

An Experience in Cooperative Learning Developing a Real Aerospacial Project

Alberto Rodríguez, Pablo F. Miaja, Manuel Arias, Miguel Rodríguez and DiegoG. Lamar.

Departamento de Ingeniería Eléctrica, Electrónica, de Computadores y Sistemas. Power Supply Systems Group
Escuela Politécnica Superior de Ingenieros de Gijón. Universidad de Oviedo. España.

rodriguezalberto@uniovi.es

Abstract — A lot of training time is devoted to help teachers arrange appropriate interactions between students and materials, and to how teachers should interact with students. However, how students should interact with each other is relatively ignored. It is a good idea that students learn within a supportive community in order to feel safe enough to take risks. Cooperative Learning (CL) is a successful teaching strategy in which small teams, composed by students with different skills, use a variety of learning activities to improve their understanding of a subject [1]. Each member of a team is responsible not only for learning what is taught but also for helping his or her teammates learn, thus creating an atmosphere of achievement. In this paper an experience in CL with a group of students with different skills and ages developing the harness subsystem of the first lunar spacecraft built and operated by students across European Space Agency (ESA) Member States and ESA Cooperating States is described.

Keywords- Cooperative Learning, aerospace project, European Space Agency.

I. INTRODUCTION

The European Student Moon Orbiter (ESMO) is planned to be the first European student mission to fly to the Moon [2]. ESMO represents a unique and inspirational opportunity for university students. ESMO provides students with valuable and challenging hands-on space project experience in order to fully prepare a well qualified workforce for 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 a strong attraction for younger students studying in universities across Europe. It also represents an opportunity to contribute to the scientific knowledge and future exploration of the Moon by returning new data and testing new technologies.

More than 300 students from 29 Universities in 12 countries are participating in the project, which has successfully completed its “Phase A: Feasibility Study” and it is proceeding into preliminary design activities (Phase B). The ESMO spacecraft is designed to be launched into Geostationary Transfer Orbit (GTO) as a secondary payload in the 2013/2014 timeframe. The student teams are expected to provide most of the spacecraft subsystems, payload and ground support systems in coordination with their universities and through sponsorship by the European space industry.

The Power Supply Systems group, which is part of the Electronic Technology Division of the University of Oviedo (Spain), submitted a letter of interest to the ESA for participating in the selection process to find a university team to develop the harness subsystem. The proposal of this group was selected, after being evaluated for experts, and now the Power Supply Systems group is the responsible team of the harness subsystem of the satellite.

The Power Supply Systems group is formed by eight researchers, four of whom are PhD Electrical Engineers and professors, and the rest are PhD students. To develop the harness subsystem of the spacecraft, the group considered to form a team with engineering students and to implement some CL strategies. This kind of learning is still uncommon in technical areas of knowledge, but it is considered a key element for improving the capabilities of students [3]-[7]. Some university students with different skills were interested in ESMO and the team was composed in February 2008.

II. METHOD

A. ESMO groups and tools for cooperative working

The ESMO project is divided by the ESA in more than twenty subsystems, which include the whole spacecraft, and other necessary tasks as the ground segment or the mission analysis. Each subsystem is developed by a group of students who belong to a European University. These groups must interact with each other so that they know about the evolution of the project. To facilitate this interaction, the ESA encourages the use of some interactive tools. The most interesting ones are:

- A Google group, in which all subsystems are signed up, to discuss and comment about critical questions. Thanks to this tool all the members of the ESMO can know each other.

- A weekly chat, in which some questions are solved talking with experts and another problems are discovered thanks to the interaction between subsystems. It is a direct way to solve problems quickly in a real time conversation with the members of the rest of subsystems.

- A biweekly work report to evaluate the progress of each subsystem. It is a good way to teach students how to write and read technical documents.

- A FTP site for each subsystem to share some of their work with the other subsystems. This is a very useful tool to be updated of all the progress of the different subsystems.

- On-line interactive programs to develop some of the work using dedicated software provided by the ESA. Students have to adapt themselves to use dedicated programs for each activity.

- Four workshops per year at European Space Research and Technology Centre (ESTEC), where one representative from each team is invited. This is the moment when all the students can talk together. They have to present their works in public, ask other members some questions, speak with experts of the ESA, etc. Usually in these workshops there are also some activities to have fun all together.

Thanks to all this tools the members of each subsystem have a global view of the evolution of the project. The interaction between students from different countries, cultures, universities, and degrees also help them to develop communication and social skills.

B. Structure of the Harness team.

The actual structure of the Harness team, defined by the Power Supply Systems group, can be seen in Figure 1 and it is described as follows.

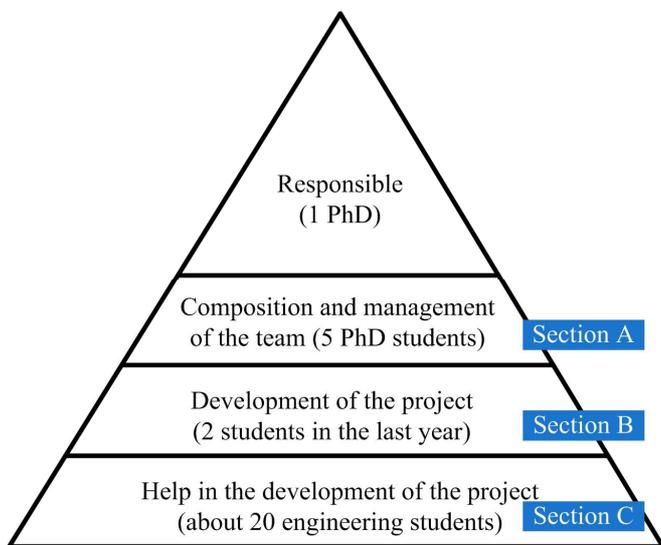


Figure 1. Structure of the Harness team

The responsible of the Harness team is the responsible of the Power Supply Systems group, an expert Electrical Engineer PhD professor, who can help the rest of the team to solve important problems. He is not the responsible of the organization of the Harness team, he only advise the other components of the Power Supply Systems group if they have great troubles.

The rest of the components of the Power Supply Systems group, particularly five of them (all of them are PhD students), have composed the Harness team and must manage and organize its work. They have to evaluate all the advances made by the students, solve the questions they could have, distribute and organize the work, etc. These members of the Harness

team are expected to participate in the project till the launching of the spacecraft. We are going to call them, section A students.

Regarding the development of the harness of the ESMO project two engineering students are making their Master thesis. They are working together, making reports, schemes of all the system and the connections needed, revising the electrical requirements of the rest of the subsystems, etc. These two students are making most of the jobs required in the design of the harness, supervised initially by section A students and latter by experts from the ESA. We are going to call them, section B students.

The Harness team is completed with a group of engineering students (about twenty) with different ages, skills and knowledge. These students do not have any benefits for participating in this project (such as money, increase in their marks, etc) except for their own learning about aerospace projects. These students are divided in small groups to analyze each subsystem. They help students section B, and at the same time they are learning about the global system and the harness subsystem. We are going to call them, section C students.

The different degrees of students forming the Harness team are specified in Table I. As can be seen, most of the students are telecommunications engineers, simply because some members of the Power Supply Systems group are teachers in this degree and they are very well know by the students.

TABLE I. DEGREES OF THE MEMBERS OF THE HARNESS TEAM.

	Number	Electrical Engineer	Telecommunications Engineer
Responsible	1	1	
Management	5	2	3
Development	2		2
Help and assistance	20	2	18

Until this moment, we have been working with this structure for approximately seventeen months with very good results. Nevertheless, variations on the student number and possible evolutions between different student sections are expected.

After being working with this structure for a time, we can recommend a range of students in each section: section A students must be between 3 and 6 to properly manage all the rest of students. Section B students must be between 1 and 3 to carry out most of the required jobs. Finally, section C students must be between 15 and 30 students to help students B. We are very proud of the great number of students who want to participate in the project and their motivation, and so we can choose the number of students in each section.

C. Cooperative tools and work

About thirty students from different degrees and obviously with different skills, as it has been mentioned before, compose the Harness team. This is a very important advantage to develop an interdisciplinary topic as the harness of a satellite.

Nevertheless, it is difficult to coordinate so many students. Several cooperative tools have been used to make easier the interaction between all the members of the team. The most important ones are:

- Biweekly meetings: these meetings are being mostly carried out by section B students, with oral presentations supported with PowerPoint slides, in which their advances are presented and discussed with the rest of students. Occasionally, section C students make some oral presentation presenting important changes in other subsystems.

- A Google group: section C students have created a Google group (different from the one of the ESA), as can be seen in Figure 2, in which all the members of the team are signed up. We can interact and express our opinions about each subsystem of the satellite and the questions discussed during the biweekly meetings.

- An electronic calendar: thanks to this tool, integrated in the Google group, the meetings can be programmed in an adequate date for most of the members of the team. It is difficult to find a satisfactory date for all the students, due to their different timetables. Usually, meetings are programmed in some particular hours in the week, that are specially good for the students, then the members of the team can confirm their attendance, and after evaluating the number of confirmed members, the date is postponed or fixed. This can be easily done using the Google group.



Figure 2. Google Group of the Harness team

- Webpage: A couple of section C students have elaborated a webpage of the team. This webpage is updated monthly with the most important advances made by the team. Thanks to this tool other students can know about this project and can be interested in participating. On the other hand, this webpage adds our sponsorships and publishes the help of some people and institutions. You can see this webpage in the following address <http://pels.edv.uniovi.es/ESMO/>



Figure 3. Presentation of the webpage

III. RESULTS AND DISCUSSION. MEETING OF GOALS

A. General learning of different section of students.

Most of the members of the Power Supply Systems group, whose structure has been mentioned before, besides working as teachers in a university are investigating in several projects. The available amount of time to carry out the ESMO project was very little. Nevertheless, the project seemed so interesting that they wanted to participate developing one of the free subsystem, in particular the harness subsystem. As they could not leave their projects, they thought about forming a group of students, with a particular structure, to carry out this new and interesting project. Initially, section A students (PhD students) were very pessimistic about the participation and collaboration of the rest of degree students, but when the announcement of the project was published a lot of students were interested and so, the Harness team was created.

Using the mentioned CL tools, the needed jobs for the harness subsystem in the ESMO project has been properly performed till this moment without too much time expended by section A students. Moreover, these members have put into practice their knowledge about CL, and have learnt about the interaction between students and between teachers and students. Their principle objective was to motivate the rest of students and give them enough tools to work together. They have not developed the harness of the ESMO but they have helped the degree students (especially from section B) to do it.

The two current section B students have carried out an excellent work which can be enough to present as a Master thesis, however they will continue working in the team (their Master thesis will be presented in December 2009). They have elaborated most of the documents needed, asking some questions to the rest of the students about the rest of the subsystems in the biweekly meetings. These two students have developed three different possible solutions for the harness of the satellite, which were presented in the last workshop in the ESA with a lot of success.

Section C Students have helped these two colleagues and have improved their knowledge about global and interdisciplinary projects in general and the ESMO project in particular. Most of these students have an important global knowledge of the whole spacecraft, which few of the rest of the participants in the ESMO project have.

In the following months section B students are going to present their Master thesis, and as they are going to finish their degree, a section C student is going to start elaborating another different Master thesis. All the students of the team have been assisting to most of the meetings, so they are well updated about the progress of the project (also thanks to the news in the Google group). As all of them have a lot of knowledge about the project, they can progress forming part of a higher section of students in the proposed structure of the team.

B. Technical proposal to the harness subsystem.

It is nearly impossible to sum up in this paper all the details of the technical solutions provided by the two section B students to the harness subsystem. However, an introduction to

the solutions provided by the team for the harness of the ESMO will be given.

The most important requirements for all the components of the harness (cables, connectors, couplers, etc.) are:

- All cables shall be insulated with modified radiation cross-linked PTFE.
- All connectors contacts shall be Gold-Plated (Be-Cu) and crimpable.
- All components shall have Space Qualification

It is also very important the distribution of the harness in the spacecraft, taking into account the allocation of the rest of the subsystems (Figure 4).

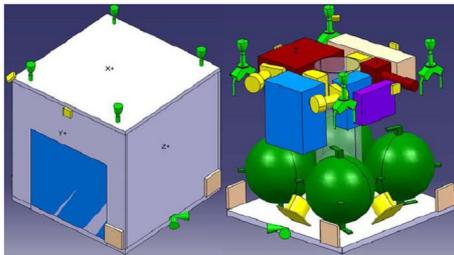


Figure 4. General structure of the ESMO

In ESMO satellite it can be differentiated the following four types of harness:

1. **Harness of Power:** The Electrical Power Subsystem (EPS) provides a 28V unregulated bus. The connectors considered are rectangular. In the EPS box there will be 4 connectors with 37-pin and in the rest of subsystems a 9-pin connector is enough, except in critical subsystems where redundant connectors are needed (Figure 5). The cable shall be twisted pair and is estimated to be 24AWG for most subsystems.

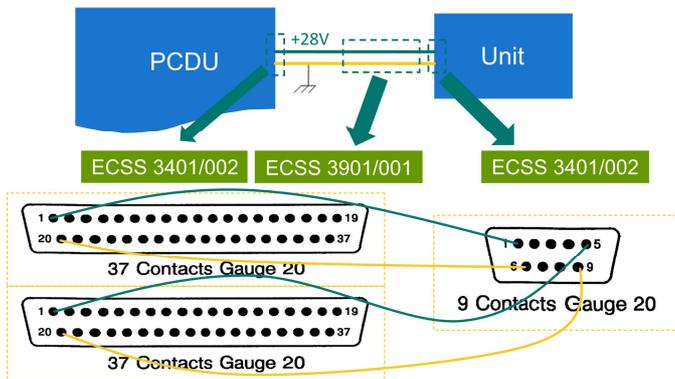


Figure 5. Distribution of the pins of the harness of power

2. **Harness of CAN:** The design of the CAN network is about to be defined by a proposal from ESA-ECSS (European Cooperation on Space Standardization). The connectors shall be compliant to specification: MIL-C D38999 and shall be a 9-pin micro-miniature D-type. The cable is recommended to be Electromagnetic Pulse (EMP) shielded. This option uses only two connectors per CAN node, both with the following pin-assignment (Table II):

TABLE II. DISTRIBUTION OF THE PINS OF CONNECTORS IN CAN BUS.

Pin	Function	Pin	Function
1	CAN_H (PRIMARY)	6	CAN_L (PRIMARY)
2	Reserved	7	CAN Ground (Required)
3	CAN_SHLD	8	CAN Ground (Optional)
4	Reserved	9	CAN_L (REDUNDANT)
5	CAN_H (REDUNDANT)		

3. **Harness of RF:** The RF connection works at 2.3GHz. There are four connections between the transceiver and the antennas. The considered cable is Coaxial with less than 0.5dB/m losses. For this purpose, SMA connectors (Military Qualified) are required in order to satisfy the requirements of total transmission losses.

4. **Harness of RS-232 & RS-422:** These connections are conceived as dedicated lines between the most critical subsystems of the spacecraft. Both protocols have a common physical layer and use the same connector and cable type. These connections will be designed in accordance with the respective standard, but taking into account the general requirements written above.

C. Learning of the members of the team.

Obviously, all the members of the team have obtained some technical knowledge about the project (depending on its section and the participation in the team) which is considered very important. This learning has been demonstrated by all the students in the meetings of the team with oral presentations, clever questions, great suggested ideas, etc. Most of them have learnt some of the following topics:

- Selection of components (connectors, cables, couplers, etc) following the requirements for aerospace missions.
- Knowledge about the different kind of electromagnetic interferences that can affect the components in the space and some ways to avoid this effect.
- CAN bus networks specially develop to use in the space.
- Different kinds of redundancy used in the harness for aerospace validation of the system.
- Use of dedicated software (DOORS) to learn how to analyze electrical requirements taking into account the specifications of the system.
- Use of dedicated software (CATIA) to develop the 3-D design of the harness of the system
- Different solutions to manufacture an electrical ground to use as the reference (this is not so obvious in a spacecraft).

They have also improved some transversals competencies such as search of information, capacity of synthesis, critical thinking, decision-making and read and write technical documents in a different language.

Also, in order to analyze other general benefits of the participation in the Harness team, we have evaluated most of the students making oral presentations. We have compared the results of the evaluation of the students participating in the

ESMO project with other students making their Master thesis in different topics, not related with the ESMO.

In Figure 6 some results are showed, where we can see that students participating in the ESMO project obtained slightly better results than the other students. We should take into account that students making their Master thesis are in their last year, next to finish their degrees, while most of the students of the Harness team are in the third or fourth course of their degrees. These results demonstrate that students participating in the ESMO project have a great level of motivation and participation, working very hard in their oral presentations without any reward.

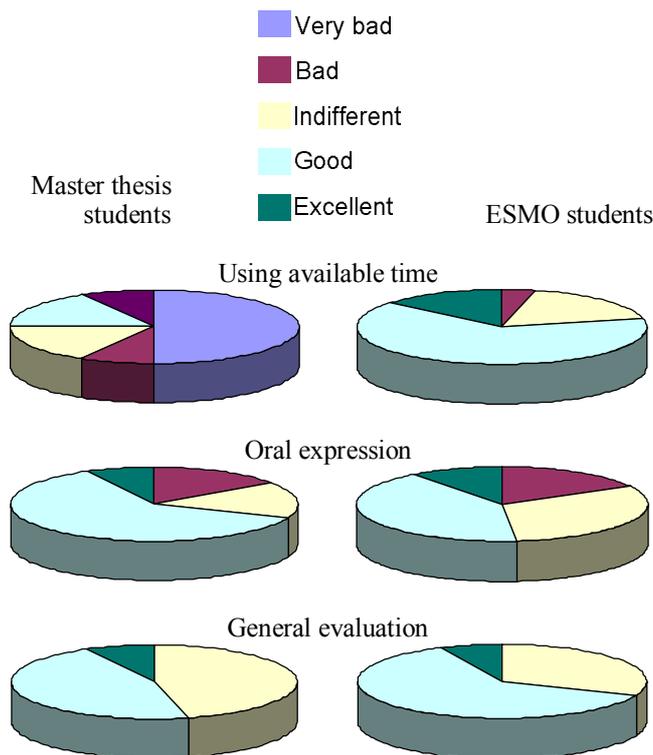


Figure 6. Evaluation of the oral presentation of the team

D. Evaluation of the progress of the team.

To evaluate the progress of the project a little opinion poll was developed to all the members of the Harness team (section A, B and C students). All of them estimate their activity in the team and the benefits in their learning of the participation in the project. The answers of different sections of students are significantly different, due to their different task developed in the team, however all the responses have been put together to evaluate the progress of the team in global.

In Figure 7, the results of the survey are showed. The project is well valued for almost all the members of the team. However some members feel that their activity in the team is very poor, especially section C students. To solve this problem we are right now carrying out different free task for this kind of students, such as oral presentations, search for sponsors, etc.

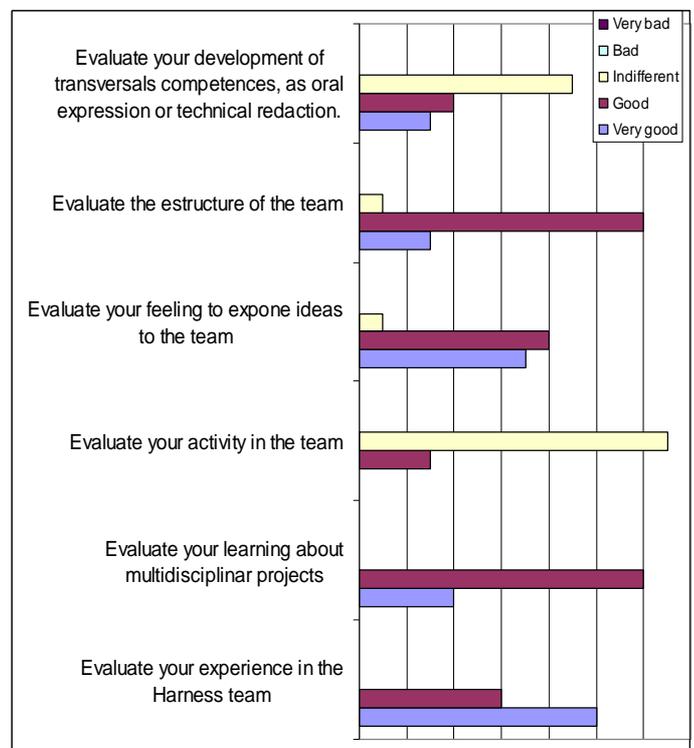


Figure 7. Evaluation of the project by the Harness team

IV. CONCLUSIONS

The possibility of being involved in a very interesting project working in aerospace topics in the ESA, like the ESMO project, was proposed to a group of researchers with very little time to work on it. In spite of this constraint, the project was so attractive that they considered trying to develop it with the help of some students. The interest of so many students for this project was surprising and aims the researchers to form a team to carry out the harness subsystem of the ESMO project.

Thanks to the help of the students the time expended by the researchers would be less, but the main problem would be how to organize and manage so many different kinds of students.

The researchers of the Power Supply Systems group decided that the project should not be developed by them and then explain the work made to the rest of students. This could be similar to the traditional way of teaching, which can be compared to a train that will go on, with or without their wagons.

On the other hand, the proposed methodology was to let the students make all the work required to carry out the project. The task of section A students would be the distribution of the work between the different kinds of students and provide suggestions, revisions and help in certain mishaps. This method is similar to the proposed way of learning by the European Higher Education Area (EHEA), which can be compared to a racing shell that will only go on if everyone row, and so the working rate will be specified by the own students [8].

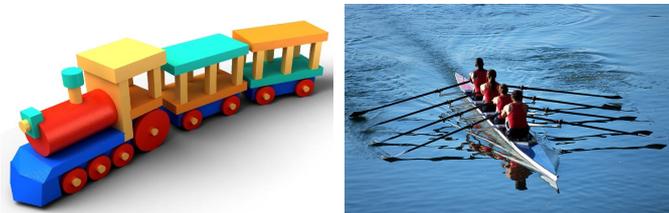


Figure 8. Metaphor between teaching (train) and learning (racing shell).

Putting into practice the CL tools and methodologies that have been described in this article, some very interesting solutions have been proposed to develop the harness of the ESMO. The learning of all the members of the Harness team has been very successful without having to expend a lot of time. Different students have learnt different concepts about harness, the other subsystems (communications, propulsions, power conversion ...), interdisciplinary projects, cooperative and collaborative working, and besides that, they have shared with each other the different knowledge they have. Moreover, they have improved a great number of transversals skills.

All the members of the Power Supply Systems group have been pleasantly surprised with the collaboration of so many students in the described project without any reward except from the learning of new topics. Moreover, the structure of students proposed and the collaboration between all of them using the CL tools detailed in this article, are considered to give very good results when developing a complex system as the harness of a satellite.

REFERENCES

- [1] Roger T. and David W. Johnson, "An Overview on Cooperative Learning". Originally published in: J. Thousand, A. Villa and A. Nevin (Eds), *Creativity and Collaborative Learning*; Brookes Press, Baltimore, 1994.
- [2] Webpage of the European Space Agency. www.esa.int.
- [3] Plaza, I. and Medrano, C.T., "Continuous Improvement in Electronic Engineering Education". IEEE Transactions on Education. Volume 50. Issue 3. Aug. 2007. Page(s):259–265. Digital Object Identifier 10.1109/TE.2007.901981.
- [4] Webpage of Richard Felder. "Resources in science and engineering education". <http://www4.ncsu.edu/unity/lockers/users/f/felder/public/>
- [5] Bermejo, S. "Cooperative electronic learning in virtual laboratories through forums". IEEE Transactions on Education. Volume 48. Issue 1. Feb 2005. Page(s): 140–149. Digital Object Identifier 10.1109/TE.2004.837045
- [6] Asif, A. "Multimedia and Cooperative learning in signal Processing techniques in communications". IEEE Signal Processing Letters. Volume 11. Issue 2. Part 2. Feb. 2004. Page(s): 278-281. Digital Object Identifier: 10.1109/LSP.2003.821675.
- [7] BinShyan Jong; YuLung Wu; TeYi Chan. "Dynamic grouping strategies based on a conceptual graph for cooperative learning". IEEE Transactions on Knowledge and Data Engineering. Volume 18. Issue 6. June 2006. Page(s):738-747. Digital Object Identifier 10.1109/TKDE.2006.93.
- [8] Valero García, Miguel y Navarro Guerrero, Juan José (2008). "Diez metáforas para entender (y explicar) el nuevo modelo docente para el EEES". @tic. revista d'innovació educativa. Nº 1, p. 3-8.