Innovative Camera Pointing Mechanism for Stratospheric Balloons

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Agenda

1. Idea of the system
2. Objectives
3. System design
4. Preflight analysis & tests
5. Results of the test flight on BEXUS 11
6. Lesson learned and recommendations
7. Final remarks and future work
8. Acknowledgements
Students Space Association of WUT

Since 1996:
- 5 Parabolic Flights Campaigns
- YES-2 Satellite
- SSETI EXPRESS Satellite (OPER)
- ESEO Satellite (OPER & CONF)
- ESMO Satellite (TCS & CONF)
- BEXUS 10/11 😊

- Cubesat „PW-Sat”
- Mars Rover „Skarabeusz” for URC
- Rocketery Section „Amelia-1”

- COSPAR 2000
- Almost all astronauts visits in Poland
- ILA, Le Bourget, Farnborough, MAKS
- ESA 20th Symposium 😊
Idea of the system

1. Remote sensing from stratospheric ballons has some advantages over satellite observations

2. Stabilization systems for UAV are expensive and not entirely suited for ballons

3. Interesting possibility to use ballons for:
   • terrestrial observations
   • environmental monitoring
   • observe other scientific payload
   • keeping ballon’s antenna pointing in desired direction
Main objectives

1. **Compensation** of balloon’s gondola attitude
2. Ability to keep camera **tracking ground targets** (selected by the Ground Station (GS) operator or read from on board memory)

- Data from Low.Co.I.N.S. experiment (BEXUS 6)
- BEXUS Manual

![Diagram of balloon's gondola attitude](image)

![Graph of angular velocity](image)
System requirements

1. Accuracy of the Stabilisation System - 1 deg
2. Record all phases of flight
3. Record movement of Pointing Mechanism
4. Gather data of Pointing Mechanism movement
5. Provide temperatures of crucial components
6. Withstand landing
7. Independent power supply
8. Independent GPS data
9. Redundant data recording
10. Autonomous mode
11. Sending TC, receiving TM by GS
System Design

- Pointing Mechanism
- Control System
- Attitude & position sensors
- On-board Computer
- Power Supply System
- Ground Station
- Thermal sensors
- Structure & insulation
- Additional Camera

- Control Algorithm
- SCOPE_F
- SCOPE_GS
# Experiment overview

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<table>
<thead>
<tr>
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<tr>
<td><strong>Total mass</strong></td>
<td>21.87 kg</td>
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<tr>
<td><strong>Mass of POM’s moving parts</strong></td>
<td>5.76 kg</td>
</tr>
<tr>
<td><strong>External dimensions</strong></td>
<td>466 x 550 x 538 mm</td>
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<tr>
<td><strong>Camera maximal deflection from vertical axis</strong></td>
<td>45°</td>
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<tr>
<td><strong>Rotations around vertical axis</strong></td>
<td>Unlimited (limited to 310° in the prototype)</td>
</tr>
<tr>
<td><strong>Compensated changes in gondola’s attitude</strong></td>
<td>30 deg/s</td>
</tr>
<tr>
<td><strong>Camera resolution</strong></td>
<td>540x576 px</td>
</tr>
<tr>
<td><strong>Operational time (available power)</strong></td>
<td>12 h</td>
</tr>
<tr>
<td><strong>Minimal operational temperature (confirmed)</strong></td>
<td>-70°C</td>
</tr>
<tr>
<td><strong>Minimal operational pressure (confirmed)</strong></td>
<td>1 mbar</td>
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Experiment overview
Experiment overview
Pointing mechanism (POM)

- 3 stages
- 3 stepper motors
- 3 interspace detectors
- 2 encoders
- Counterweights
- Video camera
Electronics components

- PC/104
- Interface Board
- Motor drivers (3)
- Status LED indicator

- Power Board
- Batteries (24)

- Additional camera

- IMU sensor
- GPS receiver
- Temperature sensors (4)
Electronics components

Electronics box  Battery box  IMU&GPS box
Control Algorithms

- **Target Tracking Algorithm** – basis on its own and selected target, calculates desired camera attitude for pointing to the target.
- **Joint Position Determination Algorithm** – basis on desired and gondola actual attitude calculates joints position.

- **Test software** created to perform tests and simulations of the experiment, based on data from Low.Co.I.N.S. experiment.
OBC software

- Communication with GS – sending TM/receiving TC
- Data Storage (IMU, GPS, Temperature, Voltage)
- Storing camera recording
- Joints positions computation and sending to the Interface Board
Ground Station

- Sending TC/receiving TM
- OBC Operational Modes
- Pointing Mechanism Operational Modes
- Pointing Mechanism joints position
- Reading from temperature sensors
- Gondola&targets coordinates
- Event history
Pointing Mechanism modes

• (1) – Desired joints position
• (2) – Pointing directly downwards (autonomous)
• (3) – Tracking selected targets, targets selected by operator and sended via GS
Tests & analysis

Control algorithms

Thermal analysis

Funcional tests

Environmental tests
Flight campaign results

Video 😊
Flight campaign results

1. No possibility to calibrate IMU
   **Result:** 3rd stage frozen -> no stabilization of gondola rotation

2. Difficult access to the cameras’ memory cards
   **Result:** No video from last phase of flight

3. Loss of communication with the Ground Station
   **Result #1:** Unable to select ground targets by operator-> system in 2nd mode, camera pointing directly downwards
   **Result #2:** Only 3 frames of data

4. Mechanical failure of the memory card
   **Result:** No data from IMU, GPS, temperature sensors
Recommendations

- Different model of IMU or another external system computing yaw angle

- Easier possibility to update OBC software
  - via Ground Station
  - via cable

- Easier access to the experiment
  - recharge batteries
  - clean Memory Cards

- Higher modularity of the experiment

- More control points

- Details:
  - Mechanical (integration to gondola, connections)
  - Electronical (cables, connectors)
Final remarks and future work

Remarks:
1. Objectives of the flight test of the prototype were not fully achieved, however provided value information about areas that need to be improved (IMU, communication, backup modes, modularity, accessibility)
2. System was tested and can work in extreme conditions
3. On-Groud tests and analysis shown properly work of the system

Future work:
1. Improving selected areas based on experience from test flight
2. IMU sensor
3. Unlimited rotation of 3rd joint – 3 Degree of Freedom system
4. Miniaturization of the system
Potential

- Low cost, interesting payload for amateurs balloon campaigns (Copernicus, Hevelius)
- Additional system to observe other scientific payload
- Stabilization system for directional antennas for balloon missions that required high amounts of data transmission
- Terrain observations from ballons
- Real time video from flight available on GS
Lesson learned

- Systematic **management** is crucial!
- **Reporting** is crucial!
- Detailed internal **documentation** helps everyone!
- **Brainstorms** and discussions are significant!
- There is time to discussion, planning and for prototypes!
- Accessibility of **workshops, facilities** is important
- Easy access to high **founds** solves many problems
- Good **time estimation** is very important! (evaluation)
- Access to the **specialists** for crucial systems
- Relevant **selection of people** to team is essential
- Appropriate **tasks allocation** is valid
- **Experience** is important!

- Listening ESA/DLR/SSC staff could be helpful...
- Sleeping is also important...
What are we doing now?

- Krzysztof Gedroyć (electronics) – Space Research Centre/owner of company
- Krystyna Macioszek (software) – Space Research Centre, Astri Polska
- Łukasz Boruc (thermal control) – lider of rocketery team, PhD will started next year
- Kamil Bobrowski (structure) – Erasmus in Glasgow (space programme)
- Tomasz Rybus (Ground Station) – Space Research Centre
This experiment was carried out as a part of the REXUS/BEXUS programme.

The REXUS/BEXUS programme is realised under a bilateral Agency Agreement between the German Aerospace Center (DLR) and the Swedish National Space Board (SNSB). The Swedish share of the payload has been made available to students from other European countries through a collaboration with the European Space Agency (ESA).

EuroLaunch, a cooperation between the Esrange Space Center of the Swedish Space Corporation (SSC) and the Mobile Rocket Base (MORABA) of DLR, is responsible for the campaign management and operations of the launch vehicles. Experts from DLR, SSC and ESA provide technical support to the student teams throughout the project.