REXUS/BEXUS CDRs

EXPERIMENT CRITICAL DESIGN REVIEW

FLIGHT: BEXUS 28
EXPERIMENT: IRISC
LOCATION: ESA/ESTEC Noordwijk, The Netherlands **DATE:** 17 May 2019 15:30

1. REVIEW BOARD MEMBERS

ESA	Alexander Kinnaird	SSC	Maria Snäll
ESA	Rodrigo Avila de Luis	ZARM	Simon Mawn
ESA	Koen Debeule	ZARM	Dieter Bischoff
ESA	Paolo Concari	DLR-MORABA	Katharina Schüttauf
ESA	Giorgio Parzianello	SNSA	Kristine Dannenberg
SSC	Stefan Kramer		

2. EXPERIMENT TEAM MEMBERS

Adam Smialek
Jack Hooper
Harald Magnusson
Sabina Bjork
Jon Mihkkal Inga

3. GENERAL COMMENTS

PRESENTATION

- The presentation was very well received by the panel.

STUDENT EXPERIMENT DOCUMENTATION

- ACTION CDR-01: The team shall use hyperlinks when printing to PDF (e.g. for the Facebook, etc.).
- ACTION CDR-02: The team shall include the PDR report in Appendix A.
- Good lessons learned section, the team is recommended to keep updating it.
- Nice technical drawings / sketches in Chapter 4 (page 100).

4. PANEL COMMENTS AND RECOMMENDATIONS

REQUIREMENTS AND CONSTRAINTS (SED chapter 2)

- ACTION CDR-03: Requirement D.05 is ambiguous, the team shall reformulate it.
- ACTION CDR-04: Requirements P.12.1, P12.2, P.13 and P.14 shall be categorized as design requirements, not performance (unless there is a particular reason, such as they affect the performance of the NIR measurements).

MECHANICS

- ACTION CDR-05: The team shall rethink the support (baseplate) design proposed for the telescope and the electronics box. A frame made out of truss profiles could be a more stiff and lighter solution. Moreover, it will provide more flexibility when attaching the frame to the Gondola structure.
- ACTION CDR-06: The team shall determine the centre of gravity of the telescope, which will allow to better understand the forces acting on the structure supporting it. Based on this information it could be convenient to add counterweights, if necessary, to ensure a smooth operation.

- **ACTION CDR-07**: The team shall discuss and improve, in coordination with Giorgio Parzianello, the design of the bearings supporting the shaft of the telescope.
- **ACTION CDR-08**: The team shall recompute the required torque to be delivered by the motors to move the telescope, including all possible friction forces, specially the static friction when initiating the movement, thermal expansion and contraction which might cause tensions on the system, grease and lubricant properties changing due to cold temperatures, etc.
- **ACTION CDR-09**: The team shall select a motor which can deliver the necessary amount of torque (recomputed value) with considerable margin (2 to 3 times).
- **ACTION CDR-10**: When describing the experiment interface, the team shall clearly indicate in the SED which bolts will be used. It is recommended to use Either standard T-bolts (M6) or shock absorbing rubber bumpers (provided by ZARM).
- **ACTION CDR-11**: The team shall provide more detail on how the structure of the electronics box will be manufactured (made out of bent plates of aluminium, screwed plates, etc.).
- **ACTION CDR-12**: The team shall update the calculations of the new design of the telescope support with respect to expected mechanical loads (torques vs stiffness; vibration damping, identify the Eigen frequencies, etc.).
- **ACTION CDR-13**: The team shall provide attachment points (like eyelets, boreholes, etc.) where safety cables or ropes could be attached, in order to prevent possible falling parts from the Gondola.

ELECTRONICS AND DATA MANAGEMENT (SED chapter 4.2.2, 4.2.3, 4.5, 4.7, 4.9)

- The team is reminded that the flight PCBs shall include a ground plane.
- The team is reminded not to use connectors no. 2, 3, 6 and 7, as shown in the CDR presentation.
- **ACTION CDR-14**: The team shall work on the control as soon as possible given that is a crucial part of the experiment, and very challenging. The team is recommended to follow two different approaches in parallel.
  LINEAR APPROACH:
  - Start investigating and determining all the inputs for your control loop, including the accuracies required, taking into account the movement of the Gondola, the data provided by the IMUs, etc.
  - Afterwards, design the control loop.
  - Afterwards, prove that the control loop works before implementation, by analysis.
  - Afterwards, implement the control loop in the hardware and test it.

  SPIRAL APPROACH: In order to ensure a minimal functionality of the system at an early stage, it is recommended that the team starts trying to implement in the control loop in the hardware from the begining; from very simple scenarios/models to more complex ones.
  - Start with a very simple approach, for example, connect the star tracker to the computer and the telescope, and implement a little algorithm, (maybe not even a feedback a close loop yet) for computing the positions of the Gondola. Do not introduce effects such as the Gondola movement (assume static). Start understanding the outputs of the hardware (start tracker) and processing that information.
  - When the team is confident with this, start implementing a simple control loop method.
  - Afterwards include more complexity such as Gondola rotation, input from IMUs, etc.
  - Keep on increasing the complexity of the system until you reach a fully functional control loop suitable for your experiment.
  - The team shall avoid including Kalman filters and sensor data fusion (complex) until the team is familiar and skilful with simpler control methods.
- **ACTION CDR-15**: The team shall provide more information on the location of the electrical connectors.
- The team shall take into account that two batteries could be allocated to the team if necessary, although this has to be coordinated with SSC.

THERMAL (SED chapter 4.2.4 & 4.6)

- **ACTION CDR-16**: The team shall correct the typo in the value of solar flux on page 43: There is a peak of 500W/m² (not 500kW/m²).
- The team provided good investigations of the environmental conditions.
- The team provided good investigations of the internal heat generated by electronic components (page 44).
- **ACTION CDR-17**: The team shall design a proper thermal cover for the motors to keep operational conditions. Insulation shall be possible, even with a thin self-adhesive insulation tape. A solution only based on a heater is not recommended by experience. Insulation will be required.
- Using heating pads the team could ensure a proper conduction onto critical surfaces/components which need to be heated. The team is recommended to use the following thermal interface pad: https://nl.rs-online.com/web/p/thermal-pads/7805852/
- **ACTION CDR-18**: The team shall avoid electro static charging when implementing the Styrofoam into the electronic box.
- **ACTION CDR-19**: The team shall ensure proper fixation of the components to avoid movement of the Styrofoam.
- The team could consider using PEEK screws to minimize heat transfer by conduction.

- The team is recommended to use a thermostat rather than a PID controller, in case the experiment requires very strict temperature ranges. Otherwise, just passive heating might be the preferred solution.

SOFTWARE (SED chapter 4.8)

- The team included vast amount of information on what the software should be doing but little on how is this going to be implemented.
  ACTION CDR-20: The team shall provide information on how the software will be implemented.
- ACTION CDR-21: The team shall update the GS software in parallel with the on board software because there might be influences in one towards the other.

VERIFICATION AND TESTING (SED chapter 5)

- ACTION CDR-22: The team shall consider verifying requirements by other means rather than only testing.
  - The team could take as a suggestion performing some analysis or review before tests – especially 2a (T) , 2b (P) and 10 (vibration).
  - The team could take as a suggestion performing an analysis before test 7 (mass).
  - The team could take as a suggestion verifying (D.14 & 15) Run time also (mainly) by analysis.
- ACTION CDR-23: The team shall consider verifying the control software not only by simulation but by test (refer to Test 5).
- ACTION CDR-24: The team shall consider if the drop test is strictly necessary (as it might damage the delicate flight hardware). In case it is consider necessary, the team shall carry it in a gentle way. The preparation of the ground will be very important: If the components are dropped on stones they will be definitely destroyed.
- ACTION CDR-25: The team shall validate the pointing system by test.
- ACTION CDR-26: The team shall re categorize Test 12 as a review.
- ACTION CDR-27: The team shall not reference Test (O.3) when the verification method is only "R".
- ACTION CDR-28: The team shall complete with the whole experiment Tests 9, 10, and 11 as much as possible.

SAFETY AND RISK ANALYSIS (SED chapter 3.5)

- ACTION CDR-30: The team shall always write the cause of the risk, for example, explain the reason why the parts might jam when introducing risk TC80.
- ACTION CDR-31: The team shall include a risk regarding structural stiffness.
- ACTION CDR-32: The team shall include a risk regarding schedule delay (work packages falling behind, not being completed on time)
- ACTION CDR-33: The team shall include the risks presented in the CDR review in the SED.
- ACTION CDR-34: The team shall reconsider the probability / severity of risk TC50 related to motors overloaded. More detail and actions to counteract the risk shall be identified.
- ACTION CDR-34: The wording shall be improved (in particular the usage of words such as 'sufficient' or 'properly' which are not used correctly.
- ACTION CDR-34: The team shall re-evaluate risk TC10, as it could be more probable / severe than stated. Further actions shall be taken to counteract this risk (for example, define assembly procedures).
- ACTION CDR-35: The team shall include a risk related to the budget.
- ACTION CDR-36: The team shall reconsider and/or reformulate risk MS80.
- ACTION CDR-37: In general, the team shall make an effort to keep the risk table updated, identify the main ones for your project and enforce actions to mitigate them as the project evolves.

LAUNCH AND OPERATIONS (SED chapter 6)

- ACTION CDR-38: The team shall use the current template of the SED when defining the electrical interfaces, including the number of IP addresses which will be required (at least 2).
- ACTION CDR-39: The team shall further define the actions which will need to be taken on site, like testing the telescope, describing what would be needed, the activities which will be carried out, etc.
- The team is reminded that the launch will most probably take place somewhere around 8am, when there is already a notable amount of light in the sky.
- The team shall ensure that all the RBFs are removed before launch
  ACTION CDR-40: The team shall request a late access opportunity to remove the RBFs in Chapter 6, indicating the time in which this procedure will be executed.
  ACTION CDR-41: The team shall propose a method to ensure all the RBFs have been removed.
- ACTION CDR-42: The team shall request in Chapter 6 the requirement of having 2 batteries.
- ACTION CDR-43: The team shall consider including in their design locking pins for the moving parts, in order not to damage the mechanism and move it accidentally, which might lead to failure.
- ACTION CDR-44: The team shall include parts dropping from the Gondola in the safety risks and include as a mitigation measure the securement of heavy parts with a safety wire.
- ACTION CDR-45: The team shall include more information about the Preparation and Test Activities at Esrange.
- ACTION CDR-46: The team shall include a recovery procedure for the experiment.

- ACTION CDR-47: The team shall consider including covers and protectors available for the used strut profiles to minimize the risk of sharp edges.

ORGANISATION, PROJECT PLANNING & OUTREACH (SED chapters 3.1, 3.2, 3.3 & 3.4)

- ACTION CDR-48: The team shall keep the component list updated, tracking and controlling long lead items in particular.
- ACTION CDR-49: The team shall keep the Gantt chart updated.
- The basic outline schedule presented by the team is good, but suggests the project is running quite behind schedule – particularly in software and mechanical design.
  ACTION CDR-50: The team shall trace the critical path to see if these delays will affect the overall project.
- ACTION CDR-51: The team shall include Jon Mihkkal in the manpower section.
- The team did not include any mapping of resource availability to schedule
  ACTION CDR-52: The team shall at least use a calendar to check when people are away (summer could be a key time). Consequently, the team shall ensure certain tasks are finished before summer.
- The proposed budget seems lower than usual (1/2 average BEXUS experiment), but could be do-able. Moreover, many components and costs are missing.
  ACTION CDR-53: The team shall ensure to include in the budget: spare parts, replacement parts, costs associated with testing, shipping costs, transport/accommodation for additional students during reviews/campaign, outreach costs etc.

- The team is producing very good blog posts.
- The team is managing good Facebook and twitter accounts.
- ACTION CDR-55: The team shall include the URL for the blog in Chapter 3.
- ACTION CDR-56: The team shall update their Facebook "about me" section as the launch date is October 2019 (not 2018).
- ACTION CDR-57: The team shall correct the acronym SNSB substituting it for SNSA.
- ACTION CDR-58: The team shall expand the outreach part of the project at this moment, including plans for the public and school events, and reflect them in appendix B.
- ACTION CDR-59: The team shall take screenshots/print outs of the newspapers online given that they might be only available online for a limited amount of time.

5. INTERNAL PANEL DISCUSSION

Summary of main actions for the experiment team:

- The team shall rethink the support (baseplate) design proposed for the telescope and the electronics box.
- The team shall discuss and improve, in coordination with Giorgio Parzianello, the design of the bearings supporting the shaft of the telescope.
- The team shall recompute the required torque to be delivered by the motors to move the telescope
- The team shall design a proper thermal cover for the motors to keep operational conditions.
- The team shall work on the control loop as soon as possible; given that is a crucial part of the experiment, and very challenging.
- The team shall aim to recruit new members in IT.

PDR RESULT: CONDITIONAL PASS
Next SED version due: 1st July 2019