GRAND CHALLENGE

Project Description

Author(s) and Contact:
Nikolaos Kalliatakis – nikolaos.kalliatakis@dlr.de
Nabih Naeem – nabih.naeem@dlr.de
Nazlican Cigal – nazlican.cigal@dlr.de

Grant Agreement number: 101097120
Project acronym: COLOSSUS
Project title: Collaborative System of Systems Exploration of Aviation Products, Services and Business Models
Start date of the project: 01/02/2025
Duration: 36 months

Project coordinator name & organisation:
Prajwal Shiva Prakasha
DLR - German Aerospace Center Institute of System Architectures in Aeronautics | Aviation System Design and Assessment
Tel: +49 40 2489641-322
E-mail: prajwal.prakasha@dlr.de

Project website address: https://colossus-sos-project.eu/

FUNDED BY THE EUROPEAN UNION UNDER GRANT AGREEMENT NO 101097120. VIEWS AND OPINIONS EXPRESSED ARE HOWEVER THOSE OF THE AUTHOR(S) ONLY AND DO NOT NECESSARILY REFLECT THOSE OF THE EUROPEAN UNION OR CINEA. NEITHER THE EUROPEAN UNION NOR THE GRANTING AUTHORITY CAN BE HELD RESPONSIBLE FOR THEM.

Funded by the European Union

SYSTEM OF SYSTEMS XPLORATION GRAND CHALLENGE AWAITS, READY TO GET HANDS ON?

Duration: March – August 2025

Wildfire growth over the past few years is reaching unprecedented and uncontrollable levels. Within 2023 alone, wildfires in Europe contributed to as much burnt area as twice that of Luxembourg [1] and it is predicted that by 2050, the frequency of significant heatwaves and wildfires are to grow up to +500% [2]. With the costs of these fires surmounting, European, American, Australian and other nations across the World are striving to develop solutions to combat the expanding wildfire concern. As a group of researchers, your task is to design new aircraft that can aid in the future of wildfire fighting whilst innovating on novel solutions that can be used alongside your aircraft. Develop creative solutions in a set of scenarios, representing an open-ended problem where there is no "one size fits all" and multiple, disparate solutions are possible!

Curate your firefighting fleet; from detection to suppression, teams will be given the chance to design the System of Systems (SoS) from the ground up. Fleet composition, suppression tactics, aircraft specific operations and more are all modifiable! Put your engineering skills and ingenuity to the test with the SoS Xploration Grand Challenge. Enhance the COLOSSUS SoS in a set of 3 scenarios, ranging from an island in Greece, to the French Alps and Californian countryside. Explore, test and validate aerial wildfire fighting aircraft concepts with a provided toolkit (Figure 1) where each scenario is defined and simulated.

Figure 1 Toolkit wildfire simulation of Los Angeles

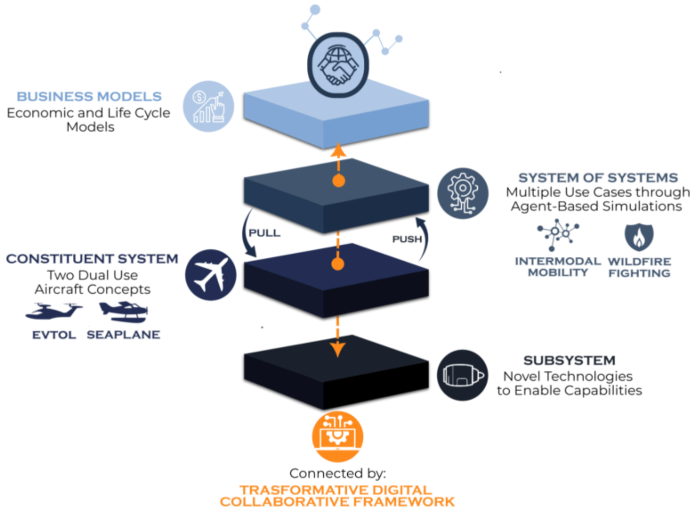


Figure 2 COLOSSUS lower-to-higher level framework connection [3]

Teams must be composed of a maximum 10 points, following the given point system:

- Bachelor students = 1 point
- Master students = 2 points
- PhD students = 3 points

Once a team is composed, go to https://colossus-sos-project.eu/xchallenge/ to finalize project participation. Team participation is handled per university basis.

COLOSSUS
COLLABORATIVE SYSTEM OF SYSTEMS

Grand Challenge Tasks

1- Conduct a preliminary design of one or more aircraft (airplane, rotorcraft, lighter-than-air vehicle or any other potential flying architecture) based on a set of constraints*:

- ✓ Maximum takeoff mass ≤ 25’000 kg
- ✓ Maximum payload mass ≤ 10’000 kg
- ✓ Targeted entry into service of 2035 (technology level up to 2035)

* The constraints are guidelines; design freedom is encouraged so long as engineering logic is maintained.

2- Construct a fleet of aircraft using those designed with a target budget of €100 million (budget increases are allowed given valid reasoning). This means an estimated cost of the designed aircraft is required.

3- Expand the SoS in the toolkit* by any ONE of the following (FURTHER CONTRIBUTIONS GIVE BONUS POINTS):

- Improving the suppression tactics and operational strategy of the aircraft and associated systems in the wildfire fighting effort.
- Develop and implement new system implementations (each of the following is considered as a separate contribution)
  - ➢ Fire monitoring/ detection systems
  - ➢ Inter-agent communication
  - ➢ Additional suppression agents (boats/ firefighters/ deforesting bulldozers/ any other future system you believe can help)- each is separate

* The COLOSSUS toolkit is a python built, agent-based simulation which will be shared with teams via a github repository. Teams will be given guides and introductions to the toolkit and have the ability to modify and extend the code base as they design their SoS.

4- Test the aircraft and SoS expansions within the COLOSSUS simulation toolkit using the given scenarios (see Scenarios) and optimize the SoS using the given key outputs and weightings (see Evaluation).

5- Summarize results and contributions in a report (maximum 20 pages excluding bibliography) and a 30 mins presentation

Scenarios

Each team is required to run their aircraft and SoS design in 3 different scenarios. The conglomerate performance between the scenarios will be used for evaluation. The scenarios are pre-defined but changes to starting conditions (time of day, ignition center location, weather, air bases, response times, etc.) are changeable so long as adequate reasoning is provided. Improper justification can reflect in grading, though changes can help understand the robustness of the SoS. The 3 scenarios are defined below. Their inputs for the toolkit are provided for and guides on how to change the scenario and the scenario details are also provided.

<u>Scenario A:</u> Salamis, Greece

Ignition Time:
17th July 2023 – 15:39
Ignition Center:
37.9115, 23.431
Smoking negligence starts a small fire in the mountainous woods, but due to dry weather conditions, a blaze erupts in highly combustible environment. Enforcement forces are made aware and contact is made with the Athens firefighting agency, which employs nearby airbases and seaports to provide aid.

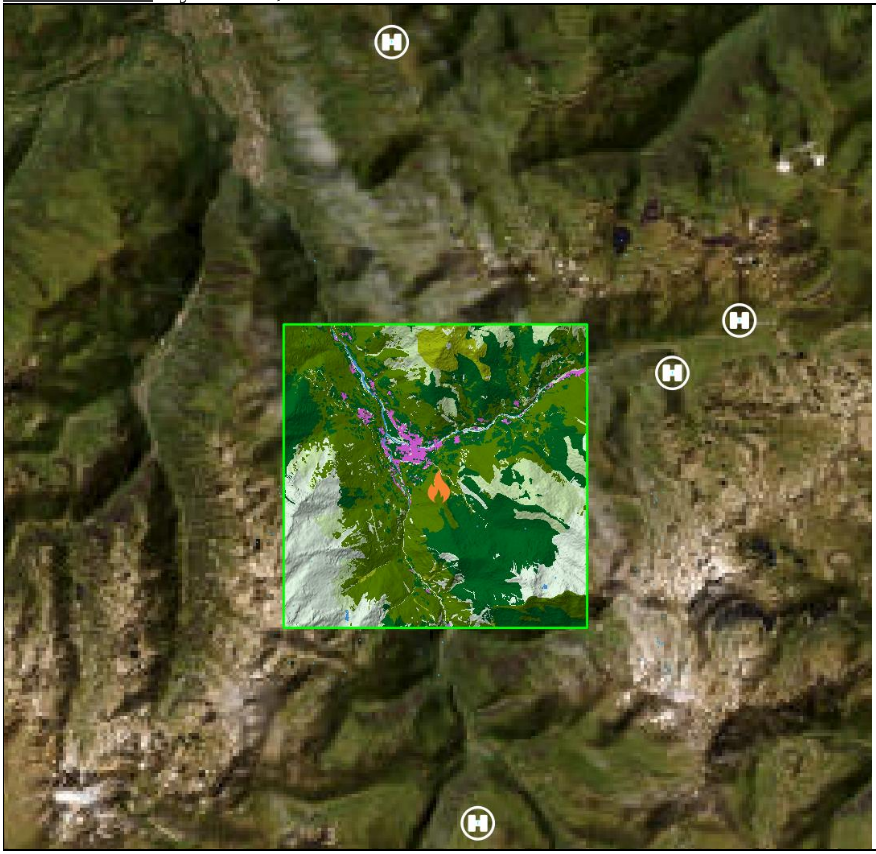
The first aircraft are able to respond after 2 hours from ignition time.

<u>Scenario B:</u> Palisades, California

Ignition Time:
7th January 2025 – 10:30
Ignition Center:
34.07022, -118.54453
A faulty electrical line alights a set of trees in the Southeast region of Pacific Palisades. Dysfunctional fire hydrant services in the area lead to sudden fire spread. The strong winds and varied elevation propel the fire towards the city and nearby suburbs. Speedy civilian call-ins allow a rapid reaction from the fire department.

The first aircraft are able to respond after 1 hours from ignition time.

Scenario C: Pyrenees, France



Ignition Time:
17th August 2023 – 06:15
Ignition Center:
42.86248, 0.00652
A group of hikers forgot to extinguish a fire they made during the night in the French mountains of Pyrenees. The next morning, the fire alights nearby trees, which catches attention of the Lourdes fire department. All nearby airbases to the national park are contacted for assistance.

The first aircraft are able to respond after 30 mins from ignition time.

Evaluation and Prize

In order to properly assess the teams considering all the variations in aircraft design and SoS exploration, a grading scheme is provided in Figure 3.

Aircraft design and engineering knowledge, where the methodologies and principles employed to create the aircraft design(s) is the major component of assessment. This will largely be based on the teachings and ability for students to accrue different methods for designing their aircraft given the technology levels and realism.

SoS knowledge will also be assessed through the developments the students make to the toolkit. It is encouraged that students explore and innovate in this regard, meaning small but significant and well justified changes may yield high grades as well. This criterion is also where additional contributions in the expansion of the SoS may yield a greater score.

To provide a quantitative comparison between groups and aid in solution analysis, an objective function is provided. Details on the function and its components are found in the Objective Function**Error! Reference source not found.** section.

COLOSSUS
COLLABORATIVE SYSTEM OF SYSTEMS

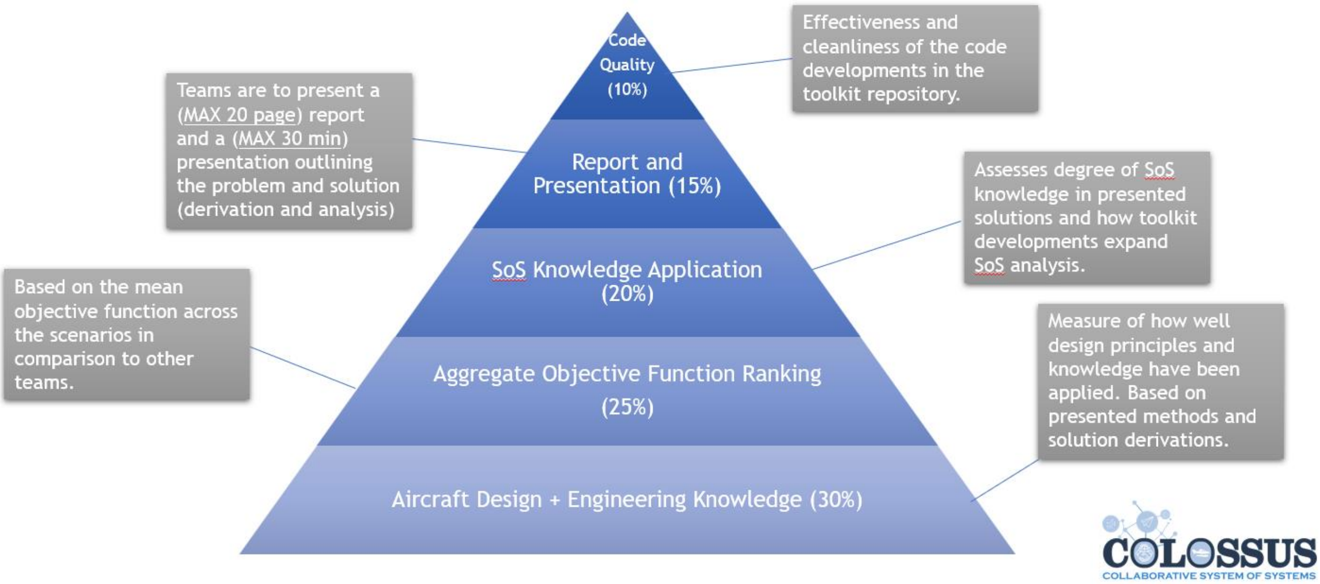


Figure 3 Grading Schema

Teams will be evaluated on a presentation and report which is to be handed in upon the challenge completion. A symposium is to be held in August, where representatives of each team will present their solution in a 30 min presentation. If team members are not able to join, a video presentation will be accepted and graded instead.

Objective Function

The objective function is a combination of all the essential outputs from the SoSID toolkit that can be used in comparison between the scenarios and between student teams. It is advised that the teams utilize the MoE to optimize their solutions and help navigate their design space. Since some variables within the MoE are terrain-dependent, each scenario has their own maximum values that can be obtained. These maximum values should be applied to normalize each simulation's results on each scenario. The MoE is presented in Equation 1 where the simulation specific results are indicated with the subscript *i*. The weights and maximum values are shown in Table 1 and Table 2 respectively. MoE values closest to 1.0 indicate a more favorable SoS solution.

Equation 1 Measure of Effectiveness

$$MoE = 1 - \left[w_1 \frac{BurntArea_i[ha]}{BurntArea^*} + w_2 \frac{CostArea_i[€M]}{CostArea^*} + w_3 \frac{EmissionArea_i[ton]}{EmissionArea^*} + w_4 \frac{FleetAcqCost_i[€M]}{100} + w_5 \frac{FleetOpsCost_i[€k]}{FleetOpsCost^*}\right]$$

Table 1 MoE Weight Values

Parameter	Value
w_1	0.2
w_2	0.2
w_3	0.2
w_4	0.3
w_5	0.1

Table 2 Scenario Maximum Variable Values

Parameter	Value per Scenario		
	Salamis	Pyrenees	Palisades
$BurntArea^*$[ha]	4146	9938	9087
$CostArea^*$ [€M]	139929	175089	1911058
$EmissionArea^*$ [ton]	7140	23641	13122
$FleetOpCost^*$ [€k]	268	167	250

The acquisition and operational cost are specific to the aircraft **and** any agents designed, meaning each team is required to derive a feasible cost modelling. Additional agent systems (outside of the aircraft system) **cannot** be neglected, an effort of modelling their costs must be made. This is to help ensure solutions which abuse alternative systems like ground fighters will not be heavily biased in the objective function. The acquisition cost is based on the summed delivery price from the manufacturer.

Operational cost is based on the availability cost, cost per flight hour and the cost of energy and fuel used by the aircraft whilst conducting the fire fighting operation. Values for the bounding term of the operational cost are obtained from the simulated performance of 2 DHC-515/ CL-415 aircraft in conducting the operation using the same constraints provided in the project. Reference values for the availability cost and cost per flight hour were used from online resources [4], with the fuel cost being based on jet fuel A cost per gallon.

The MoE must be computed for each scenario, with the total aggregate MoE being considered in assessment. The aggregate MoE is the **mean value of the MoE's across the 3 scenarios**.

Prize

The winning team will be awarded with a sponsored conference attendance to EASN October 14-17 2025 in Madrid!

BIBLIOGRAPHY

[1] European Comission Joint Research Centre, “Widlfires: 2023 among the worst in the EU in this century,” European Commission, 10 April 2024. [Online]. Available: https://joint-research-centre.ec.europa.eu/jrc-news-and-updates/wildfires-2023-among-worst-eu-century-2024-04-10_en. [Accessed 10 December 2024].

[2] D. Domeisen, E. Eltahir, E. Fische, R. Knutti, S. Perkins-Kirkpatrick, C. Schar, S. Seneviratne, A. Weisheimer and H. Wernli, “Prediction and projection of heatwaves,” *Nature Reviews Earth & Environment*, vol. 4, pp. 35-50, 2022.

[3] P. S. Prakash, N. Naeem, K. Amadori, G. Donelli, J. Akbari, F. Nicolosi, L. K. Franzén, M. Ruocco, T. Lefebvre, and B. Nagel, "COLOSSUS EU Project – Collaborative SoS Exploration of Aviation Products, Services and Business Models: Overview and Approach," in Proceedings of the 34th Congress of the International Council of the Aeronautical Sciences (ICAS), Florence, Italy, 2024.

[4] Acarter, “The most economical solution,” Fire Boss, LLC. https://www.firebossllc.com/cost-comparison/