



REXUS / BEXUS

Experiment Proposal Form



Full experiment title	<i>Suaineadh</i>
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- REXUS**
 BEXUS
- spinning with 4 Hz
 despun with Yo-Yo to about 1Hz = 6.283rad/s

Science & Organisation

<p>What is the scientific and / or technical objective of your experiment?</p>	<p><i>This description should outline the scientific / technical question addressed, the assumptions made and the research methods chosen to solve the question. Expected results should be stated.</i></p> <p>The technical objective is to deploy a large net and stabilise it by exploiting centrifugal forces and a reaction wheel. This new approach has the potential of drastically simplifying the design of a Furoshiki net while enhancing its stability and will provide an enormous scientific return on the behaviour of a centrifugally deployed and stabilised large structure in space</p>
<p>Why do you need a rocket / a balloon?</p>	<p>A rocket is required in order to achieve the experiment's goals;</p> <ul style="list-style-type: none"> ● Demonstrate release and centrifugal deployment of a space web ● Demonstrate stability control of the net using the reaction wheel launch system <p>The net deployment must be tested in micro gravity. This net deployment will take a number of seconds and therefore a high altitude is also required.</p> <p>The rocket has a quite high angular rate, even after being de-spun. These dynamical conditions can be used to our advantage to provide the mechanical energy needed for releasing and deploying a large lightweight space net. Conservation of angular momentum tells us that a package fixed on the sounding rocket shroud will acquire, when released from its constraints, a velocity relative to the rocket which scales as the distance of the package from the rocket spin axis (sling shot effect). Furthermore, the same principle tells us that the package will leave the sounding rocket while spinning at the same rate as the rocket itself. In this way, the energy needed for both release and deployment of a Furoshiki package can be provided by the rotational energy of the rocket without the need for ejection springs and avoiding a complex spin-up manoeuvre based on tangential thrusters.</p>

<p>Where did you get the idea from?</p>	<p><i>e.g. research programme at your university, already performed similar experiment, scientific publications, books, etc.</i></p> <p>The experiment is a follow on from the original Japanese experiment (Nakasuka <i>et al.</i>, 2006), when a large triangular net was deployed in micro gravity. This experiment demonstrated the ability to launch such a device. However, it failed to prove the stability of the net in micro gravity.</p> <p>Many future space technologies will rely on the ability to build large scale space structures. The deployment and control of large lightweight structures in space is thus undoubtedly one of the key milestones of space technology, which could be beneficial to a variety of space applications such as power generation, telecommunications, Earth observations and space-based astronomy. Among the different possible techniques to deploy and stabilise a large reflective surface in space a particularly efficient one is to resort to centrifugal forces. This approach has, among others, two fundamental advantages:</p> <ul style="list-style-type: none"> ● The structure stiffness and dynamical stability can be obtained without having the mass penalties of any supporting structure. In fact, the spin stabilisation scheme is the one allowing the highest surface to mass ratio attainable by a stabilised space structure. ● The number of sensors and actuators required to deploy and stabilise the structure can be minimised, reducing the system complexity and, most of all, minimising the risk during the deployment phase. <p>Many aspects regarding the design, deployment, dynamics and control of these systems were analysed using different analytical and numerical models and proposing a variety of control strategies (McKenzie & Cartmell, 2008; Gärdback & Tibert, 2008a; Gärdback & Tibert, 2008b). In this research context, the implementation of simple experiments testing the deployment process and the structure stabilisation in a free fall environment is a fundamental and necessary step which will lead the way towards the construction of future large lightweight structures in space.</p> <p><u>References</u></p> <p>McKenzie, D. & Cartmell, D., <i>Modelling of tethered space-web structures</i>, 56th International Astronautical Congress 2006. IAC-06-D4.3.07.</p> <p>Gärdback, M. & Tibert, G., <i>Deployment control of spinning space webs</i>, Journal of Guidance, Control and Dynamics, in press, 2008a.</p> <p>Gärdback, M. & Tibert, G., <i>Optimal deployment control of spinning space webs and membranes</i>, Journal of Guidance, Control and Dynamics, submitted, 2008b.</p> <p>S. Nakasuka, R. Funase, K. Nakada, N. Kaya & J. C. Mankins, <i>Large membrane "Furoshiki Satellite" applied to phased array antenna and its sounding rocket experiment</i>, Acta Astronautica</p>
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	58(8):395–400, 2006.
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Describe your experiment	<p><i>This part should link the scientific objective to the experiment itself. Explain how you are going to fulfil the scientific goal.</i></p> <p>The experiment consists of a mother section with four daughter sections attached to it. The mother and daughter sections will be spun away from the rocket using the rockets rotational speed as a launch mechanism. The package can be released in an almost completely passive manner in order to simplify the design and reduce risks. After all initial constraints are removed the package will be pulled outward by the centrifugal acceleration.</p> <p>To release the package along a free spiral trajectory it will be confined into a curvilinear groove to avoid collisions due to small errors in the release conditions. It has been seen that this option allows reduces the ejection velocity from the rocket.</p> <p>As mentioned above, due to conservation of angular momentum the package will be ejected by the rocket while spinning at the same angular velocity of the rocket (neglecting friction). In this dynamical condition the package will tend to deploy itself as soon as it will have the possibility to do it (i.e. as soon as the package constraints are released). At this point the net will start unfolding while decreasing the angular rate and conserving angular momentum. The reaction wheel will be used to stabilise the release of the net and prevent any rebound effects after full deployment (Gärdsback & Tibert, 2008a; Gärdsback & Tibert, 2008b)</p> <p>The design of the deployable net is driven by several technical and scientific requirements. Below are some key aspects to be taken into account:</p> <ul style="list-style-type: none"> ● The maximum size of the net is limited by the need to retain a sufficiently high angular rate to provide a minimum tension on the net. This will guarantee a stable dynamical behaviour. ● The net folding and deployment strategy has to be as simple as possible in order to minimise mission risks.
Which data do you want to measure?	Dynamics and kinematic (linear and angular acceleration and velocity of the mother and of the daughter sections) of the web during deployment. Net stability when fully deployed, centrifugally launched net characteristics, e.g. effects of the net self-contact on the deployment dynamics.
How do you want to take measurements?	The measurements will be made visually; cameras will be mounted on the daughter sections and mother section. We want to collect the data continuously during the flight, from the time of the net launch until it is feasibly possible to continue to obtain the data.
Describe the process flow of your experiment?	<ul style="list-style-type: none"> ● (T0) rocket launch ● innate the control sequence for the PLC ● data stream online (downlink)

	<ul style="list-style-type: none"> ● cameras start filming before deployment starts, IMU active start measuring spinning rate and acceleration ● deployment initiates ● net fully deployed ● data download (storage onboard & downlink) ● experiment finished due to landing
<p>What do you plan to do with your data after the flight?</p>	<p>The collected data will be analysed to establish whether it is indeed possible to stabilise a large net using centrifugally deployment combined with a reaction wheel. Comparisons will be made between simulations and the experiment. The results of our study will be presented in a scientific paper. The results will also allow further refinement of the design and simulations methods for possible future designs or experiments.</p>

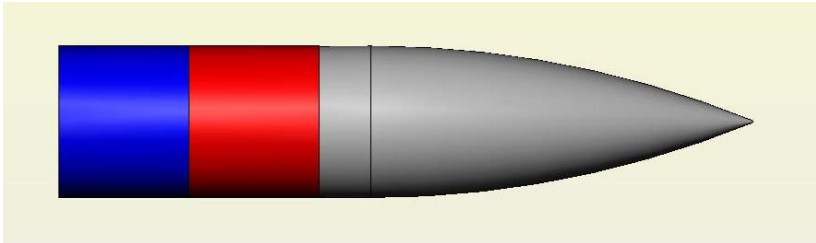
<p>Organisation of your project</p>	<p><i>How will you organise / distribute work within your team? <u>Please note that you are responsible for all aspects of your experiment (science, mechanical & electrical engineering, software, etc.)</u></i></p> <p>1 PhD students in the Aerospace Department in Glasgow working on the project and supervising 2 master students. The Aerospace department will collaborate with the Mechanical Department on the design of the mother and daughter sections dealing with all the aspects related to the space and launch environment. Furthermore, the aerospace department is responsible for the telecommunication, instrumentation and data collection.</p> <p>3 PhD students in the Mechanical Department in Glasgow working on the project and supervising 2 master students. The Mechanical department is responsible for designing and manufacturing the mother and the daughter sections, the release mechanisms and the storage system. Furthermore, they are responsible in collaboration with the aerospace department for the simulations of the deployment.</p> <p>1 PhD student helping 2 Master students from KTH with deployment simulations and net manufacturing.</p>
<p>Are you supported by an Institute or a professor?</p>	<p>Yes</p> <p>Prof. Matthew Cartmell, Department of Mechanical Engineering, University of Glasgow</p> <p>Dr. Massimiliano Vasile, Department of Aerospace Engineering, University of Glasgow</p> <p>Dr. Gunnar Tibert, KTH Mechanics, Stockholm, Sweden.</p>
<p>Do you have a workshop or a laboratory to work?</p>	<p>Yes</p>
<p>Do you have all the material and equipment which is needed for your experiment? If not, how do</p>	<p>In Glasgow, materials and tools to build the structure and the mechanisms of the mother section and of the daughters are already available. Instrumentation can be procured through university funding and sponsored support from the companies that are generally collaborating with the two department involved in this</p>

you plan to obtain it?	project. Simulations software already exists at KTH Mechanics and material for the net, etc. could be obtained from company connections.
How do you plan to finance your expenses?	In Glasgow, the two departments will support the activity and we expect some from some local companies. In Sweden, support from the department (software, computers, laboratory facilities) and from companies, for example, Lindstrand Technologies Ltd.
Who else will support you (sponsors, others)?	We will get intellectual support from the Advanced Concept Team who has previous experience with past Furoshiki type experiments.

Outreach Programme	
Describe your outreach programme for before, during and after the REXUS / BEXUS flight campaign?	<p><i>How are you planning to present your experiment to the public? e.g. newspaper, local radio, webpage, presentation at the university, etc.</i></p> <p><u><i>The execution of an outreach programme is mandatory!</i></u></p> <p>The campaign will be published on our faculties' websites; this will outline the work we will plan to carry out along with dates, other relevant information etc.</p> <p>Following the experiment the website will be updated with results and a scientific paper will be published detailing findings.</p> <p>The media communication office of the university will support us in the dissemination of the results and in publicising this activity.</p>

Experimental Set-up & Technical Information

Mechanics	
Describe your experimental set-up.	<p><i>Describe and outline the preliminary set-up of your experiment. Attach relevant documents, such as CAD drawings, to this form.</i></p> <p>As a payload of the REXUS sounding rocket we propose a package consisting of:</p> <ul style="list-style-type: none"> ● a square lightweight deployable net with a side length of 2 metres, that will be folded into a very small storage volume 0.06x0.04x0.04 m³. ● four masses at the nets end points connected to a mother section by tethers. ● a net launch control mechanism consisting of a reaction wheel and base plate that configures the launch characteristics of the device. ● a series of cameras mounted on the net corners and on the mother section, plus an IMU to measure spinning rate and acceleration on the mother and on the daughters ● a communication system to relay images and IMU readings.

	<ul style="list-style-type: none"> • a battery supply to power both cameras, communication system, spinning wheel and IMU. • a programmable micro logic controller and connection to the rockets power supply or to the onboard battery.
<p>Estimate the dimensions and the mass of your experiment.</p>	<p>The exact size and mass is not yet known, but it is estimated to be within;</p> <p>Mass: 6 kg overall system mass without margins, 7.2 kg with margins</p> <p>Stowed size: 0.1 × 0.1 × 0.1 m³</p> <p>Deployed size: 2 × 2 m²</p>
<p>Indicate the preferred position of your experiment:</p>	<p><i>REXUS:</i> <i>Indicate the preferred position in the rocket: bottom module, top module or nosecone section. Do you need access to the outside environment? Holes? Hatches?</i></p>  <p>This experiment must be located in the nose cone section. The experiment will need to be on top of the other experiments if it is not to interfere with them. No holes or hatches are required.</p> <p><i>BEXUS:</i> <i>Define preferred position in the balloon: inside or outside the gondola or in the flight train.</i></p>

<p>Electrics / Electronics</p>	
<p>REXUS only: Will you need the 28 Vdc power supply from the REXUS service system?</p>	<p><i>BEXUS experiments cannot be powered by the BEXUS system.</i></p> <p>Yes</p>
<p>Will you need (additional) batteries? What do you need for charging?</p>	<p><i>Qualified batteries are listed in the REXUS and BEXUS User Manuals.</i></p> <p>Yes, the communication device on the mother section will need a power supply. However, we expect to put a battery onboard to supply the control of the wheel and the instruments. This would remove the need for any additional power supply.</p>
<p>Estimate the electrical consumption of your</p>	<p>30-50 Watts including communication link, instruments, controller and spinning wheel.</p>

experiment.	The power required to control the deployment is included in the power required by the reaction wheel.
Do you use any equipment with high inrush currents?	<i>e.g. Motors may need high inrush currents which exceed the nominal allowed current limit.</i> No
REXUS Only: Do you need auxiliary power? Do you need a separate umbilical?	<i>Auxiliary power for charging or consumption before launch is not standard. Mention here whether you need auxiliary power and why.</i> No
Do you need uplink and / or downlink?	<i>Will you downlink your data or store it during the flight? Will you uplink commands? What is the expected data rate?</i> Downlink, data rate 35840 bit/s The command to deploy the web can be automatic or can come from the ground station. In the latter case we will need to uplink the deployment command.
REXUS Only: Do you need to use the REXUS TV Channel?	<i>There is only one TV channel available, so only one experiment can use it. Why should it be your experiment?</i> No.
Provide an event timeline, including the experiment actions during flight, such as timer or telecommand events.	<i>Describe your event timeline.</i> T-60; innate the control sequence for the PLC T0; Rocket launch T0+57; Nose cone ejection T0 + 66; Payload/Motor Separation T0+70; Cameras and instruments operational & communication link acquisition T0+100; Mother release mechanism activated T0+105; Daughter sections released T0+106; Reaction wheel operational T0+110; Net fully deployed

Environmental Questions & Safety Issues	
Does the experiment use wireless devices?	<i>e.g. Wifi (WLAN), Bluetooth, infrared, airport, data transmitters. Describe the type of devices and frequencies used.</i> Telecommunication system for uplink and downlink communication with the ground station. Wireless communication between the daughters and the mother section. A non wireless option for the communication between the mother and the daughters is also

	possible.
Does the experiment create a magnetic or electrical field?	No.
Could there be an electrostatic discharge from your experiment?	No
Is the experiment sensitive to light?	Daytime launch preferred, none of the experiment equipment is sensitive to light.
Is the experiment sensitive to vibrations?	No.
Does the experiment generate vibrations?	<i>e.g. Vacuum pump, rotating devices, etc.</i> No, though the spinning wheel represents a rotating devise. However it will not be activated till the deployment begins.
Will you use any flammable, explosive, radioactive, corrosive, magnetic or organic products?	<i>Specify any products you will use with any of these characteristics.</i> No
Will you use a laser?	<i>Which class? Is the lather path securely contained?</i> No
Is your experiment airtight? Are parts of your experiment airtight?	<i>Yields to a pressurized experiment (1 bar) when the vehicle reaches higher altitude with lower pressure values.</i> <i>This question should remind you that there will be a very low ambient pressure environment for your experiment.</i> No
Are there any hot parts (> 60°C)?	<i>Mention any parts besides electronics that heat up.</i> No
Are there any moving parts? Are the moving parts reachable?	<i>This is important for the preparation before launch. Access to the experiment will be discussed with EuroLaunch. e.g. a tappet is used for a moving part.</i> The moving part are the spinning wheel and the deployable daughters. Both will be activated and released in space. In the folded configuration the daughters are attached to the mother and the web is folded inside the mother. There is no other external moving part.
Do you need any pressure systems from EuroLaunch before launch?	<i>If you know that you need for example a pressurized nitrogen-bottle for your experiment before launch, please mention it here. All pressurized bottles will be handled by EuroLaunch personnel.</i>

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Your text should be intelligible to scientists of various fields and engineers with a general scientific background.

Before you submit your proposal, please ensure that you have read the REXUS / BEXUS Technical Overviews available at www.rexusbexus.net You can also refer to the REXUS / BEXUS User Manuals for more detailed information.

To submit your proposal to ESA, please register at www.joinspace.org and download this application form as a Word file. The completed form must be uploaded again before the deadline of 17 November 2008.