AUFRANDE

Position Description

1. General Information

Name of the position	**Impact and fragmentation behaviour of UAVs against soft targets for safety assessment**
Foreseen date of enrolment	1 July 2024
Position is funded by	• COFUND, Marie Skłodowska-Curie Actions (MSCA), Horizon Europe, European Union • ISAE-SUPAERO • Royal Melbourne Institute of Technology (RMIT)
Research Host	ISAE-SUPAERO (Institut Clément ADER)
PhD awarding institutions	Université de Toulouse & Royal Melbourne Institute of Technology
Locations	Primary: Toulouse, France Secondary: Melbourne, Australia
Supervisors	Frédéric LACHAUD, Miguel CHARLOTTE (ISAE-SUPAERO) Raj DAS (RMIT University)
Group of discipline	Aerospace and Mechanical Engineering

2. Research topics (only one of these projects will be funded)

Project 1: *Impact and fragmentation behaviour of Unmanned Aerial Vehicles (UAVs) against soft targets for safety assessment*

Context:
Currently, there are increasing reports of collisions between small civilian drones and structures or personnel on the ground. Although all these collisions do not lead in most cases to fatal injuries for personnel [1-2], nor to significant material damage, predictive numerical and experimental studies concerning the dangerousness of these collisions with people [3] become more and more necessary; the number of drones and their size are only increasing [1]. The highest human risks are related to collisions on the heads of civilians, creating potentially significant injuries [4-5-6]. Current drones have varied architectures, with masses that can reach several kilograms and, for some, flight speeds of more than 25 m/s (90 km/h). The rapid evolution of drone design has recently led to a new classification [3] according to dangerousness (European standard).

This project has received funding from the European Union's Horizon Europe research and innovation programme under the Marie Skłodowska-Curie grant agreement № 101081465

Current research on predicting the dangerousness of drones is divided into two themes:
- The analysis of the dangerousness on humans and mainly the link kinetic energy and bonds on the skull of humans,
- Analysis of damage in the context of drone collisions on aircraft and the residual strength of these aircraft [4-5-6-7-8-9].

Few works are focused on optimizing the design of drones on their dangerousness.
The project emphasizes modeling and simulation through a dialogue between numerical tests and experimental tests on the crash of drones (or similar structures) with the aim of optimization of their design to minimize their impact on humans. To our knowledge, there are very few studies in the literature of similar work. The project will not be centered on the modeling of human links but will revolve around the criticality of the design of drones on the risk and understanding of links. We will therefore use simplified link criteria in order to focus on optimizing the design of drones minimizing these links.
This subject includes upstream scientific subjects, namely the modeling of the fragmentation/rupture of composite materials at different scales; the drones being for stiffness/lightness optimization issues essentially made of composite materials.
This sub-project of this research subject will be composed of 4 parts detailed below:

I Drone scale (structure)
Experimental approach
- Experimental: multi-instrumented crash test (camera, gauge, accelerometer)
- On rigid wall plate structure, drop tower, crossbow etc.
- Representative soft structures (humans, dummy, plasticine) + Aero structures
- Identification of modes of ruins/fragmentation at the structure/drone scale
- Quantify the criticality

Numerical approach
- Test-calculation comparison
- modeling levels for comparison test calculations
- Modeling method, guided by test results

This part must outline the plan of part II, that is to say a reflection on the local modeling of the rupture/fragmentation at the material scale

II Material scale (part related to our composite themes + fragmentation)
Experimentation
- Choice of classic materials (based on carbon fiber)
- Definition and fragmentation tests
- Identification of modes of ruins/fragmentation at the material scale
- Proposal of scenarios and associated rupture laws

Numerical modeling
- Fragmentation modeling method [10]
- Test-calculation comparison
- Validation on the materials of the study

The objective of this part is to provide one or more failure models applicable to the scale of the structure.

III Synthesis (bottom-up)
The models developed in part II will be applied to the global models produced in part I. These models must make it possible to compare the criticality of the drone crash on different instrumented targets (instrumented plate, plasticine, etc.)
Analysis of the ability of the tool to predict fragmentation scenarios for human protection (passive protection), perform a system scan,
Applications:
Qualifying tests? Carry out crash studies, qualifying tests for collision on targets
Numerical modeling strategies at the structure scale including a method (at the material scale) of fragmentation of the impacting drone

This project has received funding from the European Union's Horizon Europe research and innovation programme under the Marie Skłodowska-Curie grant agreement № 101081465

Reproduction test:

- modeling levels for comparison test calculations
- Modeling method, guided by the methods developed in part II

IV Expected results (see with "delair" compagny):

- modify the design of drones: design guide according to the application
- Qualification of criticality
- define protections for the impacting drone or the impacted structure
- define flight domains according to criticality and standard (certifications)

Scientific thematic approach: In order to provide behavior models in structural analyses, different models can be used, particularly at different scales. Each type of model requires data that will lead to experimental identification and validation by associated numerical mode.

References:

[1] Jim Sharples, Cassandra Rotily. incidents impliquant des drones : état des lieux et perspectives pour la sécurité. https://www.jac.cerdacc.uha.fr/incidents-impliquant-des-drones-etat-des-lieux-et-perspectives-pour-la-securite-j-sharples-et-c-rotily/
[2] Drone market outlook in 2021. Business Insider Article https://www.businessinsider.com/drone-industry-analysis-market-trends-growth-forecasts
[3] Chung et al. (2017). Skull fracture with effacement of the superior sagittal sinus following drone impact: a case report. Child's nervous system, 33(9), 1609-1611.
[4] Choon Hian Koha, K.H. Low, Lei Li, Yi Zhaob, Chao Denga, Shi Kun Tana, Yuliang Chenb, Bing Cheng Yeapa, Xin Lia. Weight threshold estimation of falling UAVs (Unmanned Aerial Vehicles) based on impact energy. Transportation Research Part C: Emerging Technologies Volume 93, August 2018, Pages 228-255
[5] Yuhu Weng, Kewei Bian, Kalish Gunasekaran, Javad Gholipour, Charles Vidal, Haojie Mao,
Modeling small remotely piloted aircraft system to head impact for investigating craniocerebral response. Journal of Biomechanics 128 (2021) 110748
[6] Borrdephong Rattanagraikanakorn, Derek I. Gransden, Michiel Schuurman, Christophe De Wagter, Riender Happee, Alexei Sharpanskykh & Henk A. P. Blom. "Multibody system modelling of unmanned aircraft system collisions with the human head" International Journal of Crashworthiness, ISSN: 1358-8265 (Print) 1754-2111 (Online) Journal homepage: https://www.tandfonline.com/loi/tcrs20
[7] Borrdephong Rattanagraikanakorn, Michiel Schuurman, Derek I. Gransden, Riender Happee, Christophe De Wagter, Alexei Sharpanskykh & Henk A.P Blom. "Modelling head injury due to unmanned aircraft systems collision: Crash dummy vs human body" International Journal of Crashworthiness, ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tcrs20
[8] J. Berthe, F. Coussa, P. Beillas, F. Bermond, « Drone impact on human beings : Experimental investigation with sUAS. », 2019, Conference ASIDIC – Aerospace Structural Impact Dynamics International, Madrid, Spain.
[9] AESA, Decision no. 2003/2/RM of the executive director of the agency of 17 october 2003 on certification specifications, including airworthiness codes and acceptable means of compliance, for large aeroplanes (« CS-25 »), [URL: https://www.easa.europa.eu/sites/default/files/dfu/decision_ED_2003_02_RM.pdf], p. 355.
[10] Espinosa, C., Lachaud, F., Limido, J., Lacome, J. L., Bisson, A., & Charlotte, M. (2015). Coupling continuous damage and debris fragmentation for energy absorption prediction by cfrp structures during crushing. Computational Particle Mechanics, 2(1), 1-17.

Supervisors: Frédéric LACHAUD (ISAE-SUPAERO / ICA), Miguel CHARLOTTE (ISAE-SUPAERO / ICA), Raj DAS (RMIT), Christophe CHANUDET (Delair compagny: https://delair.aero/)

Research Fields: Drone, Non linear behaviour, Fragmentation modeling, Composite material, Crash, Impact, Injury

Project 2: *Computational Methods for modelling impact and fragmentation behaviour of Unmanned Aerial Vehicles (UAVs) against soft targets for safety assessment*

Context:

Currently, there are increasing reports of collisions between small civilian drones and structures or personnel on the ground. Although all these collisions do not lead in most cases to fatal injuries for personnel [1-2], nor to significant material damage, predictive numerical and experimental studies concerning the dangerousness of these collisions with people [3] become more and more necessary; the number of drones and their size are only increasing [1]. The highest human risks are related to collisions on the heads of civilians, creating potentially significant injuries [4-5-6]. Current drones have varied architectures, with masses that can reach several kilograms and, for some, flight speeds of more than

This project has received funding from the European Union's Horizon Europe research and innovation programme under the Marie Skłodowska-Curie grant agreement № 101081465

25 m/s (90 km/h). The rapid evolution of drone design has recently led to a new classification [3] according to dangerousness (European standard).

Current research on predicting the dangerousness of drones is divided into two themes:

- The analysis of the dangerousness on humans and mainly the link kinetic energy and bonds on the skull of humans,
- Analysis of damage in the context of drone collisions on aircraft and the residual strength of these aircraft [4-5-6-7-8-9].

Few works are focused on optimizing the design of drones on their dangerousness.

The project emphasizes modeling and simulation (based on particle or/and SPH methods) through a dialogue between numerical tests and experimental tests on the crash of drones (or similar structures) with the aim of optimization of their design to minimize their impact on humans. To our knowledge, there are very few studies in the literature of similar work. The project will not be centered on the modeling of human links but will revolve around the criticality of the design of drones on the risk and understanding of links. We will therefore use simplified link criteria in order to focus on optimizing the design of drones minimizing these links.

This subject includes upstream scientific subjects, namely the modeling of the fragmentation/rupture of composite materials at different scales; the drones being for stiffness/lightness optimization issues essentially made of composite materials.

This sub-project of this research proposal will be composed of the parts detailed below.

I Drone scale (structure)

Numerical modeling & Experimentation

- analyses and comparisons of the numerical modeling methods/strategies

This part notably includes an analysis on the local modeling of the rupture/fragmentation at the material scale described hereafter.

II Material scale (part related to our composite themes + fragmentation)

Advanced numerical modeling & numerical experimentation

- Choice of classic materials (based on carbon fiber) versus eco-materials (based on flax fibers)
- Definition and fragmentation tests
- Identification of modes of ruins/fragmentation at the material scale
- Proposal of scenarios and associated rupture laws
- Fragmentation modeling method [10]

The objective of this part is to provide one or more failure models applicable to the scale of the UAV structure, based on data from literature.

III Synthesis (bottom-up)

The models developed in part II will be applied to the global models produced in part I. These models must make it possible to compare the criticality of the drone crash on different instrumented targets (instrumented plate, plasticine, etc.)

Application to qualifying tests (crash studies, collisions on targets):

The numerical modeling strategies at the structure scale must include methods (at the material scale) of fragmentation of the impacting drone.

IV Expected results (see with "delair" compagny):

- modify the design of drones: design guide according to the application
- Numerical qualification of criticality for the impacting drone or/and for the impacted structure

Scientific thematic approach: In order to provide behavior models in structural analyses, different models can be used, particularly at different scales. Each type of model requires data that will lead to experimental identification and validation by associated numerical model.

References:

This project has received funding from the European Union's Horizon Europe research and innovation programme under the Marie Skłodowska-Curie grant agreement № 101081465

[1] Jim Sharples, Cassandra Rotily. incidents impliquant des drones : état des lieux et perspectives pour la sécurité. https://www.jac.cerdacc.uha.fr/incidents-impliquant-des-drones-etat-des-lieux-et-perspectives-pour-la-securite-j-sharples-et-c-rotily/
[2] Drone market outlook in 2021. Business Insider Article https://www.businessinsider.com/drone-industry-analysis-market-trends-growth-forecasts
[3] Chung et al. (2017). Skull fracture with effacement of the superior sagittal sinus following drone impact: a case report. Child's nervous system, 33(9), 1609-1611.
[4] Choon Hian Koha, K.H. Low, Lei Li, Yi Zhaob, Chao Denga, Shi Kun Tana, Yuliang Chenb, Bing Cheng Yeapa, Xin Lia. Weight threshold estimation of falling UAVs (Unmanned Aerial Vehicles) based on impact energy. Transportation Research Part C: Emerging Technologies Volume 93, August 2018, Pages 228-255
[5] Yuhu Weng, Kewei Bian, Kalish Gunasekaran, Javad Gholipour, Charles Vidal, Haojie Mao,
Modeling small remotely piloted aircraft system to head impact for investigating craniocerebral response. Journal of Biomechanics 128 (2021) 110748
[6] Borrdephong Rattanagraikanakorn, Derek I. Gransden, Michiel Schuurman, Christophe De Wagter, Riender Happee, Alexei Sharpanskykh & Henk A. P. Blom. "Multibody system modelling of unmanned aircraft system collisions with the human head" International Journal of Crashworthiness, ISSN: 1358-8265 (Print) 1754-2111 (Online) Journal homepage: https://www.tandfonline.com/loi/tcrs20
[7] Borrdephong Rattanagraikanakorn, Michiel Schuurman, Derek I. Gransden, Riender Happee, Christophe De Wagter, Alexei Sharpanskykh & Henk A.P Blom. "Modelling head injury due to unmanned aircraft systems collision: Crash dummy vs human body" International Journal of Crashworthiness, ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tcrs20
[8] J. Berthe, F. Coussa, P. Beillas, F. Bermond, « Drone impact on human beings : Experimental investigation with sUAS. », 2019, Conference ASIDIC – Aerospace Structural Impact Dynamics International, Madrid, Spain.
[9] AESA, Decision no. 2003/2/RM of the executive director of the agency of 17 october 2003 on certification specifications, including airworthiness codes and acceptable means of compliance, for large aeroplanes (« CS-25 »), [URL: https://www.easa.europa.eu/sites/default/files/dfu/decision_ED_2003_02_RM.pdf], p. 355.
[10] Espinosa, C., Lachaud, F., Limido, J., Lacome, J. L., Bisson, A., & Charlotte, M. (2015). Coupling continuous damage and debris fragmentation for energy absorption prediction by cfrp structures during crushing. Computational Particle Mechanics, 2(1), 1-17.

Supervisors: Frédéric LACHAUD (ISAE-SUPAERO / ICA), Miguel CHARLOTTE (ISAE-SUPAERO / ICA), Raj DAS (RMIT), Christophe CHANUDET (Delair compagny: https://delair.aero/)

Research Fields: Drone, Non linear behaviour, Fragmentation modeling, Composite material, Crash, Impact, Injury

Project 3: *Structural optimization and additive manufacturing of UAVs for design and safety assessment relating to impact resistance on soft targets*

Context:

Currently, there are increasing reports of collisions between small civilian drones and structures or personnel on the ground. Although all these collisions do not lead in most cases to fatal injuries for personnel [1-2], nor to significant material damage, predictive numerical and experimental studies concerning the dangerousness of these collisions with people [3] become more and more necessary; the number of drones and their size are only increasing [1]. The highest human risks are related to collisions on the heads of civilians, creating potentially significant injuries [4-5-6]. Current drones have varied architectures, with masses that can reach several kilograms and, for some, flight speeds of more than 25 m/s (90 km/h). The rapid evolution of drone design has recently led to a new classification [3] according to dangerousness (European standard).

Current research on predicting the dangerousness of drones is divided into two themes:

- The analysis of the dangerousness on humans and mainly the link kinetic energy and bonds on the skull of humans,
- Analysis of damage in the context of drone collisions on aircraft and the residual strength of these aircraft [4-5-6-7-8-9].

Few works are focused on optimizing the design of drones on their dangerousness.

The project emphasizes modeling and simulation through a dialogue between numerical tests and experimental tests on the crash of drones (or similar structures) with the aim of optimization of their design to minimize their impact on humans. To our knowledge, there are very few studies in the literature of similar work. The project will not be centered on the modeling of human links but will revolve around the criticality of the design of drones on the risk and understanding of links. We will therefore use simplified link criteria in order to focus on optimizing the design of drones minimizing these links.

This subject includes upstream scientific subjects, namely the modeling of the fragmentation/rupture of composite materials at different scales; the drones being for stiffness/lightness optimization issues essentially made of composite materials.

This project has received funding from the European Union's Horizon Europe research and innovation programme under the Marie Skłodowska-Curie grant agreement № 101081465

The sub-project of the research subject will be composed of the parts detailed below

I Drone scale (structure)
Experimental approach
- Choice of classic materials (based on carbon fiber) and eco-materials (based on flax fibers)
- Additive manufacturing of structural UAV.
- Experimental: multi-instrumented crash test (camera, gauge, accelerometer)
- On rigid wall plate structure, drop tower, crossbow etc.
- Representative soft structures (humans, dummy, plasticine) + Aero structures
- Identification of modes of ruins/fragmentation at the structure/drone scale
- Quantify the criticality

Numerical approach
- Structural optimization (micro/macro-architectures, etc.)
- Test-calculation comparison, with optimized architectures including safety criteria.

II Material scale (part related to our composite themes + fragmentation)
Experimentation
- Additive manufacturing of the new designs compatible with the making processes.
- Definition and fragmentation tests
- Identification of modes of ruins/fragmentation at the material scale
- Proposal of scenarios and associated rupture laws

Numerical modeling
- Fragmentation modeling method [10]
- Test-calculation comparison
- Numerical topologic optimization

The objective of this part is to provide one or more failure models applicable to the scale of the UAV structure.

III Expected results (see with "delair" compagny):
- modify the design of drones: design guide according to the application
- numerical qualification of criticality for the impacting drone or/and for the impacted structure
- define flight domains according to criticality and standard (certifications)

References:
[1] Jim Sharples, Cassandra Rotily. incidents impliquant des drones : état des lieux et perspectives pour la sécurité. https://www.jac.cerdacc.uha.fr/incidents-impliquant-des-drones-etat-des-lieux-et-perspectives-pour-la-securite-j-sharples-et-c-rotily/
[2] Drone market outlook in 2021. Business Insider Article https://www.businessinsider.com/drone-industry-analysis-market-trends-growth-forecasts
[3] Chung et al. (2017). Skull fracture with effacement of the superior sagittal sinus following drone impact: a case report. Child's nervous system, 33(9), 1609-1611.
[4] Choon Hian Koha, K.H. Low, Lei Li, Yi Zhaob, Chao Denga, Shi Kun Tana, Yuliang Chenb, Bing Cheng Yeapa, Xin Lia. Weight threshold estimation of falling UAVs (Unmanned Aerial Vehicles) based on impact energy. Transportation Research Part C: Emerging Technologies Volume 93, August 2018, Pages 228-255
[5] Yuhu Weng, Kewei Bian, Kalish Gunasekaran, Javad Gholipour, Charles Vidal, Haojie Mao,
Modeling small remotely piloted aircraft system to head impact for investigating craniocerebral response. Journal of Biomechanics 128 (2021) 110748
[6] Borrdephong Rattanagraikanakorn, Derek I. Gransden, Michiel Schuurman, Christophe De Wagter, Riender Happee, Alexei Sharpanskykh & Henk A. P. Blom. "Multibody system modelling of unmanned aircraft system collisions with the human head" International Journal of Crashworthiness, ISSN: 1358-8265 (Print) 1754-2111 (Online) Journal homepage: https://www.tandfonline.com/loi/tcrs20
[7] Borrdephong Rattanagraikanakorn, Michiel Schuurman, Derek I. Gransden, Riender Happee, Christophe De Wagter, Alexei Sharpanskykh & Henk A.P Blom. "Modelling head injury due to unmanned aircraft systems collision: Crash dummy vs human body" International Journal of Crashworthiness, ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tcrs20
[8] J. Berthe, F. Coussa, P. Beillas, F. Bermond, « Drone impact on human beings : Experimental investigation with sUAS. », 2019, Conference ASIDIC – Aerospace Structural Impact Dynamics International, Madrid, Spain.

This project has received funding from the European Union's Horizon Europe research and innovation programme under the Marie Skłodowska-Curie grant agreement № 101081465

[9] AESA, Decision no. 2003/2/RM of the executive director of the agency of 17 october 2003 on certification specifications, including airworthiness codes and acceptable means of compliance, for large aeroplanes (« CS-25 »), [URL: https://www.easa.europa.eu/sites/default/files/dfu/decision_ED_2003_02_RM.pdf], p. 355.
[10] Espinosa, C., Lachaud, F., Limido, J., Lacome, J. L., Bisson, A., & Charlotte, M. (2015). Coupling continuous damage and debris fragmentation for energy absorption prediction by cfrp structures during crushing. Computational Particle Mechanics, 2(1), 1-17.

Supervisors: Frédéric LACHAUD (ISAE-SUPAERO / ICA), Miguel CHARLOTTE (ISAE-SUPAERO / ICA), Raj DAS (RMIT), Christophe CHANUDET (Delair compagny: https://delair.aero/)

Research Fields: Drone, Non linear behaviour, Fragmentation modeling, Composite material, Crash, Impact, Injury

3. Employment Benefits and Conditions

ISAE-SUPAERO offers a 36-months full-time work contract (with the option to extend up to a maximum of 42 months). The employment contract includes a probation period of 3 months. The total working hours per week is 39h.

The remuneration, in line with the European Commission rules for Marie Skłodowska-Curie grant holders, will consist of a gross annual salary of EUR 29,600. Of this amount, the estimated net salary to be perceived by the Researcher is 1,906 EUR per month. It will be re-evaluated annually. However, the definite amount to be received by the Researcher is subject to national tax legislation.

Benefits include

- Becoming a Marie Skłodowska-Curie fellow and be entitled to join the Marie Curie Alumni Association.
- Access to all the necessary facilities and laboratories at ISAE-SUPAERO and RMIT University.
- Tuition fees exemption at both PhD awarding institutions.
- Yearly travel allowance to cover flights and accommodation for participating in AUFRANDE events.
- 10,000 EUR allowance to cover flights and living expenses for up to 12 months in Australia.
- 54 days paid holiday leave.
- Sick leave.
- Parental leave.

4. PhD enrolment

Successful candidates for this position will be enrolled by the following institutions and must comply with their specific entry requirements, in addition to AUFRANDE's conditions.

Applicants must have a Master of Sciences (MSc) degree or a diploma that confers the Master grade (5 years). They must additionally prove a 5-6 months' research training experience as a MSc trainee in a research laboratory.

This project has received funding from the European Union's Horizon Europe research and innovation programme under the Marie Skłodowska-Curie grant agreement № 101081465

AUFRANDE

isae
Institut Supérieur de l'Aéronautique et de l'Espace

RMIT UNIVERSITY

Applicants must demonstrate an English language proficiency equivalent to an overall IELTS Academic score above 6.5 and no band below 6. Note that the test needs to be completed no more than two years before enrolment. For more information about the tests accepted and scores required, visit: https://www.rmit.edu.au/study-with-us/international-students/apply-to-rmit-international-students/entry-requirements/english-requirements/english-language-proficiency-tests

More information on Université de Toulouse's requirements

Important: the authorisation of the Defence Security Officer may be required before admission. In case of denial, the enrolment will not be carried out.

Visit the website: https://ed-megep.univ-toulouse.fr/as/ed/actu.pl

More information on RMIT University's requirements

Visit the website: https://www.rmit.edu.au/research/research-degrees/how-to-apply

This project has received funding from the European Union's Horizon Europe research and innovation programme under the Marie Skłodowska-Curie grant agreement № 101081465