

Project Proposal for Participation in the *H.A.L.E. Project*

xgravler - Experimental Gravity Research with LEGO-based Robotics

[SpaceMaster Robotics Team]

Jürgen Leitner
Kiruna Space Campus
Luleå Tekniska Universitet, Sweden
juxi.leitner@gmail.com

David Leal Martínez
Kiruna Space Campus
Luleå Tekniska Universitet, Sweden
david.leal@gmail.com

ABSTRACT

This proposal is for the participation of the *SpaceMaster Robotics Team* in this year's High Altitude LEGO Extravaganza (H.A.L.E.) project. We intend to use the LEGO Mindstorms NXT microprocessor in connection with a Nintendo Wii Remote to measure gravitational acceleration during the operation of the balloon.

1. INTRODUCTION

The main idea presented in this paper, for flying on-board the H.A.L.E. project balloon this summer, is measuring the g -forces under changing conditions in high altitude¹ environments. This is going to be realized in by using the LEGO Mindstorms NXT processor in combination with a Nintendo Wii Remote (WiiMote) and some additional electronic hardware (e.g. LEGO Mindstorms servos). The idea was crafted after being invited by LEGO to participate and present a proposal for this project.

Micro- g is useful for a variety of scientific research areas ranging from crystal formation, biotechnology, medical/drugs research, fluid physics research to the emerging field of nanotechnology as well as interdisciplinary research. The European Space Agency (ESA) has a database of all ESA funded or co-funded experiments done in micro-gravity during the last 30 years².

We are also interested in taking part in the launch and recovery of the balloon and payload, as well as launch preparations in Nevada, if permitted and wanted by the University of Nevada, Reno and the H.A.L.E. project management team.

The following sections will explain our idea in more detail.

2. IDEA

The experiment we propose will use the LEGO Mindstorm NXT micro-controller and some additional components, e.g. the NXT servos. The NXT will be in contact with a Nintendo Wii Remote controller, via Bluetooth. The Nintendo Wii Remote is equipped with an ADXL330 iMEMS® 3-axis acceleration sensor³, which will be used to measure the ac-

celeration due to gravitation (also known as g -force). From the data a gravitational model can be built and used e.g. for the next flights and upcoming experiments. The main experiment will be to measure artificially generated micro- g environments in high altitudes. These will be produced by dropping the Wii Remote for a few meters from the balloon. During the free-fall the acceleration will again be measured and stored on-chip or another storage device. The Wii Remote is connected to the balloon via a tether and can then be brought back up to the main box, the experiment will then be repeated a few times, at various altitudes, to get more data readouts for post processing, future research and analysis.

From the experiments we hope to get new information on micro- g generation in high-altitudes. The main purpose of the mission is to check the feasibility of our idea, to check if it is doable with such a small budget and how much the acceleration is reduced by our experiment.

A tether length of a few meters to test our idea on board the balloon will be suitable. The idea is similar to a regular *drop tower*⁴ but due to the balloon being in high altitudes and above 99%⁵ of the Earth's atmosphere it provides near-space conditions. It could feature, in lower altitude, the same micro- g environments sounding rockets provide but with longer durations than those can provide (see appendix), due to the retracting and re-release (of the Wii Remote). The results should be reproducible in larger scale and for more sophisticated experiments later on and will be useful for future balloon missions. The results are to be predicted by theoretical calculations like presented in [Mathematics of Microgravity, 1999]

As a minor mission, and sort of an outreach program, we want to take pictures with a digital camera, possibly with placing ads in the picture (as is currently done by various *next-gen* space companies, e.g. JP Aerospace⁶) which would help us get more partners and funding for this project.

The main box, which includes the NXT as well as the mechanics and the tether for the "drop test" of the Wii Remote, will also hold the camera and possible a rotatable camera mount. The Wii Remote will be in a separate box

¹High Altitude is defined in various ways, here it is used to describe altitudes (within the atmosphere) of about 30 km.

²Erasmus Experiment Archive database (<http://eea.spaceflight.esa.int/>)

³see press release (http://www.analog.com/en/press/0,2890,3_99573,00.html) and presentation ([\[nintendo.co.jp/n10/e3_2006/wii/controller.html\]\(http://nintendo.co.jp/n10/e3_2006/wii/controller.html\)\)](http://www.</p></div><div data-bbox=)

⁴NASA 2.2s Drop Tower Facility (<http://facilities.grc.nasa.gov/drop/>)

⁵http://myweb.cwpost.liu.edu/vdivener/ers_1/chap_3.htm

⁶<http://www.jpaspace.com/100spacead.html>

(which basically is just the insulation for the controller and the connections for the tethers) which also will be connected by a safety tether. This second box, will then in intervals be dropped from the first box and continuously measure the acceleration. The experimental data will be post-processed and hopefully lead to a gravitational model for the selected heights, as well as a model for reduced g -force due to the drop of the sensor. For this all the data is just saved in raw form on the micro-controller or external storage.

Apart from this being an interesting project related to space research it is also well suited to demonstrate other concepts and areas of research especially in the field of robotics. The following is a short list of interesting areas within our project: Bluetooth communication of the NXT; accelerometer readout and physical-digital interface; robotic climber & retractor evaluation and construction; near-space photography with rotating camera; LEGO as "space-proof" material (e.g. insulation); etc.

3. ISSUES

In our early planning stages we identified the following as the most important and critical issues for the project and the experiment on-board the balloon. (The following list is in alphabetical order.)

3.1 Batteries

The power supplied for the motors and the camera, as well as the data storage, needs to be calculated. This will be done theoretical, as well as some empirical tests on battery life with assembled prototypes. The weight might be the biggest constraint here.

3.2 Bluetooth Communications

Since both the NXT and the Wii Remote are already Bluetooth enabled it was the obvious choice of communication. It provides wireless readouts of the accelerometer for at least a distance of 10 m and therefore eliminate the need for additional cabling.

Bluetooth has been used to connect a computer with the Wii Remote, as described by various projects on the web⁷ also the NXT supports sending of data from and to a computer via Bluetooth by default. A short research on the web also showed that controlling an NXT robot with a Wii Remote has already been tried and lead to some nice results.⁸

3.3 Data Storage and/or Download

The main issue here is the storage size, if limited storage capabilities are used, not just the camera experiments but also the "drop test" experiments will have to be limited. To ensure enough storage capabilities on-board, various ideas are being developed right now. One idea proposes to extend the NXT storage with a flash memory connected via an I2C-serial bridge. Another idea is to use a mobile phone with a memory chip and save the data via bluetooth (or also via serial). The storage can be logically split into 3 areas: the programs, the picture data and the data gathered from the sensors. Those areas can, but do not necessarily, be split physically.

Another way around that problem is a possible real-time

⁷e.g. <http://www.cs.cmu.edu/~johnny/projects/wii/>

⁸<http://www.youtube.com/watch?v=XUsMqr3Lxw0>

downlink. We currently do not know if the University of Nevada, Reno offers such capabilities for this project or how hard they are to integrate into our project. Previous balloon missions by them did fly experiments with communication equipments, this is one issue that still needs to be researched.

3.4 Environment

The near-space/high-altitude environment that exists in a 30 km altitude is rather harsh, the temperature will be dropping to levels between -50°C and -70°C (degree centigrade). The pressure will drop by some orders of magnitude. The radiation doses, which usually are low due to shielding by the atmosphere, are drastically increased for the experiments. All these factors might lead to malfunctions and errors. To test our system cooling chambers and theoretical analysis will be used to ensure a small error and failure rate. One idea was also to test the ability of LEGO as a shielding material for our components. The advantages would be the rather cheap price and the high flexibility to build all sorts of structures. This testing will probably be done in the cooling/thermal chamber here in Kiruna and will determine if it is sufficient and also suitable (e.g. weight restrictions) for this project.

3.5 Placement/Release

Too be able to do the tethered "drop test" experiment with the Wii Remote it is necessary that our experiment is the bottom-most element during the balloon flight, otherwise complications with other experiments could arise. Another possibility is to separate our experiment from the main balloon and use a parachute and SPOT system on its own, which could hopefully be provided by the University of Nevada, Reno.

3.6 Safety

To ensure the safety of the dropped elements a safety leash is added to the already connected tether. In drop tests before the actual launch the system will be tested to ensure its safety. In case of a separation from the main balloon, the SPOT system and the parachute provided by the University of Nevada, Reno, should be tested beforehand in connection with our payload.

3.7 Tether

The material for the tether (as well as the safety leash) are yet to be determined. The ideas range from basic lightweight materials (like plastic string) to stronger but also heavier materials. The main issue will be the safe deployment of the secondary (drop) box, as well as the mission cost. Carbon-composite (nano-tube) or composite fiberglass tethers as used in some space applications and the Space Elevator games are too expensive for this experiment but should be kept in mind for future missions.

One of the important evaluations will be which tether to chose for our project and which properties it shall provide (e.g. elasticity, weight, ...).

3.8 Weight Estimate

The weight estimates for the components used; these are based on using a mobile phone as memory device and are generally very rough estimates (e.g. enclosure structure is not known so the weight is very much of an estimate; the

Table 1: Weight Estimates

Component	#	Weight [g]
NXT + Batteries		250
Motor	2x	90
Cables	5x	50
Camera + batteries		160
Heater		70
Enclosure		180
WiiMote + batteries		100
Casing Wiimote		100
Storage Device/Mobile Phone		80
Bricks and Beams		70
Parachute*		140
SPOT GPS*		210
Total		1500

tether is not taking into account because of the big difference between various tethers). BUT the estimates include the parachute and SPOT GPS, which are only to be used if the experiment was to detach from the balloon. These estimates are very much at the border between the two given categories, so depending on the final configuration and the restrictions and possibilities given by the project management, the experiment can be fitted into both categories, with minor changes only.

4. CONCLUDING THOUGHTS

We think a project of this scale is doable in the given time-frame, and we already started research into the issues discussed above as well as with general project management, e.g. tasks like funding and recruiting of other students.

The facilities available to us here at the Kiruna Space Campus and the close vicinity to ESRANGE⁹ Space Center, whose staff and members are experts on the field of high-altitude balloon experiments, will help us reach the planned mission objectives. Apart from these there are currently other student projects in connection with high-altitude balloon flights done by our colleagues in the SpaceMaster course. Those are done within the framework of BEXUS and EXUS-B¹⁰ and we will work closely together with them to get valuable information and experience.

From our proposal you can see that this project is rather ambitious but we are willing to give this project a lot of time and effort to show that this can be done in a short time frame and with limited funding.

5. ACKNOWLEDGMENTS

The authors would like to thank LEGO for inviting us to participate in this project. We got valuable input about e.g. mechanical (Mark Fittock) and thermal (Sam Webster¹¹) issues, and will also try to collaborate on future issues with them and the other balloon teams here in Kiruna.

We also want to thank the University of Nevada, Reno, the

⁹European Space Rocket Launching Range

¹⁰student balloon launch campaigns by ESA (mainly SSC and DLR) and IRV/LTU/Esrange respectively

¹¹both currently with the SpaceMaster programme and former Monash University (Melbourne, Australia) alumni

project managers and all sponsors: Nevada Space Grant, The LEGO Mindstorms Team, National Instruments and the Energizer Battery Company.

All product and brand names are trademarks and/or registered trademarks of their respective companies.

6. REFERENCES

MJB ROGERS, GL VOGT, MJ WARGO: Mathematics of Microgravity. *NASA Educational Products*, 1999.

WILEY J. LARSON, JAMES R. WERTZ (EDITORS) Space Mission Analysis and Design (Third Edition). *Springer, New York*, 2006.

APPENDIX

A. ADDITIONAL INFORMATION

A.1 About Micro-g

*Micro-g*¹² (or micro-gravity, also called weightlessness, free fall, or zero-*g*), is the nearly complete absence of any of the effects of gravity. In the micro-*g* environment of a satellite, objects do not fall, particles do not settle out of solution, bubbles do not rise and convection currents do not occur. Yet at the altitude of a weather balloon the gravitational force is still 97-98% of its value at the Earth's surface and in LEO still around 90%.

In orbit micro-*g* comes about because the satellite is in *free fall* - i.e., it is continuously falling through space. In a circular orbit the forward velocity of the s/c is just enough to stop the continual fall of it towards Earth. Micro-*g* is preferably used to make clear that *g* (the acceleration due to Earth's gravitation) is changed and not the gravitation itself.

To provide micro-*g* conditions a variety of systems is used, each has specific pros and cons. The systems are: ground facilities, parabolic flights, sounding rockets, retrievable capsules, the Space Shuttle, space stations or satellites. Most experiments have been made during parabolic flights (800), followed by sounding rockets, Space Shuttle missions, and on-board space stations (each 300-400). Where sounding rockets are by far cheaper than Shuttle or station missions, but provide usually micro-*g* environments for durations of only 300-400 seconds¹³.

A.2 About the SpaceMaster Robotics Team

We, the *SpaceMaster Robotics Team (SMRT)*, are graduate students currently enrolled in the *Joint European Master in Space Science & Technology (SpaceMaster)*¹⁴ programme and currently study in Kiruna, Sweden, at the Space Campus of the Luleå Tekniska Universitet (LTU), which is co-located with the Swedish Institute of Space Science (IRF). These studies were preceded by a semester at the Julius-Maximilians-University Würzburg (JMUW), Germany and are succeeded by one year of courses and master thesis work at the Helsinki University of Technology (TKK), Finland.

The team developed a robot for and took part in this year's student design competition at the 3rd annual Human-Robot-Interaction conference held in Amsterdam, The Netherlands.

¹²paragraph mostly taken from [SMAD III, 2006]

¹³ESA's sounding rockets MASER/TEXUS (<http://www.spaceflight.esa.int/users/index.cfm?act=default.page&level=11&page=facsrockets>)

¹⁴<http://www.spacemaster.eu/>