# BEXUS
## Experiment Critical Design Review

**Flight:** **BEXUS 26**

**Payload Manager:** TBC

**Experiment:** **TUBULAR**

**Location:** ESA, ESTEC, Noordwijk, The Netherlands **Date: 31 May 2018**

**1. Review Board members**

- Michael Becker (DLR)
- Kristine Dannenberg (SNSB)
- Alexander Kinnaird (ESA)
- Veronica Botti (ESA) –Minutes
- Stefan Krämer (SSC) – Chair
- Maria Snäll (SSC)
- Koen DeBeule (ESA)
- Piotr Skrzypek (ESA)
- Grzegorz Izworski (ESA)
- Katharina Schüttauf (DLR MORABA)
- Dieter Bischoff (ZARM)
- Simon Mawn (ZARM)

**2. Experiment Team members**

- Natalie Lawton
- Erik Fagerström
- Pau Molas Roca
- Gustav Dryssen

**3. General Comments**

**Presentation**

- The presentation was very clear and complete and the panel appreciated the approach of the team in analysing and finding a solution to possible issues.

**SED**

- The team may read the SEDs of BX_COSPA or BX_A5UNIBO for more information about similar pumps and experiment principles.
- The team should be consistent with thousand markers (,) and decimal markers (.) (e.g. in the budget).
- The team should keep the appendices as indicated in the SED Guidelines (in particular A for the review reports and B for outreach) but, in general, there are some excellent additional information.
- The document is going to end up very long. This is not a problem, but the team must try to be succinct using diagrams and summary tables where possible and not including unnecessary 'discussion'.
- The team should keep images compressed without reducing the readability.
- The team should describe what the "Brain" is the first time they mention it in the document.

**4. Panel Comments and Recommendations**

**Requirements and constraints** (SED chapter 2)

- Since the team deleted a lot of requirements and the document is getting very big, maybe it would be better to rewrite the updated requirements and put the old ones in the appendix.
- The team should add a note in the introduction and in the objectives to explain the reasons for changing, the type of gas that will be detected during the flight (i.e. from N2O to CO).
- Req. F6-F7: they are software requirements. The team should be aware that it's difficult to justify them in system level functional requirements. If they really want to keep them for verification it's ok,

but in that case it would be better to put them in the design requirements or re-word them and put them in operational requirements..
- Req. F10 to F12: instead of saying “shall collect data”, the team should say “shall measure”.
- There are still some performance requirements missing, such as: amount of air, range accuracy and frequency of the flow rate, pressure measurements, temperature measurements and humidity. These requirements should be separate in different performance requirements.
- Req. D3: The requirement “shall not disturb the launch vehicle” should not be deleted but rather reworded such that is unambiguous and verifiable.
- Req. D4: the team should be more specific and define the type of connector, protocol, etc.
- Req. D5: the team should be more specific and define the type of connector, voltage, ripple, grounding, etc.
- Req. D7: the requirement only makes sense with the reference voltage. The team should add it.
- Deleting the duplicated temperature requirements does make sense, but the team shouldn’t delete those ranges. The team is advised to put them in the verification plan now.
- When stating “profiles of flight” the team should either state the specifics and/or reference the section manual.

**Mechanics** (SED chapter 4.2.1 & 4.4)
- The rack built out of strut profiles is a good choice because of flexibility in fixating the components inside and stiffness properties. The team should consider the attachment to the gondola which does not allow tolerances of the rails and which functions as lot of heat bridges.
- The team should consider how to absorb vibrations/shocks of the pumps? (“Bismat” clamps could be a solution).
- The team should specify how they plan to activate the valves. The team should be aware that they will heat up after a while and that there are valves with a high activation power but a lower holding power.
- The team should specify what kind of tubes and connectors are used and consider how to perform a leakage test, how to access any connection and how to seal any connection (it could be easy just raising the torque a little more, but could be difficult as well in case that an O-ring or sealing has to be changed).
- The team should avoid sharp corners, especially at racks with lower space and fulfilled with equipment (such as the “brain”.).
- Inline pressure sensor from ”FESTO” could be good.
- Mechanical pressure sensors based on pitot tubes may also be an option.
- The team should clarify what is the expected maximum pressure inside the bags and tubes. The team is advised to check the datasheet of the valves regarding leakage rate or perform tests with different pressure on both sides to ensure proper function.
- The team should make sure to define and use the right procedure to clean pumps and valves.

**Electronics and data management** (SED chapter 4.2.2, 4.2.3, 4.5, 4.7, 4.9)
- The team should consider the connector location carefully. It is very good to have easy access but it’s not good to have the cables/connector pointing out of the gondola, because the turn may protrude outside and increase the risk of damage during launch/landing. This issue can be discussed with payload manager during accommodation session.
- In general, the accessibility of the connector panel is pretty good but without any protection. The team should move this panel upwards to the top cover (access from above).

**Thermal** (SED chapter 4.2.4 & 4.6)
- Regarding the EPS extruded Styrofoam, the team should ensure that this material is suitable for low pressure environment. Many foams expand when the pressure decreases but do not restore completely when back in normal pressure which would cause open gaps of the insulation cover.
- From a thermal point of view the team is suggested to install big heat bridges with this attachment. It would be better to use a flat material or another strut profile fixated with thermal spacers and attached to the gondola with the help of rubber bumpers.
- The team should investigate any hot spots of the setup and try to spread the heat with heat sinks to serve better conditions for the surrounding components.
- In general, there are too many heat bridges in the experiment setup.
- To raise the conditions at the beginning the team could insert chemical heater(s) like hand warmers during late access.
- The team could colour the strut profiles with black paint to count on the effect by heating up by the sun while the setup faces into it.

- The team should be aware that the expected lowest temperature on a BEXUS launch in October (day flight) is around -55°C.
- The team should specify how will the implementation of the insulation material looks.
- An internal temperature around +5°C is low. The team should consider that the performance decreases at lower temperatures.

**Software** (SED chapter 4.8)
- The team is suggested to implement hysteresis for automatic mode change and to filter the sensors.
- Regarding the process diagram in figure 44, there is no way out from the manual mode. The team should specify what are they planning to do if the connection to the ground station is lost.
- The team should clarify if/how they are planning to keep track of the time.
- A list of telecommands and supported telemetries is missing. The team should not forget to insert a command to query the storage status, general system status, update automatic timeline, update time and perhaps reinitialise/clean up the storage.
- The team should specify which is the file system used on the SD card. FAT is not recommended.
- The team should clarify the concept of mode switching based on the pressure sensors.
- It's a good choice to use three tasks for Arduino but in the Software design section the identification of these three tasks is missing. The team should add it.

**Verification and testing** (SED chapter 5)
- Only positive software testing is currently foreseen. The team should explore failure scenarios: resets of the microcontroller (during auto mode), loss of communication at inconvenient times, multiple loss of communication, loss of SD card (unplug, broken filesystem, etc.).
- Req. P12 to P14: the requirement should be verified by Review of Design and not by Inspection (you review a data sheet you inspect a model/build).
- The team should be careful that where items are already verified by analysis, the analysis remains valid if/when the design changes/evolves.
- The team should state within the test plan whether the testing item is flight, prototype or another kind of model; they should also state within the test plan which requirements will be verified and then write the plan to make sure it will clearly verify those requirements.
- The team should insert all these tests in the Gantt Chart and have a global test plan which would lays them out logically.
- The team should consider what happens if a test fails and a change is needed and understand how far to come back in the test plan.
- Doing a vibration test on a shaker is good learning experience for the team, but the team should pay attention to which spectrum(s) are applied to the experiment, as there are none specified for BEXUS.
- There is no need to remove the walls during the test. The team should engage a good test engineer to understand the process.
- The team should include a summary of one or two paragraphs (maybe with figure where relevant) for each test, and then make a separate complete report in the appendix.
- The team should specify for which reasons there are no concerns about bag burst.

**Safety and risk analysis** (SED chapter 3.5)
- Risk TC40: the severity is too low.
- The team, in general, should avoid the word "proper" when defining an action to mitigate any risks.
- EN10: the team should better clarify which is the risk and which is the foreseen action. "Vibration" does not mean anything.
- The team should consider some management risks, in particular regarding time availability.
- The team should also consider some operational risks.
- The team should check again the severity of some risks. In general, it is too high.
- In general there are many risk with the same code (same probability and severity) that are considered sometimes acceptable and sometimes unacceptable and an action is always foreseen. This is confusing. The team should clarify what is an acceptable risk for them and what is unacceptable and, based on that, they should think of an action or accept the risk.

**Launch and operations** (SED chapter 6)
- The team should add any safety risks associated with pressurised vessels during recovery.
- It is very good that there is already a checklist. The team should check it with SSC to confirm it is all possible before flight after the final ECTs.
- The team should use this checklist during the systems tests and update them, including photos, and making sure that the person doing the final version is the person who did it before.

- The team should add any launch site requirements, such as a room, a laboratory for preparations or testing on ground.
- The team should add risk connected to the use of chemicals.
- The team should think of what could happen in case of hard landing and exposed gas or liquid.
- The team should insert in the launch and operation chapter (or link to the appendix) the cleaning procedure of the pump and valves.
- The team should use the checklist during the tests.
- The team should be aware that from T -3h to T- 1h the experiment will work on external power.

**Organisation, project planning & outreach** (SED chapters 3.1, 3.2, 3.3 & 3.4)

- In the Resources section, under Table 6, it is written that all the team members are currently enrolled in LTU master programmes. However, according to the team details, most of the students are bachelor students. The team should clarify.
- The team should be aware that, during the last months they will need to allocate more resources to the experiment.
- In the outreach section is written "a website WILL be launched…". If it has already been done the verb should be at the past, not at the future.
- The team should clarify who is responsible once the subsystems are assembled (i.e. system level AIT and launch/operations).
- The team should try to trace the critical path to know where to focus their efforts.
- The team should better clarify if the exam period is really blocked out.
- It is very good to have some internal deadlines.
- It seems that there is a very little margin at the moment (testing completed at the start of October); the team should not forget to plan some buffer time and, in case of late testing, the team should think about the associated risks and how to mitigate them (e.g. good analysis).
- The team should relate their resource availability to the Gantt chart and clarify how the impact of any delays on the project planning.
- Regarding the budget, the team should specify if they have considered any contingency for unexpected events.
- It would be great to have a dedicated outreach timeline/media plan to see when these events are happening; they could be used to punctuate the project (a nice break or celebration for you) and/or to build excitement around certain events.
- The team should add a picture of the experiment on the website.
- In the "Project" Section, in the website, the first word is "Problem". The team should change it with something like "objective", or something similar.
- The team should add a headline in the website to capture the attention of the reader. Something like "we launch an experiment to the edge of space…." could be a good starting point.
- The team should look again at the relative logo sizing (SNSA is too small) in the website.
- The website loads very slowly, especially large header photos. The team should consider optimising this and check its compatibility for mobile devices.
- In the Facebook page the team should expand the "about" section to include mention of the REXUS/BEXUS programme.

**5. Internal Panel Discussion**

- **Summary of main actions for the experiment team**
  - Update the mechanical design as per the recommendations.
  - Make the design decision regarding inlet pressure and humidity measurement (contact their mentor for further advice).
- CDR Result: **Pass**
- Next SED version due: **SED_v3-0**, due **3 weeks before IPR. Date TBD**