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EUROPEAN SPACE AGENCY

SCIENCE PROGRAMME COMMITTEE

Selection of the L1 mission

Summary:

Following the process that started with the "Call for Missions" issued in 2007, three proposed concepts were studied as candidates for the first "Large" launch slot of the Cosmic Vision plan. Due to the unavailability of the proposed international partnerships, these were re-formulated in the course of 2011. These re-formulation studies having been concluded, three mission concepts (namely ATHENA, JUICE and NGO) are now mature for an SPC decision to select one as the element of the Science Programme for the L1 launch opportunity of the CV2015 plan. Following the scientific assessment performed by the Advisory Structure, the Executive is herewith proposing the SPC to select the JUICE mission for the L1 launch slot.

Decision:

The SPC is invited to approve the selection of the JUICE mission as the "L1" mission in the Cosmic Vision plan, with a foreseen launch date of 2022.

Voting rights and majority required:

Simple majority of all Member States.

Legal basis:

SPC Terms of Reference, Section (a).

ESA Convention, Art. XI. 5(a)(i).

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1. Executive summary

Following the completion of the re-formulation studies for the three Large mission concepts ATHENA, JUICE and NGO, the Executive has solicited the Advisory Structure to recommend one of the three missions for selection for the first "Large" slot of the Cosmic Vision plan (the "L1" slot). At its meeting on April 3 and 4, 2012 the SSAC has recommended the JUICE concept as the L1 mission. On the basis of this recommendation, the Director of Science and Robotic Exploration is proposing to the SPC to select JUICE as the L1 mission.

2. Context

The Cosmic Vision Plan started with a broad community consultation that took place in 2004, setting the science goals for the ESA Science Programme for the decade 2015-2025. The first Call for Missions for the Cosmic Vision Plan took place in March 2007, at the time soliciting proposals for both Medium (Soyuz-class) missions and Large (Ariane 5-class) missions. The original planning for the Programme, embodied in the 2007 Call, foresaw the selection of one Medium mission for launch in 2017 and one Large mission for launch in 2018. The selection process was based on two rounds of competitive down-selections, the first to select the mission concepts to enter the Definition phase and the second to select the ones to enter Implementation phase. Two separate (but simultaneous) selection processes for the M and for the L missions were envisaged.

Proposals for L missions, defined as missions with an ESA CaC capped at 650 M€ (2007 e.c.), were solicited in the first "Call for Missions" for the CV plan issued in 2007. About a dozen proposals for L missions were received, and the SSAC recommended to study two of them, i.e. the large X-ray observatory XEUS and a mission to the outer planets. For the latter, the choice between a mission to the Saturn system and a joint Europe-US mission to the Jupiter system was left open. At the time of issuance of the Call, it was also announced that the LISA gravitational wave observatory would have been a de facto candidate for the L1 launch slot.

During the study activities the XEUS study activity was merged with the US study activity on a large X-ray observatory "Constellation-X", resulting in a joint study activity named IXO. About at the same time, the ESA and NASA Executive performed a selection between the two alternative Outer Planet mission concepts, resulting in the EJSM-Laplace study for a mission to the Jupiter system.

The three L1 candidate mission concepts as originally proposed significantly exceeded in their projected CaC the financial envelope allocated for the L1 opportunity in the Science Programme. As a consequence, all three concepts were studied under the assumption of an implementation in cooperation with international partners, with Europe playing a significant role and undertaking key responsibilities in the mission implementations. International study teams were assembled for the three missions, and the study activities were carried out in coordination with the prospective international partners. For all three missions, NASA had been planned to be a major partner, and for IXO ISAS/JAXA had proposed to take a significant role.

In February 2009 a re-planning of the Programme took place (SPC(2009)3), and it was decided, in the light of both the evolution of the situation with the proposed international partnerships of the L mission candidates and of the increase in the projected cost of the Medium mission candidates, to postpone the first L mission slot until 2020.

The Assessment Phase studies for the three L mission candidates were effectively finished at the end of 2010. At the time, the Executive had carried out the customary review on programmatic issues and cost, in all three cases confirming that the cost of the complete mission exceeded by a significant factor the ESA CaC ceiling (650 M€ at 2007 e.c.), thus making international participation a pre-requisite for the mission implementation.

In March 2011, during a bilateral meeting at Director's level, NASA informed the Executive that it was highly unlikely that they could become a major partner in an L mission on the schedule foreseen by the ESA Science Programme's planning (i.e. an early 2020's launch date). Given the resulting impossibility to continue with the mission concepts defined in the Assessment Phase, the Executive terminated the relative activities for EJSM-Laplace, IXO, and LISA, and informed the members of the three Science Study Teams of the termination of their mandate.

To preserve as much as possible the investment of the scientific community and of the Member States in the study activities of the L mission candidates, the Executive implemented a recovery action in the form of a fast-track re-formulation activity. The aim has been to ascertain if and which of the science goals of the L mission candidates could be implemented in the context of a programmatically feasible European-led, or potentially European-only mission.

Science Study Teams of experts in all three areas were appointed, in all cases with significant overlap with the scientists that were involved in the study of EJSM-Laplace, IXO, and LISA. The boundary conditions established by the Executive for the re-formulation activity were based on a target envelope for the ESA CaC of 850 M€ (at 2010 e.c., equivalent to 870 M€ at 2012 e.c.) and an early 2020's launch date. The resulting missions were to be European-only or European-led, with international participation limited to an approximately 20% ceiling, to allow the eventual implementation of the missions on a European-only basis. This approach was discussed with the SPC in June 2011 (ESA/SPC(2011)16).

Needless to say, missions within these constraints must be significantly less complex than the original L mission concepts selected in 2007. To emphasize the point, the new mission concepts have been given different names. The three mission concepts studied during the re-formulation phase that took place throughout 2011 were:

- ATHENA, a large collecting area X-ray observatory,
- JUICE, a mission to the icy moons of the Jupiter system,
- NGO, a gravitational wave observatory

The Executive discussed the approach to the selection of the L1 mission with the SPC in November 2011 (ESA/SPC(2011)45), explaining the rationale leading to the selection of one single candidate mission in early 2012. The plan foresaw a single mission to be selected for a Definition Phase, to be followed at a later stage by the mission's adoption, subject to the a satisfactory TRL level being reached for all the mission elements.

The re-formulation phase activities were completed at the end of 2011, and the resulting mission concepts have been subject to the customary independent technical and programmatic reviews, providing the elements necessary to estimate the CaC's of each of the three missions and the attendant risks. As shown later, all three missions were found to be feasible, although with somewhat different risks, development schedules and costs.

Following the completion of the re-formulation studies, the three mission concepts were submitted to the Advisory Structure for a recommendation on which of the three to select for the L1 launch slot. The reports from the re-formulation phase activities[1] (traditionally called ”Yellow Books”) were issued and made available to the Advisory Structure in January 2012. All information about the scientific goals and scientific performance of each mission, as well as about its proposed implementation, can be found in these reports.

The recovery action implied by the re-formulation studies has been highly successful as all three teams were able to define and study missions that have been assessed as feasible by the internal review process and as scientifically excellent by the Advisory Structure (as stated in the attached SSAC recommendation).

3. Mission definition

3.1 ATHENA

Science goals

The ATHENA mission is a large collecting area X-ray observatory, based on unique and innovative X-ray optical technology. While maintaining the flexibility of an observatory-type mission, whose observing programme will be defined through a peer review process, ATHENA’s science case rests on its capability to address three key pillars, namely to

1. Map the innermost region around accreting black holes and other compact objects and to probe matter under strong gravity and high-density conditions.
2. Reveal the physics of feedback from AGN and starbursts on all scales and quantify supermassive black hole growth and its relationship to galaxy evolution.
3. Trace the formation and evolution of large-scale structure via hot baryons in galaxy clusters, groups and the intergalactic medium comprising the cosmic web.

Mission profile

The mission will operate as an observatory from an L2 halo orbit, which will be reached following an Ariane 5 launch and a transfer phase of approximately 100 days in duration. The design lifetime is 5 yr with consumables sized for 10 yr. The total ΔV requirements for 10 yr are about 120 m/s. The mission scenario is similar to e.g. Herschel’s.

Spacecraft description

The ATHENA mission comprises two D-shaped, co-aligned X-ray telescopes of 12 m focal length, providing 1 m^2 effective area at 1 keV and 0.5 m^2 effective area at 6 keV, with a spatial resolution of 10 arcsec (5 arcsec goal). Two fixed instruments (one at the focal plane of each X-ray telescope) form the instrumental complement. The X-ray Microcalorimeter Spectrometer (XMS) provides non-dispersive, high spectral resolution spectroscopy (3 eV at 6 keV) over a limited field of view (2.3 arcmin square), while the Wide-Field Imager provides imaging and low-resolution spectroscopy (150 eV at 6 keV) over a wide field of view (24 arcmin square). The S/C will have a configuration similar to XMM-Newton’s and will have a dry mass of 3.8 tons.

[1] Accessible at the URLs http://sci.esa.int/jump.cfm?oid=49835 for ATHENA, http://sci.esa.int/jump.cfm?oid=49837 for JUICE and http://sci.esa.int/jump.cfm?oid=49839 for NGO. They have only been published electronically.

Management and responsibilities

The mission's management and responsibilities will be along an approach similar to other recent ESA astronomical observatories, with the Agency providing the S/C, launch and mission operations, and nationally funded consortia providing the two focal plane instruments. Science operations will be a shared responsibility, with an ESAC SOC complemented by nationally-funded Instrument Team Centres. International partners have expressed an interested in contributing to the XMS detectors (NASA) and cryogenics (JAXA).

3.2 JUICE

Science goals

The JUICE mission will visit the Jupiter system concentrating on the characterization of Ganymede, Europa and Callisto as planetary objects and potential habitats and on the exploration of the Jupiter system considered as an archetype for gas giants in the solar system and elsewhere. The focus of JUICE is to characterize the conditions that may have led to the emergence of habitable environments among the Jovian icy satellites, with special emphasis on the three ocean-bearing worlds, Ganymede, Europa, and Callisto. The mission will also focus on characterizing the diversity of processes in the Jupiter system which may be required in order to provide a stable environment at Ganymede, Europa and Callisto on geologic time scales, including gravitational coupling between the Galilean satellites and their long term tidal influence on the system as a whole.

Mission profile

The mission will be launched in June 2022 by an Ariane 5 ECA and will perform a 7.5 yr cruise toward Jupiter based on an Earth-Venus-Earth-Earth gravitational assist. The Jupiter orbit insertion will be performed in January 2030, and will be followed by a tour of the Jupiter system, comprising a transfer to Callisto (11 months), a phase studying Europa (with 2 flybys) and Callisto (with 3 flybys) lasting one month, a "Jupiter high-latitude phase" that includes 9 Callisto flybys (lasting 9 months) and the transfer to Ganymede (lasting 11 months). In September 2032 the spacecraft is inserted into orbit around Ganymede, starting with elliptical and high altitude circular orbits (for 5 months) followed by a phase in a medium altitude (500 km) circular orbit (3 months) and by a final phase in low altitude (200 km) circular orbit (1 month). The end of the nominal mission is foreseen in June 2033.

Spacecraft description

The spacecraft is 3-axis stabilised, and powered by solar panels, providing around 650 W at end of mission. Communication to Earth is provided by a fixed 3.2 m diameter high-gain antenna, in X and Ka bands, with a downlink capacity of at least 1.4 Gbit/day. To perform its tour of the Jupiter system the spacecraft will have a ΔV capability of 2700 m/s, and the shielding will limit radiation to 240 krad at the centre of a 10 mm Al solid sphere. The spacecraft dry mass at launch will be approximately 1.8 tons. While the actual payload will be chosen through a competitive AO process, the study has identified a model payload based on a suite of 11 instrument totalling 104 kg. These comprise cameras, spectrometers, a sub-mm wave instrument, a laser altimeter, an ice-penetrating radar, a magnetometer, a particle package, a radio and plasma wave instrument as well as a radio science instrument and ultra-stable oscillator.

Management and responsibilities

The mission's management and responsibilities will be along an approach similar to other ESA planetary missions, with the Agency providing the S/C, launch and mission operations, and nationally funded consortia providing the payload suite. Science operations will be a shared responsibility, with an ESAC SOC complemented by nationally-funded PI teams. NASA has expressed an interested in contributing to the payload.

3.3 NGO

Science goals

The key goal of the NGO mission is to detect and observe for the first time gravitational waves by careful determination of the relative distance of three spacecraft traveling on drag-free orbits. These gravitational waves, coming from cosmic sources, will allow pursuing a number of scientific goals, including:

- To survey compact stellar-mass binaries and study the structure of the Galaxy;
- To trace the formation, growth, and merger history of massive black holes;
- To explore stellar populations and dynamics in galactic nuclei;
- To confront General Relativity with observations;
- To probe new physics and cosmology.

Mission profile

The three spacecraft will comprise one mother and two daughter spacecraft, which will travel in heliocentric, Earth-trailing, drag-free orbits, forming an equilateral triangle 1 Mkm on a side. This constitutes a two-arm interferometer, with a mother spacecraft at the vertex of the two arms, and one daughter spacecraft at the end of each arm. The spacecraft constellation will trail Earth by 20°, with the triangle inclined by 60° with respect to the ecliptic. The arm-length variation will be < 1 %, with angular variation limited to ±0.8°, and the relative velocity between spacecraft limited to < 20 m/s. The three spacecraft will be launched by two Soyuz, one with the mother spacecraft, the other with the two daughter spacecraft, and inserted into an elliptical transfer orbit. A chemical propulsion module will separately bring each spacecraft to its final orbit. As the system detects gravitational waves coming from any direction in the sky, no pointing of the spacecraft constellation is necessary.

Spacecraft description

The three spacecraft are very similar, each containing a carefully monitored 46 mm cube free-flying test mass providing the guidance signal necessary to maintain the spacecraft on an inertial, drag-free orbit, and implementing a 2 W laser-based link with the spacecraft at the other end of the interferometer arm, making use of a 20 cm off-axis telescope. The mother spacecraft implements two interferometer arms and the daughter spacecraft one arm each. The dry mass of the mother spacecraft is 624 kg and that of each of the daughter spacecraft 496 kg. The power requirement of the mother spacecraft is 638 W and of each of the daughter spacecraft 548 W.

Management and responsibilities

The mission's management and responsibilities will be along an approach similar to other ESA science missions, with the Agency providing the S/C, launch and mission operations, and a nationally funded consortium providing the payload (with the telescope and laser system falling under ESA's responsibility). Science operations will be a shared responsibility, with an ESAC SOC complemented by nationally-funded Data Processing Centre. The mission is planned to be implemented on a pure European basis.

4. Mission status, risks, schedule

The risks of each of the three L1 mission candidates can be grouped in two categories. The first category comprises risks that may affect the mission's adoption. These are essentially related to technology readiness, with a potential impact on the definition of the space segment. The minimum technology readiness level required for all mission elements at the time of the mission's adoption is TRL 5. This level does not necessarily require the full development and qualification of all critical subsystems, but rather focussed developments and bread-boarding for removing the performance uncertainties on elements with low heritage. TRL 5 requires the validation of the critical functions in the relevant environment. When this level is reached for an element, the development schedule for the element can be established with a reasonable confidence. Conversely, not reaching TRL 5 potentially implies an open schedule, since basic difficulties could be encountered during qualification, inducing substantial delays and even full redefinition of the element.

The second category comprises risks that occur after the mission adoption, assuming the minimum TRL is effectively reached. These risks impact the mission development schedule and the launch date. They can have multiple causes during the development including: payload development delays, specific industrial difficulties for some sub-systems or components leading to late deliveries, management of complex interfaces, and unexpected integration and verification difficulties. For science missions, which are by nature one-off ambitious missions with new payload elements, the development schedule and risks are often driven by the payload development. The development schedule for the three candidate missions has been carefully assessed and critically reviewed by independent teams, taking into account the specific payload development needs. These reviews confirmed that payload development drives the schedule for the three L1 mission candidates, and it is of utmost importance to adequately fund the payload elements already during the Definition Phase for securing the schedule.

Each mission feature specific risks in the two categories, which are linked to the space segment concept. They are further detailed in the following sections.

4.1 ATHENA

Definition status and technology maturity

The ATHENA concept comprises substantial simplifications with respect to its predecessor IXO, lowering and sometimes completely removing a number of risks that had been identified for IXO. The most important simplifications are: the focal length reduction to 12 m enabling the replacement of the deployable structure by a fixed structure that is compatible with the Ariane 5 fairing volume, the reduction of the collecting aperture to 1 m^2 therefore lowering the number of Mirror Modules to 500 (instead of 1800 in the previous design) and the reduction of the science payload from five instruments to two, namely the X-ray imaging Microcalorimeter Spectrometer (XMS) and the Wide Field Imager (WFI). In addition, the two instruments have been simplified and are no longer mounted on a rotating platform but are fixed at the focus of each D-shape mirror. The service module relies on available technologies and the ATHENA mass is estimated to be largely within the Ariane 5 launcher capability.

Despite the above simplifications, three critical major elements of ATHENA have not yet reached TRL 5: the Mirror Modules, the focal plane detection assembly of the XMS instrument and the cooling chain of the XMS instrument. Among these three elements, the most critical is the mirror modules, for which development schedule uncertainties remain although the confidence for meeting the requirements is reasonably high.

Mirror Modules

The Mirror Modules (MM) of ATHENA are based on the Silicon Pore Optics (SPO) technology which has been under development by ESA for about ten years. An elementary mirror module consists of two stacks of mirrors co-aligned with a dedicated holding structure and used in grazing incidence. For a Wolter 1 telescope configuration, the first stack is made of parabolic mirrors and the second stack of hyperbolic mirrors. The number of mirrors for each stack is typically 35 and the required angular resolution is 10 arcsec (goal 5 arcsec) below 7 keV. The best performance achieved to date at Mirror Module level is about 16 arcsec with two stacks of 45 mirrors, measured at 3 keV. However, the SPO technology is continuously improving and there is reasonable confidence that the 10 arcsec resolution can effectively be reached with the proposed technology, with a limit for the resolution for the SPO technology estimated at around 5 to 7 arcsec. Recent successful vibration testing of a full mirror module assembly also provides confidence that the stacking and assembly processes will be compatible with the launch environment constraints. The demonstration of 10 arcsec resolution on a single Mirror Module is currently expected to be reached in 2013.

Once the performance is reached and TRL 5 demonstrated at Mirror Module level, a second difficulty for ATHENA is to build 500 such modules, with varying physical and optical characteristics along the ATHENA mirror radius. The technology intrinsically well adapted to such serial production since the stacks are produced by robots. Nevertheless, there is a need to put in place and qualify an industrial structure for ensuring the serial production in the ATHENA implementation phase. The Mirror Module production throughput (two MM/day) should ideally be demonstrated before starting the implementation phase. Some preparation activities for the industrialisation process have been initialised, but the industrialisation cannot be implemented until the manufacturing process is effectively finalised and frozen.

XMS focal plane detection assembly

The focal plane detection assembly of the XMS instrument consists of Transition Edge Sensor based micro-calorimeters, with 32x32 pixels of 250-300 micron size using Time Division Multiplexed (TDM) SQUID readout. Currently, 4 eV resolution has been demonstrated by SRON (NL), but without multiplexing. Arrays of 32x32 pixels have been made, but not fully wired. TDM multiplexing technology exists but has not been demonstrated at the required number of pixels and resolution level. Further technology developments are required but the existing heritage in SRON and PTB (DE) makes credible reaching TRL 5 by 2014.

XMS cooling chain

The cooling chain can be conveniently split in two parts: the pre-cooling chain, consisting of a series of Joule-Thomson or Stirling coolers enabling to reach 2 K with typically three stages starting from ambient temperature, and the last cooler assembly also featuring 2 to 3 stages for cooling the detectors from the 2 K stage down to 50 mK by using Adiabatic Demagnetisation Refrigeration (ADR). In the potential international collaboration scenario, the pre-cooling chain would be provided by JAXA and the ADR cooler by NASA, building on the ASTRO-H development. In the full European scenario, the ADR would be provided by the Member States (with relevant, SPICA-based, developments, already existing) and the pre-cooling chain would be provided by ESA. All the required coolers are currently either existing or under development, and should reach TRL 5 by 2012 to mid-2013. A system level verification of the pre-cooling chain can be envisaged by 2014.

If ATHENA is built with international collaboration by involving JAXA for the pre-cooling chain of the XMS instrument and NASA for the focal plane assembly and the ADR cooler assembly, the technology readiness risks associated to the XMS focal plane assembly and to XMS cooling are essentially removed assuming that the ASTRO-H development will be successful (ASTRO-H's launch is currently foreseen in 2014). The technology risks associated to the optics performance and production remain unchanged.

Schedule and development risks

Assuming TRL 5 is effectively reached for all the ATHENA elements by mid-2014, including the optics serial production demonstration, the mission can be adopted by September 2014, and the industrial kick-off for the spacecraft development can reasonably be expected in early October 2015. The estimated development time is 7.25 years and the critical path is then driven by the XMS instrument development.

For securing the development schedule, it is highly desirable to reach TRL 6 (as a minimum at EQM level) for the XMS focal plane assembly and the various coolers, including the ADR last stage, ideally before the industrial kick-off and at the latest within one year following the kick-off, therefore by Q3 2015.

Under the above assumptions, the ATHENA launch can be envisaged by the end of 2022. This schedule is based purely on technical considerations and does not include any financial constraints. When taking into account the estimated ESA CaC and the financial impacts on the Science Programme, the technical schedule needs to be increased by six or nine months respectively (depending on the JAXA participation), leading to a realistic and affordable launch date for ATHENA in mid or late 2023 respectively.

4.2 JUICE

Definition status and technology maturity

Contrary to the two other candidate missions, the re-formulation exercise did not result in major modifications to the JUICE spacecraft with respect to the previous ESA Jupiter Ganymede Orbiter (JGO) concept. The evolution consisted mainly in the change of the mission profile to recover in part the science planned for the US-provided Europa orbiter spacecraft. The new mission profile includes two Europa fly-bys and a modification of the previous Callisto fly-by phase for exploring the high latitudes of the Jovian magnetosphere.

As for JGO, the proposed space segment for JUICE relies on available technologies. The proposed model payload has significant instrument heritage, although specific issues on performance and sensitivity need addressing, mainly due to the environment of the mission. Specific measures will have to be taken for coping with the radiation environment, both at spacecraft and at payload level. The overall risk is deemed low for instrument developments relying on proven technology, and medium for new developments.

There are three technology developments that are currently running for this mission, but they are either anticipation measures for securing the overall schedule or activities for improving existing solutions. These are:

LILT: The activity on Low-Temperature Low-Light solar cells is nearing completion and a technical solution was found for preserving the solar cells performance under JUICE's conditions. The back-up scenario was to screen the cells. The future work will have to pay attention to the new generation of cells that are being developed and should be used for JUICE. The expected improvement in cell efficiency has not been considered at this stage.

SSR antenna structure: This specific activity anticipates the need to deploy a 5 m boom for the Sub-Surface Radar (one of the instruments in the model payload). TRL 5 should be reached by 2012. Continuation of the activity to reach TRL 6 could be envisaged in the Definition Phase, but will be subject to the payload confirmation and balanced with other pre-developments.

Material Qualification at Low Temperature: Most of the materials have been tested for previous missions down to –205°C only. The activity is an anticipation measure to qualify some materials down to –230°C, since this temperature can be experienced for some external elements of the spacecraft during long eclipses. The delta-qualification is not considered as critical. The activity will be completed in 2013 and could be extended as necessary depending on the detailed design evolution.

In addition to the above developments, the use of Ka band could be considered for further improving the science data return. The current design and telecommunication budget are based on the use of X band and available technologies. The use of Ka band would require the development of a 100 W Ka band amplifier.

Regarding the overall design maturity and potential associated risks, two items deserve to be further detailed for the JUICE spacecraft: the radiation dose level and the mass criticality with regard to the launcher capability.

Radiation levels and cumulated dose

Radiation levels in the Jovian system have been known to be a design driver since the beginning of the study. The radiation environment is dominated by electron particles arising within the Jovian system, which can be efficiently shielded as in a geostationary orbit.

A substantial effort was spent during the re-formulation phase for further consolidating the expected radiation levels and shielding mass estimates. The ESA Jovian radiation model was upgraded by taking as reference the NASA Galileo mission data. Test cases indicate that the ESA model is now in satisfactory agreement with the JPL model. The updated model has been already used for the radiation analyses with the new mission profile.

In parallel to the modelling improvements, detailed analyses have been made by industry for better quantifying the natural shielding that can be expected from the spacecraft structure, in view of consolidating the shielding mass allocation.

The JUICE mission profile and shielding mass result in a cumulated radiation dose at the end of life comparable to (or smaller than) the level experienced by telecommunication spacecraft in geostationary orbit, including appropriate margins. Therefore, although the radiation levels are on the high side for a science spacecraft and will definitely require specific attention during the development phase, they are judged to be manageable.

Mass margins and associated risks

At the time of the independent review, the mission profile was still being optimized and this optimization is not fully completed and will naturally be pursued during the Definition Phase. When considering the current mission profile and the Ariane 5 launch capability improvements that are agreed and being implemented by end 2012/early 2013 – and retained for Bepi-Colombo – the system mass margin is today at 20%, as required at this stage of the definition.

Development schedule and risks

The development risks after the mission adoption will remain associated to mass margins and radiation impacts, in particular for the science instruments development. Activities will be initiated during the Definition Phase for further securing these risks.

For radiation issues, a centralized procurement approach for radiation-tolerant components will be elaborated as far as possible, including for science instruments. Specific pre-developments of spacecraft elements, aiming at full qualification, will also be envisaged for further securing the development schedule.

For the risks associated to mass increases, the nominal hardware mass will naturally be further consolidated during the Definition Phase. In particular, the resources allocated to the science instruments will have to be strictly monitored. The independent review team has rightly stressed the need to carefully monitor the spacecraft mass for a high ΔV mission such as JUICE. A number of mass margin improvements have been identified and will be investigated to further increase the system mass margin above the 20% level at the start of the Definition Phase, without decreasing the mass allocated to the science payload. This will be useful not only for ensuring a stable design compatible with the launcher capability, but also for enabling a straightforward and schedule-efficient approach to radiation shielding.

The development schedule is estimated at 6.25 years, including 6 months of margin. The current space segment definition is technically compatible with issuing the Announcement of Opportunity for the payload shortly after the mission selection. The mission adoption can be reasonably targeted for June 2014, and the industrial kick-off for the spacecraft development in early September 2015. The nominal launch date defined by the planetary transfer using Earth and Venus gravity assist is June 2022 (back-up is August 2023). Therefore, the current schedule exhibits an additional margin of six months with respect to the launch date. This situation is satisfactory for a planetary science mission and it is strongly recommended, for securing the June 2022 launch slot, to preserve this margin until the start of the implementation phase, by avoiding delays in the instrument selection and the mission adoption.

4.3 NGO

Definition status and technology maturity

The NGO re-formulation introduced substantial simplifications with respect to the LISA concept, aiming at minimising risks and costs, and at taking best benefit of the LISA Pathfinder heritage. The most important evolutions are the suppression of one interferometric arm leading to hardware reduction on two spacecraft (now called the daughter spacecraft) and the reduction of the inter-satellite distance to 1 Mkm (from 5 Mkm) enabling to reduce the telescope diameter to 20 cm and partly downscale the payload. The three spacecraft can now be launched with two Soyuz launchers, one carrying the mother spacecraft and one the two daughter spacecraft. Each spacecraft is mounted on a LISA-PF like propulsion module.

The NGO concept remains similar to that of LISA, using exactly the same payload concept and measurement principles. The propulsion module is based on available technologies and could actually be very close to that of LISA-PF, with a modification of the tank size for ensuring the Soyuz launch compatibility. Assuming that GAIA's cold gas micro-propulsion thrusters will be used for NGO, the service module will also be based on available technologies. The laser beam acquisition and tracking for the three spacecraft is a complex task that is however estimated to be achievable. Therefore, the NGO technology maturity is essentially related to its payload elements.

The NGO payload consists of five building blocks, all equally essential for the science measurement: the Gravity Reference Sensor (GRS) subsystem with its electronics and ancillary elements, the optical bench, the phase-meter system, the emitting/receiving telescope and the laser subsystem in charge among other things to produce the emitted signal. While the GRS performance demonstration is relying on the successful operation in orbit of LISA-PF, the four other elements are today not yet at TRL 5, with a variable degree of maturity. The highest schedule uncertainties for reaching TRL 5 are on the laser and the telescope subsystems, which are both proposed to be implemented under ESA's responsibility.

The Gravity Reference Sensor

The GRS subsystem carries the free-falling proof mass and has a strong heritage from the LISA-PF development. The GRS cannot be fully tested in the relevant zero-gravity environment on ground, and therefore cannot by nature reach TRL 5 for NGO through ground testing. This is one of the main reasons for developing LISA-PF; the GRS subsystem will reach TRL 7 – and even TRL 9 for some parts that would be re-used without modification – following LISA-PF successful demonstration in orbit. Actually, the overall Disturbance Reduction System concept will be demonstrated in-orbit by LISA-PF.

Additional developments are nevertheless needed for the NGO GRS subsystem on the Front-End Electronics (FEE). The GRS FEE is in charge of the electro-static actuation and sensing of the Proof Mass, and the development is needed for enlarging its operational domain down to 0.1 mHz (1 mHz for LISA-PF) with similar actuation and sensing noise requirements. The GRS FEE technology activity is currently running and is expected to be completed Q1 2013.

The Optical Bench

The optical bench will largely be based on the LISA-PF developments for the optics conception and integration. The optical bench includes the four-quadrant photodiodes for the heterodyne detection. These InGaAs detectors are at TRL 4 and require further qualification. In case of severe technical or schedule difficulties, procurement of US detectors could be envisaged as fall back solution.

The phase-meter system

The phase-meter system is in charge of recovering the useful phase signal from the heterodyne detected signal by taking into account the frequency Doppler shift due to the relative motions of the satellites and retrieving the satellite clock and ranging signals. It is being prototyped and is expected to reach TRL 5 by end 2012.

The Telescope assembly

The telescope is of moderate size and is not critical in terms its optical wave-front error, which, while high-performance is within the state of art. The specificity of the NGO telescope is its unprecedented picometre dimensional stability requirements over the useful frequency band of NGO, which is over few tens of minutes in the time domain. It is unlikely that a telescope system can be manufactured that is permanently stable at the picometre level, even by fully mastering the thermal environment, because of ageing effects in the materials and space radiation damage. However, meeting the requirement over the NGO frequency band is likely possible, in particular by filtering out very low frequency changes such as ageing through the phase data processing on ground, while preserving the useful science signal. A technology development is running based on the previous LISA design and limited to the telescope structure bread-boarding and testing. This development should deliver its results by end 2012. New developments will be initiated for the NGO configuration, possibly exploring an all-Zerodur telescope concept, and aiming at achieving TRL 5 for the full telescope assembly. This activity can be started when the telescope configuration is sufficiently advanced, and could be completed by early 2015, in conjunction with LISA-PF demonstration in orbit.

The Laser subsystem

The Laser Subsystem fulfils several functions in the NGO concept: its primary function is to produce a high-power (2 W) laser beam on each interferometric arm, to be sent from one spacecraft to the other. The beam optical path variations generated along the inter-satellite travel distance carries the useful science signal. A second function of the laser subsystem is to produce a low power laser beam for mixing it with the received signal in heterodyne detection mode and producing the electrical signal at the beat frequency that is send to the phase-meter system. The laser subsystem is also in charge of ancillary functions, in particular for transmitting the local clock information from one spacecraft to the other and for inter-spacecraft ranging, by using sideband modulation.

The NGO laser architecture consists of a low-power master laser, derived from the LISA-PF seed laser, followed by a fiber-coupled electro-optic phase modulator and followed by a fiber amplifier. Low free-running frequency noise is required in order to enable fringe acquisition/lock at the remote spacecraft. The electro-optic modulation and the power amplifier following it must not degrade this information, i.e., high phase fidelity is required between the carrier and the sidebands of the transmitted beam.

The baseline approach is to derive the Laser Subsystem from TESAT's (DE) NdYaG laser developments for space optical communications, operated at 1064 nm wavelength. TESAT is currently qualifying a 5 W fiber amplifier for the Laser Communication Terminals for the European Data Relay System EDRS, which will be mounted on EDRS spacecraft in geostationary orbit and Sentinel 1-2 spacecraft in low-earth orbit. Therefore, assuming this development is successful, the power level is not anticipated to be an issue. The low-power seed laser performance is compatible with the NGO needs and can rely on the LISA-PathFinder laser development. The missing part is related to the laser modulation and amplification: the qualification of the amplification system for NGO is not completed and it is highly desirable to produce a full prototype of the NGO laser subsystem for demonstrating that its operability and noise performances are compatible with the science measurement needs. No credible industrial alternative to the TESAT laser has been developed to date. This indicates that the specialised field of high-power space lasers is essentially sustained by space optical communications and lidar developments. The laser subsystem prototyping and testing will be a major ESA-driven development aimed at reaching TRL 5 by early 2015 and enabling the potential adoption of NGO by the time of LISA-PF in-orbit demonstration.

Development schedule and risks

The need for developing a full laser subsystem is reinforced by pure development schedule considerations, and is actually applicable to the major payload subsystems. Indeed, it is a specificity of NGO to require the development of three spacecraft all comprising unprecedented payload. The development time is estimated at 8.5 years, including the nominal 6 months margin, provided the required technology maturity is fully reached at the time of the mission adoption. Since the payload will have to be replicated essentially four times, small series will have to be produced for a number of payload components and it is mandatory to ensure proper qualification through an Engineering Qualification Models (EQM, or possibly proto-flight) campaign at the start of the implementation phase, before producing the recurring elements.

Although the detailed development approach will be optimised in the Definition Phase, the 8.5 year development time assumes EQMs of the critical payload components to be available preferably at the start of the industrial contract for the space segment development, and the latest approximately one year after kick-off (typically by the system PDR). The critical components are those of the five above-mentioned payload building blocks: the GRS subsystem, telescope, laser subsystem, phase-meter system and optical bench. This reinforces the need to allocate adequate financial resources during the Definition Phase, not only for reaching TRL 5 prior to the mission adoption, but also targeting TRL 6 one year after adoption for critical payload components.

The overall implementation schedule is driven by both LISA-PF's demonstration and the need to reach TRL 5 for the critical payload components. Assuming this point is reached by early 2015, the mission adoption can be envisaged in Q1 2015, the industrial kick-off for the space segment development would be in Q1 2016 and the earliest possible launch around mid-2024. This schedule is purely based on technical considerations and is not including any financial constraints. When taking into account the estimated ESA CaC and the financial impacts on the Science Programme, the technical schedule needs to be increased by six months, leading to a realistic and affordable launch date for NGO in early 2025.

5. Scientific priorities

The Advisory Structure to the Science Programme held an extraordinary meeting on April 2 to 4, 2012. On that occasion the Executive solicited a clear recommendation on which of the three candidates (ATHENA, JUICE and NGO) should be selected for the L1 launch opportunity.

The Advisory Structure was given, as input, the Yellow Books for the three missions and the technical review reports, and was invited to put questions in writing to the respective Science Study Teams prior to the meeting. Members of the Science Study Teams presented their missions to the Advisory Structure at a plenary session on April 2. In the same context, the Executive informed the Advisory Structure of the technical status of the studies (along the lines exposed in Section 4 of the present paper), and has stated that any of the three missions would be feasible programmatically, i.e. in terms of financial constraints on the Programme and in terms of technical feasibility, although with different launch dates and with different impacts in terms of the Programme planning.

The Working Groups met on April 2 and 3, with the AWG recommending the ATHENA mission, the PSWG recommending the NGO mission and the SSEWG recommending the JUICE mission. The SSAC met on April 3 and 4 and, after taking into consideration the recommendations of the Working Groups, and discussing each mission in detail, recommended the JUICE mission to be selected for the L1 launch opportunity. The recommendations of the WG's and of the SSAC are as customary attached to the present paper.

6. <u>Estimated Cost at Completion and programme planning</u>

At the end of the re-formulation Phase activities for all three missions, technical and programmatic reviews were held, providing the elements necessary to estimate the CaC's of each of the three missions and the attendant risks.

The following table shows the CaC estimate for all three L1 mission candidates in 2012 e.c. The table included, on a purely indicative basis, a rough estimate of the cost of the payload to be provided under the responsibility of the Member States.

	ATHENA *With NASA & JAXA participation on XMS*	ATHENA *Europe only option*	NGO	JUICE *With NASA participation on P/L*
Development time (yr)	7.25	7.25	8.5	6.75
Cruise Phase (yr)	0.25	0.25	1.1	7.6
Nominal Science Operations (yr)	5	5	2	3.5
ESA Cost at Completion estimate	**907 M€**	**970 M€**	**1060 M€**	**830 M€**
Launch date ("technical")	Q4 2022	Q4 2022	Q2 2024	Q2 2022
Launch date ("programmatic")	Q2 2023	Q3 2023	Q1 2025	Q2 2022
Member States P/L cost estimate	*238 M€*	*272 M€*	*208 M€*	*241 M€*
NASA possible contribution to P/L (up to)	*34 M€*	–	–	*68 M€*
JAXA possible contribution (XMS pre-cooling chain)	*81 M€*	–	–	–

Table 1: Estimated ESA Cost at Completion estimate for the 3 L1 mission candidates. All amounts in M€ at 2012 e.c. The "technical" launch date is the "earliest possible" technically feasible launch date, regardless of financial constraints. The "programmatic" launch date takes into account the Programme's financial constraints and assumes a constant purchasing power for the Science Programme. Also shown is a rough estimate of the cost of the P/L provision by the Member States, and the possible value of the international participation in the mission.

For ATHENA, two CaC estimates are shown, one (higher) with the assumption that the mission were to be executed by Europe alone and another (lower) with the assumption that the mission were to be executed in collaboration with JAXA and NASA. Note that the JAXA participation would affect the ESA CaC, while the NASA participation would affect the Member State cost for the payload.

The international participation discussed for the JUICE P/L does not affect the ESA CaC, but does impact on the possible level of Member State participation to the mission.

7. Proposed decision and follow-on steps

Based on the recommendation by the SSAC, the Director of Science and Robotic Exploration is proposing to the SPC the selection of the JUICE mission as an element of the Scientific Programme, for the L1 launch opportunity in 2022.

The effect of the proposed decision on the Programme planning is shown in the form of the usual waterfall diagram in Fig. 1. As shown, the Programme's planning allows for the implementation of JUICE as the L1 mission for a launch in 2022 while maintaining the launch dates of the previously selected missions, and maintaining a foreseen launch date for the M3 mission of 2023. Such planning is performed under the assumption of a constant purchasing power for the Programme following the 2012 C/MIN, with a level of over-planning in adherence with the Programme's management practice. The Programme's long-term planning would also allow for the second Large mission launch slot (L2) to be scheduled in 2028 (depending among other things of course on the outcome of this year's C/MIN).

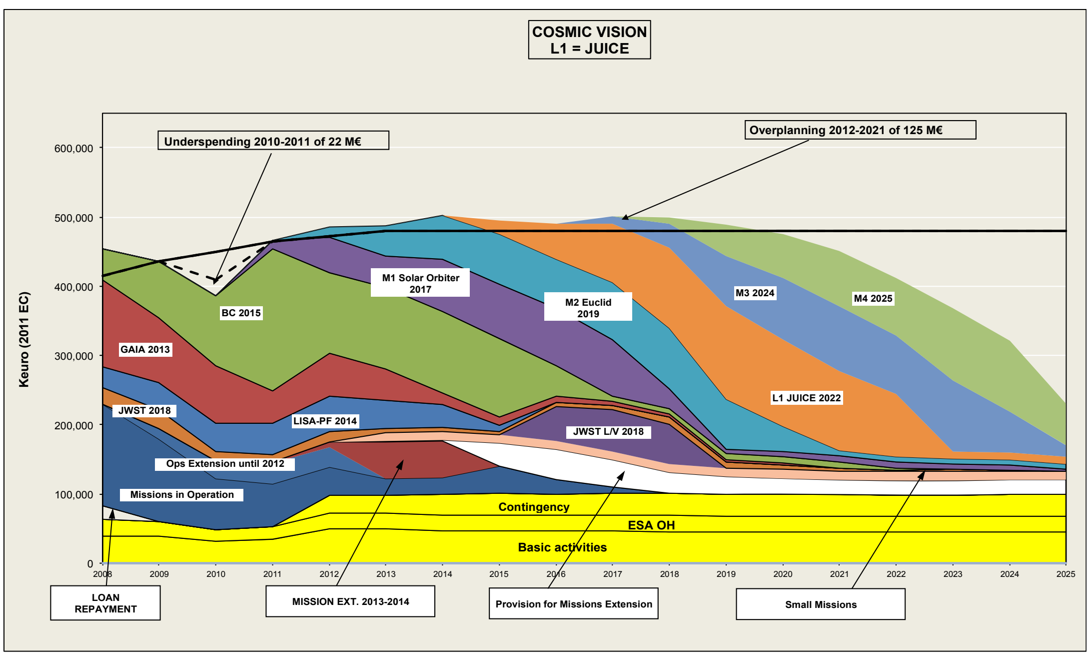

Fig. 1: Financial planning for the Science Programme showing the impact of the implementation of JUICE as the first Large mission in 2022, as proposed in the present paper.

Concerning the JUICE mission, the Executive intends, should the SPC approve its selection, to start its Definition Phase activities, with a view to reach the adoption of the mission by mid-2014. The relevant activities will include the start of competitive industrial Definition Phase contracts, the preparation of a Science Management Plan for SPC's approval, and the issue of an Announcement of Opportunity for the mission's payload. In parallel the Executive will proceed rapidly to confirm eventual international participation in the payload.

Regarding the two missions not selected for the L1 opportunity, namely ATHENA and NGO, the SSAC recognized their scientific value and their "flagship science value", and recommended continuing the technology activities necessary to make both missions strong candidates for the next L mission opportunity. The Executive intends to implement this recommendation by maintaining, for ATHENA, the technology activities relative to development of the X-ray optics, and for NGO to initiate the technology activities relative to the development of the laser for inter-spacecraft link and possibly for the telescope. System-level industrial activities for both studies will be terminated, as will the Science Study Teams. The Executive may appoint a small group of scientists to advise on the technology activities in question and issue Technical Assistance contracts to industry for focussed definition activities.

The Executive plans to release a "Call for Large Missions" in 2013 to define the L2 mission. This call will offer the opportunity to the teams proposing the ATHENA and NGO missions, as well as to any other teams to propose their mission. The details of the Call will depend on the outcome of the 2012 Ministerial-level Council and on the long-term Programme view that will be discussed with the SPC on the occasion of the May 2012 workshop.

8. Conclusions

Following the conclusions of the re-formulation study activities for the 3 L1 mission candidates, and the recommendation issued by the Advisory Structure to the Science Programme, the Director of Science and Robotic Exploration is proposing to the SPC to select JUICE for the L1 launch opportunity.

ESA/SSAC(2012)3
Att.: ESA/AWG(2012)1
ESA/SSEWG(2012)1
ESA/PSWG(2012)1
Paris, 4 April 2012
(English only)

EUROPEAN SPACE AGENCY
SPACE SCIENCE ADVISORY COMMITEE (SSAC)

Recommendation on the selection of the L1 mission

At its 138th meeting held at Paris on April 3-4 2012, the SSAC met to recommend the mission to be selected for the L1 launch slot of the Cosmic Vision Programme. The SSAC considered the three missions ATHENA, JUICE, and NGO.

The SSAC would like to begin by congratulating the teams involved in all three missions for the work carried out during this selection process, for the documentation produced, the presentations given, and the answers to the questions posed by the advisory structure. Given the particular circumstances that have led to the re-formulation of all three missions during a good fraction of the past year, the teams, supported by the Member States and by the Executive, have carried out a superb job. The result illustrates the flexibility and response capacity to rapid and significant changes in the international situation by ESA's Science Programme working in partnership with the scientific and industrial community in the Member States.

The SSAC based its discussions and its conclusions on its prior knowledge of the missions and their respective science goals, on the Assessment Phase Reports ("yellow books") of the missions (made available on 31/01/2012), the technical and programmatic review reports (made available on 14/03/2012), the external assessment of each of the mission by a senior member of the community, the presentations and discussions during the plenary session of the advisory structure on the day preceding the SSAC meeting, and on the recommendations from the Working Groups whose discussions SSAC members could attend. SSAC was unanimous in considering that the information provided was detailed enough and of sufficient quality to allow for an informed recommendation.

Before beginning discussions, SSAC addressed once again the conflict of interest issue. Three members were deemed to have a serious personal conflict of interest. Two of these three members being the chair of SSEWG and the chair of the PSWG selection sub-committee, Deputy chairs were appointed ahead of time in order to report to SSAC the discussions and the conclusions reached within the Working Groups. It was decided early on that neither the conflicted members nor the deputy chairs would participate in the final discussion and in the vote.

The SSAC carefully considered both the scientific and programmatic aspects concerning the three mission candidates, including their scientific value and the overall impact on the Science Programme. After an extensive discussion the SSAC came to a consensus and recommends the JUICE mission to be selected as the L1 mission leading to a launch in 2022.

The SSAC unanimously recognized the high science value of NGO and therefore recommends continuing the necessary technology activities to enable a gravitational wave observatory to be a strong candidate for the next launch slot.

The SSAC also recognized the science value of ATHENA and therefore recommends continuing the technology activities for enabling an X-ray observatory to be a strong candidate for the next launch slot.

ESA/AWG(2012)1
Paris, 3 April 2012
(English only)

EUROPEAN SPACE AGENCY
ASTRONOMY WORKING GROUP (AWG)
Recommendation on the Selection of the L1 mission

At its 147th meeting held on 2-3 April 2012 at ESA HQ, Paris, the Astronomy Working Group (AWG) evaluated two astronomy assessment studies, ATHENA and NGO. The group based its discussions on the mission assessment study reports (Yellow Books), answers to questions, one anonymous external referee report per mission, the technical and programmatic review reports, and presentations at the plenary session of the Advisory Structure. In addition, the AWG asked questions and discussed with representatives of the mission science teams during its meeting.

The AWG was greatly impressed by the assessment studies that have led to a successful reformulation of the two L1 mission candidates, and by the high quality of the documentation provided. The AWG recognised the outstanding science cases of the missions, and the crucial advancements and breakthroughs that they will be able to make in vast areas of astronomy and fundamental physics.

After careful analysis and in-depth discussions of the input received, the AWG ranked the missions and recommends that ATHENA is selected as the L1 mission in the Cosmic Vision programme.

ATHENA is a robust mission devoted to X-ray imaging/spectroscopy with unprecedented sensitivity and spectral resolution. It is an observatory-like mission which will cover a broad range of astrophysical topics, from solar system objects to the first stars and black holes. The three major drivers are the environment close to black holes, cosmic feedback, and the large-scale structure of the Universe. ATHENA's simultaneous capability of high spectral resolution and imaging, combined with the large collecting area, is undoubtedly a major leap forward with respect to all previous and upcoming X-ray missions. It will also be a powerful complement for major ground and space-based facilities that will be available simultaneously. ATHENA will establish Europe’s world-leading role in X-ray astrophysics, on the track paved first by EXOSAT and later by XMM-Newton.

The AWG found NGO to be an extremely strong proposal with high potential for ground-breaking new science, opening a new window on the Universe. Developments to date on LISA Pathfinder have already contributed substantial confidence in the technical viability of the NGO mission concept, and the existence of eight known “verification binaries” well above the anticipated sensitivity limit gives high confidence that the promised source numbers are achievable. This innovative and technically-challenging mission concept has potential for major European-led breakthroughs both in fundamental physics and in understanding the astrophysics of black holes.

ESA/SSEWG(2012)1
Paris, 3 April 2012
(English only)

EUROPEAN SPACE AGENCY
SOLAR SYSTEM EXPLORATION WORKING GROUP (SSEWG)

Recommendation on the selection of the ESA L1 Mission

The SSEWG attended the plenary joint meeting with SSAC, AWG, and PSWG held in the morning of April 2, 2012 and dedicated to presentations of the three candidates for the selection of the ESA L1 mission.

A dedicated SSEWG meeting took place soon after the Plenary meeting, on April 2 (afternoon) – 3 (morning) 2012, during which additional Question and Answer sessions where held with the representatives of the three Science Study Teams.

After detailed discussion the SSEWG arrived at a unanimous and enthusiastic endorsement of JUICE as Europe's first L-class mission. The SSEWG appreciated the high scientific value of the other two mission proposals. Whilst ATHENA, in particular, and NGO might have relevance for some specific aspects of planetary science, these were sufficiently marginal that SSEWG felt unable to contribute anything substantial to SSAC's deliberations.

The SSEWG expressed consensus that the JUICE mission will produce groundbreaking, L-class science in the following areas:

- The Jovian System is a template for planetary systems – analogous to a "mini solar system" – throughout the Universe and JUICE will provide unprecedented insight into these complex worlds.
- Ganymede, JUICE's prime target, is the largest known moon and is an archetype for the class of planets known as water-worlds – planetary bodies with a substantial fraction of mass composed of liquid water.
- The comparison of Ganymede, Europa and Callisto performed by JUICE will probe the possibility that exo-moons can provide habitats for life.
- In studying the Jovian System as a whole, JUICE will explore, for the first time, complex electromagnetic phenomena that connect the solar wind, the internally fed magnetosphere and the upper atmosphere, and the material and energy flows between them.
- In addition, the Jovian System is a plasma laboratory in which the fundamental astrophysics of magnetised bodies and their associated processes can be sampled and studied at a level of detail impossible in more distant systems.
- JUICE will perform long-term meteorological studies of the complex weather systems on Jupiter.
- JUICE will provide a detailed chemical and isotopic inventory of the Jovian System – planet, moons and magnetosphere – essential to our understanding of the early Solar System and its subsequent evolution.

JUICE will therefore provide powerful insights into the development and workings of the largest planet in the Solar System, its moons and its giant magnetosphere, insights that will revolutionise our understanding of Solar System origins and evolution.

More generally, the unprecedented results of JUICE will provide the essential scientific pillars on which the characterisation of exoplanets can be firmly constructed; these encompass astrophysical areas as diverse as habitability and plasma interactions and the production of detectable radio waves from exoplanet systems. Thus JUICE is a mission not only for planetary science but for astronomy as a whole.

The JUICE team carries forward a powerful legacy from those European space scientists involved in Cassini / Huygens, from which they have clearly learned important lessons, whilst nurturing a new generation of young scientists. Indeed, many of the names now listed as science study team members cut their postgraduate or post-doctoral teeth on Cassini, and are coming through to leadership positions.

The SSEWG is also highly impressed by the integrated, multi-disciplinary approach the JUICE team has taken to address their key scientific goals. As the Assessment Study Report and presentations have made very clear, scientists from the areas of plasma and atmospheric physics will work closely alongside astronomers, geologists and chemists in tackling the problems JUICE will investigate. They will be joined by astro- and extremophile biologists in investigating the key questions concerning habitability. Thus JUICE offers scientific opportunities for an extremely large and wide-ranging scientific community.

Moreover, the JUICE team has made clear that they will deploy the full mission instrument suite to investigate their key scientific issues. This, too, is a legacy from the involvement of several JUICE investigators with Cassini / Huygens, and we note it was the JUICE proposer who initiated this approach for Cassini during the investigation of water emission from Saturn's moon Enceladus.

The JUICE team has clearly and explicitly addressed the issue of impact and public involvement. Indeed, they have flagged up the additional contributions that can be made by the amateur community (as well as professional ground-based observers). And there is no doubt that planetary science and astrobiology are hugely inspirational – one can expect a significant "JUICE effect" on the recruitment of new students to a wide range of sciences.

It is clear to the SSEWG that JUICE is a mission that will meet the 2022 launch deadline, the optimum launch date for a Jupiter mission, with adequate margins. Uniquely, the JUICE team stated under questioning that they have no significant modifications or improvements that they would like to make, indicating that the mission is scientifically and technologically mature.

JUICE offers an unprecedented opportunity for Europe to visit and perform a complex tour of an outer planet and its neighbour, on its own, and making use of European technology. As Europe's first L-class mission it will genuinely mark a "coming of age" for the European Space Agency. It will show Europe to be an independent major player in planetary exploration, particularly significant at a time when there are seismic shifts in the international balance of power and capability in space.

In terms of science, timeliness and prestige, JUICE is the L1 mission to select.

ESA/PSWG(2012)1
Paris, 3 April 2012
(English only)

EUROPEAN SPACE AGENCY
PHYSICAL SCIENCES WORKING GROUP (PSWG)

Recommendation on the selection of the ESA L1 Mission

Having compared the fundamental physics and more generally the science impact of the three candidates PSWG has reached the following conclusion:
There is no doubt that of the three L1 candidates NGO has by far the most convincing science case in fundamental physics. It will allow unique tests of gravitation in the strong field regime, including direct evidence of black holes, which cannot be obtained by any other means. NGO will provide a wealth of data enabling the study of space-time geometry close to the event horizon of black holes with very high precision. Furthermore the collected data will be essential to studies of black hole and galaxy formation, their co-evolution and the formation of large scale structure. NGO will shed light on the early universe up to a redshift of z=20. Scientists of all fields will have access to data of a completely new kind to stimulate and advance their studies.
ESA has a tradition of stamping its own mark in space science projects which other space organizations have not attempted, and NGO is a prime example of that. By opening a completely new window on the universe NGO has the potential for major new discoveries. It will give Europe a decisive lead in the field of gravitational physics, much as CERN has provided a lead in particle physics.
PSWG thus recommends the selection of NGO as the ESA L1 mission.