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THE EUROPEAN STUDENT MOON ORBITER (ESMO) PROJECT: ATTRACTING AND TRAINING A NEW GENERATION OF LUNAR EXPLORERS

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ABSTRACT

The European Student Moon Orbiter (ESMO) project is a planned educational mini-satellite mission in the Student Space Exploration and Technology Initiative (SSETI) programme managed by the ESA Education Office. During the present Phase A Feasibility study, the ESMO spacecraft is being designed to be launched in 2011 as an auxiliary payload into a highly elliptical, low inclination Geostationary Transfer Orbit (GTO) on either Ariane 5 or Soyuz. From GTO, the small spacecraft would use an on-board propulsion system for lunar transfer, lunar orbit insertion and orbit transfer to its final polar orbit around the Moon. The payload consists of a narrow angle camera for lunar surface imaging, and a nano-subsatellite called Lunette for global lunar gravity field mapping.

INTRODUCTION

ESMO would be the third mission developed and performed by European students through the SSETI programme after SSETI Express (launch in October 2005) and ESEO (planned for launch in late 2009), and if successful would be the first ever European student-built spacecraft to leave Earth orbit and achieve an orbit around another solar system body. This would be a remarkable achievement, and would allow an educational mission to join a long list of previously successful government agency missions to the Moon such as Apollo, Luna, Clementine, Lunar Prospector, and more recently ESA’s first lunar mission, SMART-1. ESMO represents a unique and inspirational space education opportunity for university-level students, providing them with valuable and challenging hands-on space project experience in order to fully prepare them for successful careers on future ESA missions, particularly those planned by the Exploration and Science programmes in the next decades. In addition, ESMO has a powerful education outreach aspect and strong attraction for younger students studying in high schools across Europe, by lowering the entry-level for lunar exploration to attainable university project activities. ESMO also represents an opportunity for students to contribute to the scientific knowledge of the Moon and assist in any European lunar exploration efforts by providing valuable data of use in future ESA missions.

ESMO is a technically and operationally demanding mission for university students to realise within the tight mass and volume constraints of a piggyback launch opportunity. This makes it a challenging vector for hands-on education, but also requires a level of project management and professional technical support which is higher than a conventional educational project. Through a combination of building upon the lessons learned from the previous two SSETI missions, applying tailored space project standards and system engineering/assurance best practices, providing expert support from ESTEC and ESOC and relying upon flight-qualified spare hardware in critical areas, the probability of mission success will be maximised. The success of small lunar missions such as Clementine (424 kg), Lunar Prospector (295 kg) and SMART-1 (360 kg), as well as recent studies by European industry/academia on deep space missions to asteroids (SIMONE), Mars (MicroMars, MMM), the Moon, and the Sun-Earth Lagrange points (Earthshine) utilising micro- or mini-satellites with low-cost piggyback payload opportunities, gives some confidence in the technical feasibility of the ESMO mission. However, this needs to be confirmed.

On 15 March 2006, ESMO was approved by the ESA Education Department for a Phase A Feasibility Study. It is the primary objective of the Phase A Feasibility Study to not only determine whether such a mission is feasible based largely on university student built equipment with flight spare equipment in critical
areas, but also whether it is affordable to ESA, and that the associated risks are manageable. A Call for Proposals was issued by ESA Education Projects Division in June 2006 to European student teams for the requirements and design definition of the spacecraft subsystems, ground segment, and scientific payload during the Phase A study. There was a large response to the Call from universities across Europe, and a team selection for the Phase A was made by ESA Education Department and ESA technical experts in September. This was immediately followed by a Pre-Phase A Mission Assessment study on ESMO in the ESTEC Concurrent Design Facility (CDF). The selection process has resulted in a project consisting of 20 primary teams, 14 backup teams, and a 9-student System Engineering team. Currently, 290 students are working on the project from 29 universities across 12 different ESA Member States and Cooperating States. The go/no-go decision to implement the ESMO mission and proceed to launch will be made by ESA following the Phase A study review to be conducted in July 2007. 

ESA support to the ESMO Phase A study includes: project and system engineering management, the provision of technical advice and support by ESA specialists, including studies in the ESA Concurrent Design Facility and mission assessment studies by industry at QinetiQ (UK), and organisation of ESMO student workshops. As with previous SSETI projects, student teams communicate and collaborate through the use of an internet-based project infrastructure maintained by the SSETI Association, a network of students working on the ESA SSETI projects. The Association also assists them to obtain industry sponsorship.

OBJECTIVES

Clear objectives have been defined, along with mission requirements and system requirements in order to guide the system and mission design work performed by the students during Phase A study.

The general objective of the ESMO project is to prepare students for careers working on future projects of the European space exploration and space science programmes by providing valuable hands-on experience on a relevant & demanding project.

The primary objectives of the ESMO mission are:

1. To launch the first lunar spacecraft to be designed, built and operated by students across ESA Member States and ESA Cooperating States.
2. To place the spacecraft in a lunar orbit.
3. To acquire images of the Moon from a stable lunar orbit and transmit them back to Earth for education outreach purposes.
4. To transfer to a science orbit, and deploy a nano-satellite for conducting global, precision lunar gravity field mapping.

Details of the mission and system design work are given below.

MISSION DESCRIPTION

If approved, ESMO would be launched in 2011 as a auxiliary payload into a highly elliptical, low inclination Geostationary Transfer Orbit (GTO) on either Ariane 5 or Soyuz. From GTO, the small spacecraft would use its on-board propulsion system for lunar transfer, lunar orbit insertion and orbit transfer to its final polar orbit around the Moon. The activities performed in each of the mission phases are described in Table 1 below.

The duration of the ESMO is planned to be 10-24 months depending upon the propulsion system chosen. The difference is due to use of either chemical propulsion (10 months) or Solar Electric Propulsion (24 months).

<table>
<thead>
<tr>
<th>Mission Phase</th>
<th>Main Activities</th>
<th>Duration</th>
</tr>
</thead>
</table>
| LEOP & Checkout | - slow spin deployment of the spacecraft into GTO from the launcher upper stage  
- attainment of a stabilised attitude  
- deployment of solar array  
- complete spacecraft and ground segment system checkout & functional tests during ground station visibility periods to be completed within one week in order to minimise radiation dose | 1 week |
<table>
<thead>
<tr>
<th>Mission Phase</th>
<th>Description</th>
<th>Duration</th>
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<tbody>
<tr>
<td>Lunar Transfer</td>
<td>Manoeuvres with an on-board propulsion system in order to clear the inner</td>
<td>3-15 months (</td>
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<td></td>
<td>proton belt and inject the spacecraft on a Moon-bound trajectory</td>
<td>depending on</td>
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<td></td>
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<td>propulsion)</td>
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<tr>
<td>Lunar Capture</td>
<td>Manoeuvres with an on-board propulsion system during lunar approach in order</td>
<td>1-3 weeks (</td>
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<td></td>
<td>to place the spacecraft in a stable lunar polar orbit with perilune altitude</td>
<td>depending on</td>
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<tr>
<td></td>
<td>of 200 km</td>
<td>propulsion)</td>
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<td></td>
<td></td>
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<tr>
<td>Lunar Imaging</td>
<td>5 images of the lunar surface downlinked to ground per day</td>
<td>3 months</td>
</tr>
<tr>
<td>Lunar Gravity Mapping</td>
<td>Manoeuvres with an on-board propulsion system to transfer the spacecraft into</td>
<td>3-9 months (</td>
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<tr>
<td></td>
<td>a near-circular polar orbit of 100 km altitude</td>
<td>depending on</td>
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<td></td>
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<td>propulsion)</td>
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<td></td>
<td>Slow deployment of the Lunette Subsatellite from the ESMO spacecraft into a</td>
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<td></td>
<td>trailing along-track co-orbit</td>
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<td></td>
<td>Continuous Doppler tracking of the Subsatellite from ESMO over a period of</td>
<td></td>
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<td></td>
<td>10 weeks for 3 global gravity maps</td>
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</tbody>
</table>

Table 1: Description of the ESMO mission phases

PAYLOAD DESCRIPTION

A miniaturised payload would perform measurements of lunar orbit phases over a period of a few months. During the Phase A study, two different core payload options have been considered: an “Outreach” option which utilises a Narrow Angle Camera for optical imaging of the lunar surface, principally for education outreach purposes, and a “Science” option consisting of the Narrow Angle Camera and a Subsatellite for global lunar gravity field mapping. The two options differ not only in mass, but also in terms of operational orbit requirements, and they are treated as different missions in the system design trade-off.

Narrow Angle Camera

The education outreach payload selected for the Phase A study is a small Narrow Angle Camera (NAC) providing medium resolution imagery of the lunar surface. Although the education outreach programme associated with the ESMO mission is yet to be studied, it is expected that the camera will provide stunning views of the Moon’s surface features and very striking celestial events such as Earthrises when the spacecraft emerges from the lunar far-side. These images, and others such as the slow drift of the Lunette subsatellite after deployment, should provide a powerful outreach tool to high school level students. One possible idea under consideration is a series of competitions involving high school students calculating where to point the camera in lunar orbit in order to take pictures of given surface locations. The winners would then receive their own image of the location taken by the Narrow Angle Camera.

The camera is being designed by a student team from the University of Liege in Belgium. The main requirement is for the camera to provide 10m/pixel resolution colour images at 200 km distance from surface, which is a similar performance to SMART-1’s AMIE camera. This is provided by a refractive optics design of 30 cm focal length, and a 1024 x 1024 pixel CMOS APS detector. The current NAC instrument design has a mass of 2.5 kg, consumes a power 10 W during operation, and its configuration consists of a 20cm long optics column into the detector plane, which is housed along with its proximity electronics in a small 3mm thick aluminium box providing radiation shielding. The camera is pointed with an accuracy of 20 arcmin or better by the spacecraft AOCS with a stability of $10^{-2}$ deg/s. After initial processing by the proximity electronics, the images are transferred via a high data rate SpaceWire link to the on-board computer for compression by a factor 10. They are then stored in mass memory, and later transmitted to ground during the next downlink session.

The orbital requirements for NAC call for a lunar polar orbit with perilune altitude of 200 km or less, which is stable (ie. no station-keeping required) over 6 months. This requirement could be met either by a highly elliptical orbit with 200 km perilune or by a near-circular orbit of 200 km altitude or less.
Gravity Mapping Subsatellite

The scientific payload selected for the Phase A study is a Nanosat subsatellite for precision global gravity field mapping via accurate radiofrequency tracking of the subsatellite from the main spacecraft. Such a Nanosat, called Lunette, would need to be deployed in a near-circular polar orbit at 100 km altitude.

The science performed with such a payload is new, complementary to upcoming lunar missions and valuable for both lunar science investigations and future human and robotic exploration of the lunar surface. The construction of a high-resolution map of the irregular lunar gravity field is essential to obtain information about the geological properties of the lunar interior, such as mass concentrations. It is also invaluable for accurately planning and executing future lunar missions, such as precision lunar landers aiming to touch down safely on the ‘peaks of eternal light’ located on the rims of polar craters. Previous gravity-mapping missions have tracked lunar spacecraft orbital motion on the near-side from Earth-based ground stations in order to determine the gravitational perturbations and hence construct near-side maps. However, this has only been able to provide extrapolated measurements of the far-side gravity field due to the lack of tracking data during Moon occultations. Gravity-mapping payloads utilizing satellite-to-satellite range and range-rate tracking between a lunar orbiter and co-orbiting subsatellite have been proposed on previous lunar missions and studies, but have not yet flown.

Figure 1: Configuration of the Lunette subsatellite (courtesy University of Toronto)

A student team from University of Toronto Space Flight Laboratory, using expertise and design heritage from the CanX nanosatellite program, is in the process of designing “Lunette,” the gravity-mapping nanosatellite that will separate from the parent spacecraft in the 100 km circular polar lunar orbit. The 9 kg Lunette nanosatellite (see Fig. 1) includes a coherent S-band radio transponder, three-axis attitude determination and control, and a propulsion system with 40 m/s delta-V, allowing it to maintain an along-track orbital formation and measure the range-rate between itself and the parent spacecraft using Doppler tracking. The main requirement is to acquire 1 mm/s accuracy range-rate measurements that will be used to construct a full-sphere lunar gravity map with a resolution of 20 mGal or better with 50-100 km spatial resolution, comparable to the current best resolution near-side gravity map from Lunar Prospector data.

The Lunette package consists of the deployable 25 cm cube subsatellite, and a separation system and radio analyzer that remain on the ESMO spacecraft. The separation system utilises a spring-loaded pusher plate on guide rails. The radio analyser comprises a monopole antenna, ultra-stable oscillator and processing electronics.

MISSION ANALYSIS

A student team from University of Glasgow has performed the mission analysis for the ESMO Phase A study. The analysis has focussed on finding stable operational orbits for the two different payload mission options, optimising trajectories for the GTO to operational lunar orbit transfers with respect to different propulsion options, and determining associated eclipse and ground station visibility events.

Operational Lunar Orbits

Orbital perturbations due to Sun and Earth gravity and lunar gravity field harmonics can have a significant influence on the dynamics of lunar orbits and their stability. Depending to the initial orbital conditions, spacecraft in lunar orbit can escape or impact the surface in short timescales. Due to the requirement of having no station-keeping manoeuvres during 6 months of lunar operations (to minimise propellant), initial orbits must be sought that satisfy payload requirements and are robust to perturbation effects.

For the Outreach mission option with only the NAC payload, a highly elliptical polar operational orbit was identified by following a similar strategy taken by SMART-1. Namely, a reduction in the eccentricity
oscillations can be achieved by placing the argument of periapsis at 290° over the lunar south pole and choosing an initial periapsis altitude slightly lower than the required 200 km, so that secular reduction in the argument of periapsis through 270° (see Fig. 2) causes periapsis altitude to first increase above 200 km then decay below it before reaching zero altitude. The periapsis altitude was fixed at 100 km and the apoapsis altitude varied to investigate the effects of eccentricity on the Sun/Earth gravity-induced oscillation in periapsis.

As presented in Fig. 3, the higher the eccentricity of the orbit, the higher the maximum periapsis altitude in the oscillation, and also the lower the insertion delta-V. Hence, a compromise was necessary between minimising delta-V and maximising NAC payload performance over the 6-month operational period.

The operational orbit chosen for the Outreach mission option has a maximum periapsis altitude of 250 km over its 180-day orbital lifetime and a mean periapsis altitude of less than 200 km, thus satisfying payload and orbit stability requirements. The initial orbit parameters are as follows:

- Periapsis altitude: 100 km
- Apoapsis altitude: 3600 km
- Eccentricity: 0.522
- Inclination: 89.9°
- Argument of perigee: 293°
- Right ascension of ascending node: arbitrary (minimal deviation of lifetime)

A sensitivity analysis was conducted with respect to orbital lifetime over the full range of right ascension of ascending node. Only minimal deviations from 180 days were observed, allowing right ascension to be a free parameter in the transfer trajectory optimisation and giving flexibility with respect to arrival date (and hence launch date).

For the Science mission option, the requirement for a stable 100 km near-circular polar orbit for gravity mapping with no station-keeping over 6 months can only be met by using a so-called “frozen” orbit. A frozen orbit is one in which the semi-major axis, inclination, eccentricity and argument of the periapsis do not suffer any long term perturbations or secular effects. Based on linear stability analysis and use of a 40th harmonic lunar gravity field model, the following frozen orbit parameters were found for the Science mission option:

- Periapsis altitude: 100 km
- Apoapsis altitude: 135 km
- Eccentricity: 0.009
- Inclination: 90°
- Argument of perigee: 90°
- Right ascension of ascending node: arbitrary

Correct choice of eccentricity and argument of periapsis for the given semi-major axis are important in order to ensure inherent orbit stability. As with the highly eccentric orbit of the Outreach mission option, the right ascension is again a free parameter for the transfer trajectory optimisation.

**Transfer from GTO to Operational Lunar Orbit**

In addition to having two different payload mission options with different operational lunar orbits, two different propulsion options for the GTO to
operational orbit transfer were considered: chemical (liquid) propulsion and solar electric (ion) propulsion. This lead to the definition of four different system design options: Chemical-Outreach, Chemical-Science, Electric-Outreach and Electric-Science. Full trajectory optimisation was performed on each of these options in order to calculate their total transfer manoeuvre delta-V and propellant requirements. The chemical and electric-based spacecraft options have fundamentally different mission designs due to the radical differences in thrust level, requiring the use of different mission analysis methods and tools.

In the two chemical propulsion spacecraft options, high-thrust impulsive burns of the propulsion system would be used to insert the ESMO spacecraft from GTO onto a Weak Stability Boundary (WSB) trajectory via the Sun-Earth Lagrange point L1 in order to reduce the propellant cost of achieving lunar orbit at the expense of a longer transfer duration of 3-4 months, compared to a direct transfer lasting a few days. Further impulse burns would be performed in order to target the Moon from L1, then insert the spacecraft into a highly eccentric, polar lunar orbit with 100 km altitude periapsis over the south pole, and later to acquire the final 100 km near-circular frozen orbit in the case of the Science mission option.

Trajectory optimisation was conducted on a range of possible WSB transfers from a standard Ariane 5 GTO to the Moon during the launch year of 2011 due to the fact that, as an auxiliary payload, there is no control over the launch date. An example can be seen in Figure 4. This analysis has determined that a worst-case delta-V of 1080 m/s is needed in order to perform the WSB transfer and capture ESMO into the highly eccentric polar orbit described above. In this case, the transfer duration is about 3 months. An additional 400 m/s would then be required to transfer the spacecraft from this operational orbit down to the 100 km frozen orbit in the Science mission option.

In the case of the SEP spacecraft options, a continuous or semi-continuous low-thrust would be produced to gradually spiral out the trajectory towards the altitude of the Moon over a period of months. Then, the SEP system would perform a series of low-thrust manoeuvres from a high altitude parking orbit in order to phase the ESMO spacecraft with the Moon and approach with a low relative velocity. Then, the SEP system would be used to capture ESMO into lunar orbit and spiral down to the highly eccentric polar lunar orbit described above for the Outreach mission option, finally spiralling down to the 100 km frozen lunar orbit in the case of the Science mission option.
Trajectory optimisation has been conducted with the DITAN tool\textsuperscript{13} on a range of possible low-thrust transfers of ESMO from a standard Ariane 5 GTO to the Moon during the launch year of 2011 due to the arbitrary launch date. An example can be seen in Figure 5. Assuming a spacecraft wet mass of 175 kg at launch and an SEP system with thrust of 20 mN and specific impulse 3250 s, the analysis has determined a worst case Xenon propellant consumption of 21 kg and a transfer duration of 15.3 months for a transfer from GTO to the highly eccentric Outreach mission operational orbit. Due to the GTO injection orbit and a slow spiral out through the radiation belts by the SEP system, the total radiation dose accumulated behind 4 mm of Al shielding in this scenario would be 35 kRad (Si). This is high compared to the chemical propulsion option, which exits immediately above the radiation belts due to its high-thrust trans-lunar injection manoeuvre.

SYSTEM DESIGN

Based on the total mission delta-V obtained from the mission analysis and the defined payloads described above as input, the system design process was performed by ESA and the student teams on the four different system design options: Chemical-Outreach, Chemical-Science, Electric-Outreach and Electric-Science. The objective was to obtain well-optimised design solutions of each option and then conduct a system-level trade-off analysis leading to the selection of a baseline system design for proceeding into detailed design activities in Phase B.

The system design work commenced at a one-week workshop held in the ESTEC Concurrent Design Facility (CDF) in January 2007. Student team representatives received training on the use of the CDF infrastructure and design model by CDF staff, and then worked together with ESA in an interdisciplinary team towards producing the first iteration system design solutions that met the mission objectives, requirements and constraints. All four initial system designs were then iterated, refined and optimised over a period of 6 months, using a new online version of the CDF design model called iCDF in order to enable weekly ‘virtual’ spacecraft design sessions with distributed participation of student teams from all over Europe and Canada.

A summary of the final optimised design solutions is presented in Table 2 below. The mass values are based on equipment level margins defined according to development maturity, margins on propellant mass, and a 20% system margin. The associated 3D CAD configurations can be seen in Figure 6. The design solutions assume that most of the subsystem equipment is developed and built by the student teams at their participating universities, and the spacecraft structural/thermal and protoflight models are
integrated and tested by ESA and students at ESTEC. The exceptions to this university student-provided equipment are items which are either too costly for universities or too demanding in terms of complexity or reliability/safety requirements. These items include solar cells, rad-hard on-board processors, and the majority of the propulsion system (either chemical or electric). In these cases, the equipment is furnished by ESA from either technology development programmes or flight spares procured by past ESA projects.

The system-level trade-off analysis between all four feasible system design options was based on the criteria of science return, mass, cost metrics, radiation dose, mission duration, and operational complexity. The Science mission was generally preferred to the Outreach mission due to the significantly improved science return. Although the total wet masses of the Science mission spacecraft are 25 kg (electric) and 55 kg (chemical) heavier than the Outreach options respectively (due to the additional payload and propellant mass), leading to the need to take the ASAP
Mini launch opportunity rather than the smaller ASAP Micro slot, the overall cost metric was found to be still within bounds. Should this turn out not be the case, then alternative launch opportunities could be sought for the Science mission in Phase B or the project could revert back to the scaled down Outreach mission later as a backup.

The trade-off between electric and chemical propulsion spacecraft proved to be very interesting. For the Outreach mission, where the total delta-V is lower than the Science mission, the chemical spacecraft was slightly lighter than the electric spacecraft, and this situation was reversed for the Science mission. However, the differences were not found to be significant in the context of launch margins. The cost metrics were also found to be very similar, with values for the electric propulsion spacecraft slightly higher due to the need for rad-hard components and greater ESA support during operations due to a longer GTO to lunar transfer duration. The deciding factors in the baseline selection were related to the latter aspect. The very long duration of the electric propulsion spacecraft transfer to operational lunar orbit (21 and 28 months for Outreach and Science missions respectively) is excessive for a student mission. In addition, the operations were found to be too complex for students, due to the need for constant control of the low-thrust trajectory. Although an autonomous navigation system would certainly alleviate the 2 year operational burden, the development and implementation of such a system (which has not yet been demonstrated in Europe in any professional mission) was deemed too complex and risky for a student undertaking. Therefore, the chemical propulsion spacecraft...
performing the Science mission was selected as the ESMO baseline on the basis of good science return at low mass and cost, short mission duration, and relatively simple operations due to the small number of main engine burns.

PROJECT MANAGEMENT

Normal ESA space project management and system engineering practices are applied to the running of the ESMO project, using the ECSS standards, including the conduct of formal reviews with required technical documentation, and the performance of proper qualification and integration testing activities for acceptance, should the project be approved for implementation by ESA following the Phase A review. This aspect is considered to be an essential and highly beneficial educational part of the hands-on project experience, and provides students with preparation and know-how for working on professional space projects in industry and science institutes in the immediate future. Enhanced levels of system engineering and Product/Quality Assurance support are being provided by ESA experts in this respect. Given the tight mass constraints, the spacecraft is largely a single-string design with little redundancy. However, redundancy has been targeted in failure-critical areas such as the avionics systems, and flight spare hardware will be used for mission-critical areas such as the propulsion system to bolster mission reliability.

CONCLUSIONS

The ESMO project was approved by the ESA Education Office for a Phase A Feasibility Study in March 2006. After recruitment of university students teams via a Call For Proposals, the Phase A has now been completed. The study considered an Outreach mission involving a camera payload to take images of the lunar surface from a highly eccentric polar lunar orbit, and a more demanding Science mission with an additional gravity-mapping nano-satellite payload to be deployed in a near-circular 100 km polar lunar orbit. The study also considered two different methods of propulsion for transfer of the ESMO spacecraft from initial GTO to operational lunar orbit: chemical and electric propulsion. This led to the definition and optimisation of four different system design options. All four design options were found to be feasible, low mass and low cost and in compliance with mission and system requirements. They were traded-off against one another, and the Chemical Propulsion-based Science mission was selected as the baseline configuration due to its short mission duration and much simpler operational complexity for students. This baseline will be submitted for the Phase A review and further detailed definition in any Phase B, should ESMO be approved by ESA for implementation. If the project is approved, then a Call For Proposals for Phases B/C/D will be made in early 2008.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the hard work, dedication and significant contribution of the entire ESMO project team including Matthew Cross, ESMO Young Graduate Project Coordinator, and all 300 students from the 26 universities participating in the ESMO Phase A study:

Payload:
University of Liege, University of Toronto (primary)
Open University, University of Rome, University of Barcelona, Ecole Polytechnique (backup)

Electric Propulsion:
University of Southampton (primary)
University of Stuttgart (backup)

Chemical Propulsion:
Politecnico di Milano, University of Stuttgart (primary)

Electrical Power System:
University of Warwick (primary)
University of Sherbrooke (backup)

Data Handling:
Budapest University of Technology, TU Munich, Universidad Politecnica di Madrid (primary)

Attitude Control:
Narvik University College, SUPAERO, University of Lisbon (primary)
Politecnico di Milano, Ryerson University (backup)

Communications:
Wroclaw University of Technology

Structure:
University of Southampton (primary)
Universidad Politecnica di Madrid, University of Porto (backup)

Thermal:
University of Rome (primary)
Politecnico di Milano (backup)
Mechanisms:
INSa de Lyon (primary)
University of Porto (backup)

Mission Analysis:
University of Glasgow (primary)
University of Zaragoza (backup)

Mission Control Centre:
University of Rome

Ground Stations:
University of Rome, TU Munich

Programmatics:
Politecnico di Milano

Flight Dynamics
University of Rome (primary)
University Carlos III Madrid (backup)

Simulation:
Warsaw University of Technology

System Engineering:
Narvik University College, Lulea University,
University of Rome

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