Sloshing Rocket Workshop 2019 - 2020

Competition Rules

WITH SUPPORT FROM

1. INTRODUCTION

1.1 BACKGROUND

Modelling the behaviour of sloshing liquids is of significant interest in various fields of the aerospace industry.

In aircraft design, the study of fuel movement in tanks is of paramount importance for the design of the fuel management control system, the evaluation of the handling characteristics of the aircraft and ultimately the assessment of the structural integrity of the containment structure [1].

For modern satellites, the design is often driven towards lightweight structures, high pointing accuracy and long life expectations. These can result in a large proportion of the overall weight being allocated to the liquid propellant. Therefore the movement of the liquid fuel within its containers can significantly affect the dynamics of these systems, during in-orbit controlled manoeuvers and atmospheric gust encounters in the launch phase [1].

1.2 AIRBUS SLOSHING ROCKET WORKSHOP

The Airbus Sloshing Rocket Workshop 2020 is a competition in which teams are tasked to design, build and fly a low cost reusable rocket which is destabilised by the movement of water stored within an unpressurised tank. The rocket design shall incorporate mechanisms to manage the dynamic forces introduced by the sloshing water to maximise its range, time of flight and liquid payload capacity. The controlling mechanism can be made of passive and/or active means and its performance is a key aspect of the design.

This challenge is designed to simulate the conditions experienced by real world aerospace vehicles containing liquid propellant.

The competition will be formed of three phases:

1. **Online Phase - Rocket Design**
   The objective of round 1 is to design the rocket and stabilisation system. The description and justifications for the design are to be presented in the format of a design report and supported by calculations, simulations and/or results from prototype testing.

2. **Physical Phase - Rocket Workshop and Mission**
   The 5 highest scoring teams from the first round will be invited to attend a weeklong workshop at the University of Patras. Teams will be tasked with building their designs to compete in a demonstration at the end of the week. This will involve using provided data loggers to collect data from the launches.

3. **Data Analytics Phase**
   After the event, there will be a two week period where teams will analyse and present their data. The data can be presented either by a video of a powerpoint presentation, or in a two page report.

The second phase will take place during late July. More details will be given at a later stage.

2. TECHNICAL REQUIREMENTS

The rocket design must conform to the requirements outlined in this document.

2.1 PHYSICAL

The rocket's total dimensions shall not exceed the following:

- Maximum length = 1.5m
- Maximum wingspan = 2.25m

The primary structure of the vehicle shall be formed of readily available items, such as plastic bottles, forming two or more water tanks:

- **1 unpressurised tank** containing a minimum of 500ml of water. The tank must contain 50% water and 50% air to generate sloshing loads. The fill level at 50% volume must be clearly marked to facilitate easy visualisation for the judges.

- **1 or more pressurised tanks** containing water for propulsion. The total mass of the propellant must be no greater than the mass of the sloshing liquid**.**

The total rocket weight at take-off shall not exceed 5kg when filled with liquid.

The arrangement of the tanks does not have to conform to a traditional rocket shape. Teams are encouraged to consider a range of aircraft concepts and evaluate their potential benefits and drawbacks.

2.2 MISSION

The success of the mission shall be assessed based on the following criteria:

- **Distance travelled** – measured from the start point for the first flight and landing point from the previous flight for subsequent flights. A greater distance travelled by the vehicle will be awarded more points. Points will be deducted for landing outside of the designated flying area. Details of the flying area will be provided at a later date.

- **Time of flight** – measured from the point of take-off. Maintaining a sustained, controlled descent will be awarded with extra points.

- **Sloshing mass carried** – measured at the end of a mission. An efficient design will be able to carry a large payload for a given take-off mass. Loss of all payload during a flight will result in scoring zero for that flight.

- **Turnaround time** – teams will be given 5 minutes to set up and launch their rocket from getting to the position where the vehicle lands to launching again (this is to simulate the fast turnaround times of civil aircraft; any delays result in severe points penalties).

2.3 LAUNCH MECHANISM

The rocket must be launched vertically at a pressure less than 10 atmospheres [or 147psi].

The rocket design shall incorporate a means of pressurising the propulsion tanks with air via a standard bike pump Schrader valve connector.

Only air is permitted as an inflation gas and no propellant other than water is permitted. This forbids the use of propellers, propulsive gas, engines and lighter than air gases such as helium.

Jettison of any part of the vehicle during flight other than the propellant is forbidden.

The ratio of air-to-water inside the propulsion tank or tanks (not the payload tank) is customisable and should be exploited to optimise the performance of the vehicle.

A premature launch or failure to launch the rocket altogether will be counted as one of the three mission flights. Designs incorporating a reliable propellant discharge mechanism are therefore more likely to score highly.

2.4 CONTROL MECHANISM

The design shall incorporate a means of controlling the descent of the rocket to counteract the destabilising motion of the sloshing liquid. Details of how the sloshing liquid behaviour has been predicted and justification for the embodied solution shall be provided as part of the design submission. This could be achieved by using passive or active means or a combination of both:

- **Passive Control** – e.g. baffles Any baffles inside the tank cannot cover more than 50% of the cross sectional area of the tank. The use of parachutes is not permitted.

- **Active Control** – e.g. control surfaces
  An active control kit will be available to teams (upon request) including:
  ○ an Arduino, ○ 3 servos and ○ an altimeter Additional sensors and servos can be added to suit the specific needs of the design. The design of the controller and the configuration of hardware used shall be finalised during the design phase, leaving the tuning of the controller gains to the workshop phase.

2.5 MANUFACTURE

The vehicle shall be designed to be manufactured during the workshop taking into account the time constraints and available facilities and resources in Terrassa.

Further details on manufacturing will be noticed to the teams during the design phase.

Teams are advised to confirm with EUROAVIA prior to submission of their design reports that their proposed method of manufacture is feasible.

2.6 MATERIALS & COTS ITEMS

The rocket design shall not rely on COTS (Commercial off-the-shelf) items costing in excess of €300.

A bill of materials and cost breakdown is required as part of the design submission. Cost efficient solutions will be awarded more points.

A list of all items to be bought in for the workshop must be provided including part name, part number, supplier, quantity, cost (including post and packaging) and a URL link (if available). This is expected to also include some reasonable provision for spares.

The total cost of the rocket must not exceed €500.

2.7 SAFETY

The design shall employ the use of appropriate materials and components to ensure safety of the competition.

Batteries used in the rocket shall contain bright colours to facilitate their location in the event of a crash. If a battery combination is deemed high risk in the opinion of the judges it may be disqualified.

Any electronics shall be protected or isolated from water to minimise the risk of electric shocks.

The data loggers are sensitive to water; they are to be housed in waterproofed containers or have similar measures in place. More data will follow on dimensions.

3. COMPETITION MARKING

The overall competition winner will be decided based on the following formula:

***Overall Score** [400]* = ***Design Report** [100]* + ***Mission** [300]*

3.1 ROUND 1 - DESIGN REPORT

The design report shall be limited to no more than 20 pages and shall include the following content which will be marked according to the assigned weightings:

- **Introduction** [5%]
  - Background information on the challenge of sloshing liquid propellants in the aerospace industry.
  - Overview of the design approach taken.
  - Team organisation.
- **Requirements Capture** [5%]
  - Using a table format, define the requirements for the design.
  - Mandatory and optional requirements shall be clearly identified.
- **Concept Design** [15%]
  - Descriptions of several design concepts including explanations of how each concept is derived from the design requirements.
  - Justification for concept selection, supported by explanations of how the mandatory requirements will be met by the chosen concept.
  - Concept selection may include basic sizing and performance calculations.

- **Detailed Design** [40%]
    - Explanation of how the sloshing behaviour has been predicted and how the control mechanism has been designed to tackle the dynamic loads introduced.
    - Finalised vehicle geometry, possible generated from a 3D CAD model
    - An accompanying analysis which may include design trade studies and optimisations to maximise mission performance.
    - Detailed description of manufacture including: Bill of Materials, component manufacture, assembly sequence and a cost breakdown.
    - Explanations of how safety and operability have been considered in the design of the vehicle.

- **Design V&V** [20%]
    - An assessment of the final design against the requirements showing how all the mandatory requirements have been met.
    - A test plan showing the means by which compliance with each requirement has been demonstrated by prototype testing or will be demonstrated during flight testing at the workshop.

- **Conclusion** [5%]
    - Conclusion summarising design outcomes, reflecting on initial objectives

- **General Report Quality** [10%]

3.2 ROUND 2 - MISSION

Each mission flight will be scored based on the follow formula:

$$\text{Flight Score} = \frac{\text{Final Payload Mass [kg]}}{\text{TOW [kg]}} \times (\text{Distance Travelled [m]} + \text{Time of Flight [s]}) - \text{Penalties}$$

The maximum score for each flight is capped at **100 points**, giving a maximum possible score of 300 points.

In the event that the flight scores across every team are less than 70 points a calibration factor will be applied to ensure fair weighting between the mission and report scores:

$$\text{Calibrated Flight Score} = \frac{100}{\text{Maximum Flight Score across all teams}} \times \text{Flight Score}$$

Teams will be allowed to refuel in between flights. The penalty for a late launch will be **-20 points**. Failure to launch after 10 minutes will lead to disqualification from that flight.

The rocket will be required to stay within the defined flying area. Any distance travelled out of this area will not contribute to the flight score. There will also be a penalty of **-20 points** for landing outside of the designated flying area.

3.3 ROUND 3 - Data Analysis

More details to follow.

4. BIBLIOGRAPHY

[1] F. Gambioli und A. G. Malan, „Fuel Load in Large Civil Airplanes,“ in *International Forum on Aeroelasticity and Structural Dynamics*, Como - Italy, 2017.