the cost is estimated around ($1.9 billion) could help to clean up busy orbit such as LEO and GEO by collecting or sinking them into ocean. The cleaning satellite would work on nuclear power and would be capable to work up to 15 years, he said. The company Energia that would be in charge of this task announce a complete assembly by 2020 and test the device no later than in 2023. In the same way, Alliant Techsystems (ATK) is currently developing a new system specially designed to tackle debris too small to be tracked by ground-based telescopes but large enough to penetrate satellite shielding.[566] The plan is to launch a spherical spacecraft enclosed in multiple layers of a lightweight material. The spacecraft would operate in low Earth orbit as a sweeper or shield, breaking up debris particles and reducing their velocity.

5.6. Innovation policy

The U.S. space strategy seems to take a more practical path while President Obama makes a no binding promise of developing by 2025 "a new spacecraft designed for

long journeys to allow us to begin the first-ever crewed missions beyond the moon into deep space" [567] and furthermore by the mid-2030s to send human on Mars. The devotement to favour new technologies can be seen through the budget which shows a sharp engagement in research and development programs[568] Obama is asking the U.S. Congress for $19 billion for NASA for the year ahead, a 1.5 percent increase over the agency's 2010 budget. The spending includes particularly new technology programmes such as robotic missions and propulsion research. The main rise concerns primarily science Earth observation that focuses the U.S. efforts. The agency intends to use prize competitions, to encourage public-private partnerships and other approaches to develop next-generation technologies. The great new of the Obama space program was the cancellation of the Constellation programme. Indeed, that has released funds particularly devoted to develop new initiatives such as commercial crew program, heavy Lift and Propulsion or in orbit refueling.

Russia shows a strong will to cope with international competition in space. A determination noticeable in several occasions. Russia is expected to launch a scientific mission after a long absence in this area.[569] The astrophysical observatory Spektr-R is to fly in May-June 2011 and should study interplanetary magnetic field and black holes. Interplanetary station to Mars' moon Phobos-Grunt is to be launched in late 2011. This one is to deliver soil from Mars' moon and to study both Mars and Phobos. Satellites such as Loutch-5A spacecraft whose the launch is scheduled for 2013 is intended to reinforce the Russian position in space by deploying a multi track and effective relay satellite capable of transmitting data from any other spacecraft. It will be effective for agriculture, military, weather forecast and other services.[570] Russian government includes the space sector in its plan of modernization and technological evolution by providing extra money to Roscosmos the national agency.[571]

ESA has chosen its main scientific missions in 2010. The topics selected are Dark energy which is currently studied by project such as the AMS, habitable planets around other stars, and the nature of our own Sun.[572] The Euclid mission will be particularly devoted to addressing key questions relevant to fundamental physics and cosmology and particularly concerning dark energy and dark matter which are known to be crucial in the functioning of the universe. The PLATO mission will concern rather more the frequency of planets around other stars and especially the fascinating possibility to find another habitable planet. Finally, Solar Orbiter will be designed to studying more closely the activity of our Sun especially concerning solar far side when it is not visible from Earth. All three missions present challenges that will have to be resolved at the definition phase, the decision is thus not definitely made. Participation to the Japanese SPICA infrared telescope programme is also envisaged. Beyond its scientific choices, ESA as its U.S.

counterpart is broadening its effort to encourage space technology spin-offs through investments in the creation of a new fund specially dedicated to this purpose with the Open Sky Technologies Fund specialised in arising from space technologies and satellite applications for terrestrial industries is expected to reach not less than €100 million in 2011.[573] This help will take the form of aid to small companies and protecting patents from ESA work which particularly crucial for modest size companies considering their deterrent cost especially when they must be taken in the U.S. ESA is also strongly engaged to find concrete application on earth of space technologies, we can observe a result for instance with a spin-off company supported by ESA which develops software that uses conventional satnav signals to obtain accurate positioning with centimetre precision. Based on ESA satellite-control software, it has already attracted customers in the oil and gas industry.[574]

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