CNES PARABOLE 2018 CAMPAIGN, WSS TEAM (Supméca, KTH)

This document bears the purpose to explore the construction, funding and results of the experiment designed by the WSS (Water Space Suit) team from KTH and Supméca, for the CNES' (French space agency) "Parabole 2018" competition which brings students towards opportunities to try out physical constraints of (zero) gravity on student-proposed experiments directly on an airplane owned by NOVESPACE. The call for application was sent by the end of October 2017 and selected teams were revealed in January 2018. The three selected teams then set sails on the first week of October 2018 as two to three students per team operated their experiment on board the A310-ZeroG airplane for one flight each, also seen as thirty 22-second parabolas.

THE EXPERIMENTAL PURPOSE

In an attempt to shift the paradigm on hygiene in space, the WWS team aims to design a suit in which one would be able to shower in micro-gravity conditions instead of using the wet towels and dry shampoo used on the ISS nowadays. The team believes that with perfected engineering and problem definition it would be possible to create a technical solution that is easy to use, fast, with little maintenance, highly comfortable, with little-to-no resource utilization (recycling), meaning that it would be mass-competitive after a certain time spent in space compared to stored wet towels. The change in paradigm that the team is trying to induce is that on longer space travels (to Mars for example), the well-being of astronauts will be challenged every day, on a physical and psychological level. Therefore, if everyday tasks can help reduce stress that is something to consider. The current hygiene operations are rather minimalistic, with *bearable* comfort but not *enhanced* comfort. The team hopes to prove that the suit can change this while being as little time-consuming and at least as little resource-consuming as the wet towels. But first, the physical principles of the suit have to be proven, hence this experimental study.

THE EXPERIMENT

Due to constraints related to experiment deployment inside the airplane, no suit could be worn by a team member and limited water supplies were to be brought and safely contained in the experimental area (glove box). Therefore, the team went for a sample experiment consisting of a skin simulant (white leather oiled up with hydrating beauty cream – this combination giving the best water-retention/repulsion attributes when compared to actual skin behavior), a suit simulant with required transparency (either hydrophilic or hydrophobic polymer, transparent to enable see-through measurements with cameras), a water containment set as test area (taken from a household water filter-holder, later customized to fit our needs), a water circulation system (water pumps), a robust water circuit with pressure sensors, gas-exchange outlets that allow air flows in and out of the system (for pressure balance and test area filling/emptying operations when changing the test sample), high-speed cameras, and a few possible test sample configurations (different water constitution overtime and change from hydrophilic to hydrophobic suit material). Water was mixed with soap ('Savon de Marseille', natural soap with minimum ingredients).

To understand the cleaning capacity of the system, a particle visualization as well as a material deposition method were introduced. The skin sample would be covered in a mixture of fully infused tea particles (<1mm, with no further possible infusion in water) and hydrating beauty

cream, similar to the one used to oil-up the leather skin simulant. The mixture forms a rather strong layer of material which, even if not comparable to any normal skin pollution (sweat, dead skin, etc), gives a taste of particle and grease collection when subjected to a shear flow of water. One would expect that if such a layer can be taken down and dissolved in just a few seconds or minutes, normal skin pollution should not be a problem.
The particle visualization is made possible by the tea particles which, once taken out from the hydrating cream by the water flow, move with the flow until they exit the test area where they are finally collected via a filter. The residual material deposition is assessed post experiment: the used skin sample is covered in cacao (commercial alimentary use) directly after extraction from the test area, during flight. The cacao is able to stick to the remaining oily parts of the skin and color even the leather once the sample is finally fully cleaned on ground after flight. The color patches on the leather can then be compared and liked to the video recordings of each sample.

EXPECTATIONS
With six sets of five parabolas and a five-minute 'break' in between two sets, the team expected to test six skin samples with varying outside conditions. The varying conditions were the suit's hydro-philia/-phobia and the increasingly oily water. Since the water is not cleaned in between tests, the oil from the hydrating beauty cream remains in the water and the oily content increases over time. This has supposedly an effect on the physical properties of the fluid and on the cleaning efficiency. The skin and suit samples were supposed to be modified during each break. This operation requires emptying and filling of the test area and opening of the glove box. Cameras would record the entire flight and pressure sensors would tell us about the internal pressure differentials. The water circulation was first induced only during micro-gravity periods and then continuously over a set of parabolas.

RESULTS AND CONCLUSIONS
First, the sensors which had correctly been tested and calibrated on ground the last three days before flight did not give out any coherent signal during flight. Therefore, this part of the experiment was lost right away.
Second, a hole in the water injection tube of the test area resulted in a significantly decreased jet flow during the first parabola. This was fixed in between parabolas 1 and 3, meaning that parabola 2 was lost. The jets performed as planned afterwards.
Third, the time scale is extremely challenging during flight and periods of time seem to last much less due to the difficult environment. This meant that some operations had to be rushed which imposed extra stress on the team. Nothing unbearable, fortunately.
Finally, the pump once had difficulties to start the flow which resulted in an additional emptying/filling operation, reducing the flow quality during 5 more parabolas. Overall, 25 parabolas out of 30 were executed with sufficient quality to gather results, and one set was doubled to be sure of its quality, leaving truly only 20 parabolas of 'distinct' data.

The first notable result is that the samples got cleaner over time, meaning that the system was operational. A review of the video footage revealed that both micro-gravity and normal gravity conditions were responsible for the cleaning. However, most of the cleaning was performed in normal gravity conditions, showcasing a lack of efficiency of the system in micro-gravity. This was not clear during flight and the team then believed that microgravity periods were the best at cleaning (most probably because we were really only the most attentive

during these periods and not during normal gravity periods…). Therefore, before reviewing the footage the team hypothesized that pockets of air inside the test area allowed water jets to spray further away on the skin sample, without having to battle against water, meaning that they would carry most of their momentum until the end of the test area. In reality, air pockets were sticking to the skin more than to the suit, dividing the test area into two volumes: air next to the skin, water next to the suit. With such a disposition, no consistent water flow could be sustained on the skin and less cleaning was performed. This was seen for both hydrophilic and hydrophobic suits, but the hydrophobic behavior was not that extreme ('hyper hydrophobic') and only barely above the hydrophobic/hydrophilic limit…
Careful, however, to take into account the relative duration of each phase: micro-gravity = 22s and normal/hyper gravity = 2min30s. Still, the problem was visible when putting it into this perspective.

The second result is based on residual matter on the skin. By comparing the color patches after flight, no major difference was found between tests with increasing oil content inside the water. This means that the samples got cleaned the same amount regardless of the already collected greasy skin contents. This could hypothetically forecast a constant cleaning rate throughout a cleaning session in a real-life scenario (but of course, water would be continuously cleaned up in that case).

Finally, the water flow could be improved. It would be difficult to imagine cleaning someone fully under 10 to 15 minutes with this method, which is still pretty slow afterall. It would be too difficult to make sure that no air pocket is ever between the skin and the suit, meaning that air pockets should be part of the technical solution anyway. In addition, higher pressure jets should be introduced, with better aiming towards the skin. These are the conclusions to this experimental study.

USE OF KTH FUNDING

Funding of the project was shared between KTH and SUPMECA Paris, with an initial distribution of 10 000 SEK for KTH (roughly 1000 euros) and 500 euros for Supméca. Later on, the funding from Supméca was also brought to 1000 euros. In total, 2240.91 euros were spent on this project. 995.98 euros were spent on KTH, while 1002.51 euros were spent on Supméca, for a total in sponsorship of 1998.49 euros. The remaining 242.42 euros were being taken care of by the team leader's savings. Below is the detail of the use of KTH's funding, mainly consisting of parts constituting the final experiment, while Supméca's funding was spent mostly on research steps during the project development. Invoices and evidence of purchases can be found at the end of this document.

(Prices in euros)
Amazon
29.46 – *(Electronic valves)*
57.92 – *(Threaded metal connections for valves and pumps)*
36.99 – *(Peristatic pump)*
216.38 – *(Electronic valves, LED band, Arduino mega)*
7.29 – *(Plastic tubing)*
(347.94)

DiproClean
174.41 – *(Most of the connectors for the tubing circuit)*
13.00 – *(Tubing derivations T and Y)*
(208.91)

RS
73.33 – *(Power adapters for valves, pumps, pressure sensors)*
279.03 – *(Aluminium beams and structural elements for experiment mount)*
(352.36)

John Steel Pro
70.50 – *(Aluminium plate cutting for experiment mount)*
(70.50)

Easy Composites
33.59 pounds (37.77 euros at purchase) – *(Microfiber cloth for humidity control)*

Total = 995.98 euros

IDEAS FOR FUTURE DEVELOPMENT

In addition to the improvements set as conclusion of the experiment, power consumption and duration of operations before and after cleaning are the main design concerns. Based on previous research papers and technologies tested in micro-gravity, a shower technology would never be an alternative to current solutions if these two points are not reduced to a minimum.

The overall design has been challenged a few times since the flight, based on the feedback received from supervisors and friends. A solution seems to have been found, which would fit under a 5+15+5 minutes bill of operations, with power consumption still to be assessed. Further development is scheduled by the team leader (Sébastien Ruhlmann) during 2019 with a plan to patent this technical solution.

PORTFOLIO

Links to Google Photo albums of the components and assemblies:
https://photos.app.goo.gl/QgMgk8mwHY6ysXvv6

https://photos.app.goo.gl/rReFnhuKzaWzRQQi8