Progress of the Development of a Two-Stage Supersonic Rocket within a Student's Association

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Abstract
The Ares mission is part of a student-led project with the aim of developing a two-stage supersonic amateur rocket. This paper discusses the progress since its foundation in 2016 and how it is planned to continue progressing to achieve this objective.

Currently, 4 rockets have been built and launched, evolving different aspects of the design and construction process in each one. From the Ares I, a two-stage rocket intended to test the electronics and the structure, the mission has evolved into designing the Phobos, a rocket whose aim is to compete in European Rocketry Challenges for universities. The final objective of the Ares Mission is to launch a two-stage supersonic rocket, the Ares III.

Keywords
Rocket, two-stage, supersonic, composite materials, 3D printing

Acronyms/Abbreviations

SSEA	*Symposium on Space Educational Activities*
UPCSP	*UPC Space Program*
ESEIAAT	*Escola Superior d'Enginyeries Industrial, Audiovisual i Aeroespacial de Terrassa*
EuRoC	*European Rocketry Challenge*

1. Introduction

The UPCSP project is part of the Euroavia Terrassa student Association, forming the most technical part of the set of activities that are developed within the aerospace field. The UPCSP project is a program fully formed by more than 80 students whose objective is to apply the knowledge acquired during the degrees of Industrial, Electronics, Mechanical and Aeronautical Engineering at Missions related to the aerospace field. Within the Program, 5 branches of missions are developed: stratospheric balloons, drones, robotics nanosatellites and rockets.

The Ares mission aims to design, manufacture and launch rockets inside the UPC Space Program. Since its beginning in 2016, the rocketry team has achieved four successful launches and aims to keep up and increase the pace in the coming years.

From the Ares I, a two-stage rocket intended to test the electronics and the structure, the mission has evolved into designing the Phobos, a rocket whose aim is to compete in European Rocketry Challenges for universities.

Figure 1. UPCSP (left) and Ares (right) logos

2. Ares I

The Ares I was the first rocket to be designed and launched. This two-stage rocket is intended to test the newly developed electronics and to test a simple structure with a low power launch that is capable of stage separation.

Figure 2. The first Ares members alongside the Ares I rocket

The rocket was launched on 18th November 2017, in Alcolea de Cinca, Spain. It reached a maximum altitude of 150 m. The team was able to recover the two rocket stages thanks to two deployable parachutes. This same system has been used to recover all the subsequent rockets.

The avionics system successfully registered and stored the flight data, thus validating the electronics in the rough environment of a rocket launch.

3. Deimos I

Afterwards, the Deimos I was built using a more advanced construction technique involving composite materials. The rocket presents high structural capabilities as it was designed following the traditional means of amateur rocketry provided by the Spanish amateur rocketry association. The aim of this launch was to test a more robust composite rocket structure to incorporate in bigger rockets.

The rocket was made using a cardboard tube as a work base for the structure. The cardboard tube was covered with two layers of fiberglass and epoxy resin. The epoxy excess was removed with a vacuum chamber, while the fiberglass was being cured. The fiberglass roughness was reduced by applying a layer of putty and polished by hand.

Meanwhile, the ogive geometry was extracted through the Open Rocket Software [1] and built by 3D printing. The 3D printing inconsistencies were also polished manually.

The Deimos I was launched with a G-class solid rocket motor.

Figure 3. Ares members and Deimos I rocket after its second launch (September 7th, 2019)

In its first flight on the 13th of April 2019, the Deimos I recorded the launch thanks to a camera that the team placed in the small window that can be observed in the rocket (Figure 3). During this flight, the rocket registered a maximum altitude of 150 m.

As a result of its highly resistant structure, the Deimos I could be subsequently launched on the 7th of September 2019. The video of this flight could not be recovered due to issues during landing that damaged the camera.

In both flights, the electronics successfully registered flight data such as the altitude reached.

4. Ares II

The Ares II, being a two-stage rocket, incorporated several new features on top of the experience of its predecessors. In terms of design and construction, additive manufacturing polymers were introduced to the rocket structure, which led to more complex geometries in the insides of the rocket without sacrificing structural integrity. Moreover, the electronics evolved to a new board with more capabilities improving in its size and design.

The Ares II rocket was launched on the 7th of September 2019 to test the newly incorporated characteristics on top of verifying the integration with the already proven ones.

Unlike Ares I, the new design was built using additive manufacturing and composite materials. The structure of the fuselage was printed in nylon PA12 [2] and, in order to add structural integrity, covered with a layer of fiberglass and epoxy.

Figure 4a and 4b. The Ares rocket leaving the launch rail (September 7th, 2019). Successful ignition of the second stage of the Ares II (September 7th, 2019)

5. Deimos II

Furthermore, the last rocket to be built is the Deimos II, whose main objective is to allow the association to be certified in the use of level 1 engines (see Table 1).

It is designed to have the same structural design as the Deimos I while having the capability to use more powerful engines. Moreover, to have a smoother surface finish, the team implemented new manufacturing techniques, such as the use of a vacuum bag to ensure proper layer cohesion, and the use of a lathe to avoid epoxy dripping on one side.

The Deimos II is expected to be launched in May 2022.

Figure 5. Deimos II rocket

Table 1. Solid motors classes and their requirements to be bought and launched. Tripoli Rocketry Association. [3] [4]

Class	Impulse (N·s)	Requirements
Micro	0–0,3125	No certification required for motors with less than 125g of propeller
1/4 A	0.3126–0.625	
1/2 A	0,626-1,25	
A	1,26-2,50	
B	2.51–5.00	
C	5.01-10.0	
D	10.01–20.0	
mi	20.01–40.0	
F	40.01–80.0	
G	80.01–160	
H	160.01–320	Level 1 certification required
I	320.01–640	
J	640,01–1,280	Level 2 certification required
K	1.280,01–2.560	
L	2.560,01–5.120	
M	5.120,01–10.240	Level 3 certification required
N	10,240–20,480	

6. Phobos

Finally, the mission has been designing the Phobos rocket. Its main objective is to participate in the EuRoC [5]. The Phobos is a single-stage rocket that, following the success of the Ares II structure, incorporates an optimized polymer structure paired with a fiberglass composite skin. It also features improved avionics capable of live data transmission as well as a more reliable recovery system.

Structurally, the main improvement is that the 3D printed fuselage is mass-optimized through generative design (see Figure 6).

The Phobos rocket is capable of deploying up to 5 CanSat-size experiments at a maximum altitude of 3000 m. This high altitude is reached with a class M solid rocket motor.

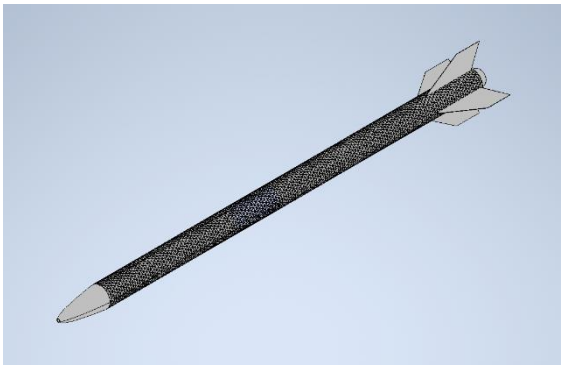

Figure 6. Optimized lattice structure for the Phobos rocket through Autodesk Inventor [6]

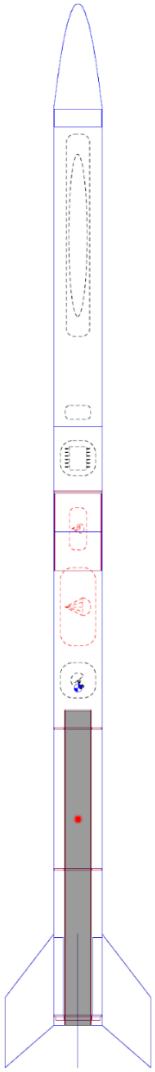

Figure 7. Phobos general configuration through Open Rocket design

7. Ares III

The Ares III rocket, which features a two-stage system, is in an early design phase pending the launch of the Phobos rocket to incorporate the tested structure. The Ares III aims to be the last rocket of the mission as it has been designed to reach supersonic speeds in a similar two-stage design as the Ares II.

This last proposed rocket marks, as we like to say between the student members of the UPCSP, the end of the beginning of the Ares mission, and after it, always aiming higher and beyond our possibilities. Thus, consolidating all our projects and becoming known among the rocketry associations nationwide and at an international level.

Figure 8. Generative design on the Ares III's motor section structure

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