UNIVERSIDADE BEIRA INTERIOR

AFCEA PORTUGAL

V Encontro dos Clubes de Estudantes da AFCEA Portugal

AFCEA Covilhã Student Club

September 21st - 24th, 2020

UNIVERSIDADE BEIRA INTERIOR | DCA DEPARTAMENTO DE CIÊNCIAS AEROESPACIAIS | AFCEA PORTUGAL

Summary

- Club Composition;
- Analysis of the small scales of the cascade in supercritical conditions: the Kolmogorov scales;
- Structural optimization of composite UAV wings;
- Air Cargo Challenge – AERO@UBI;
- Numerical modeling of freezing water droplets using a two-way coupling approach;
- Human Factors and Flight Safety – The Case of Cognitive Fatigue in Airline Pilots;
- Development of an Unmanned Aerial Vehicles Cooperative System for Forest Fires Detection and Monitoring;
- Optimal Robust Trajectory Control of Atmospheric Flights;
- SECURIoTESIGN.

AFCEA Covilhã Student Club

- Active Members 2020:
  - **President:** João B. F. Sequeiros
  - **1st Vice President:** Tiago N. Sanches
  - **2nd Vice President:** Filipe M. J. Silva
  - **Secretary:** Alexandre J. R. Nunes
  - **Faculty Advisor:** Jorge M. R. Silva
  - Kawser Ahmed
  - Pedro J. F. Alves
  - Cátia S. A. Simão
  - João M. N. Cleto
  - Rúben D. S. O. Meireles
  - Joaquim V. R. Sousa
  - Luís M. O. Estanqueiro
  - Mariana L. M. Couto
  - Nuno M. V. C. Quental

Analysis of the small scales of the cascade in supercritical conditions: the Kolmogorov scales

Why the interest?

- General tendency to operate under increasing pressure conditions, in rocket engines, gas turbines and diesel engines (gains in terms of **traction**, **power** or **efficiency**).

↓

Increasing pressures: possibility of exceeding the species' critical values.

↓

Supercritical conditions

- Use of water in supercritical conditions in steam generators in power plants.
- Role in the area of **fuels**, **cooling**, etc..

Analysis of the small scales of the cascade in supercritical conditions: the Kolmogorov scales

- For example, the Vulcain engine operates at a combustion chamber pressure of 10 MPa, i.e., twice the critical pressure of oxygen, 5.03 MPa.

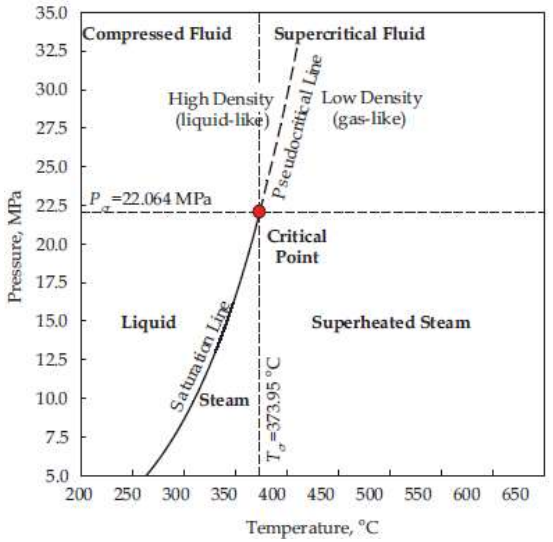


Vulcain (Ariane 5)

M.Sc.

Analysis of the small scales of the cascade in supercritical conditions: the Kolmogorov scales

- Each pure substance has its **critical pressure and temperature**, which are specific to the species in question. The following diagram is only presented as an example.

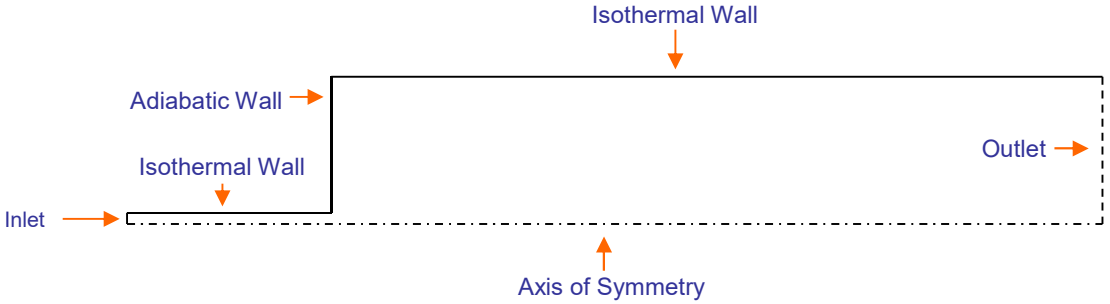


Pressure-Temperature diagram for water

- In the vicinity of the critical point, properties such as density, dynamic viscosity, specific heat, thermal conductivity, etc., undergo **drastic changes**, so it is necessary to carefully analyze the evolution of these properties.
- The figure shows the **critical point** in which the distinction between the liquid phase and the gas phase is not possible, i.e., the two phases have the same temperature, pressure and volume.
- This point is a thermodynamic singularity.

M.Sc.

Analysis of the small scales of the cascade in supercritical conditions: the Kolmogorov scales



- A sketch of the geometry and boundary conditions is shown above where only half of the chamber is simulated.
- The simulations are divided into two distinct parts: a first, where nitrogen injection is simulated into a nitrogen-filled combustion chamber; and a second one, where a coaxial helium injection is added.
- Several test cases will be investigated where parameters such as **chamber pressure**, **temperature** and **velocity** of the injected fluid(s) are changed.
- Therefore, the objective of present work is to study the small scales of the cascade as well as the interaction between species.

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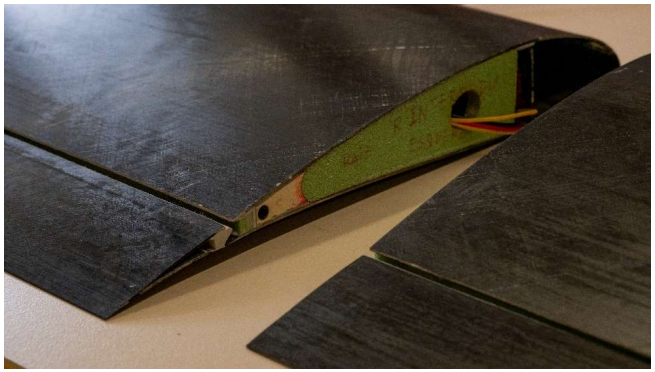
Structural optimization of composite UAV wings

- Development of a code that optimizes the materials' arrangement along a UAV wing;
- Coupling of finite element analysis and evolutionary optimization algorithms;
- Minimize wing mass considering manufacturing constraints;



M.Sc.

Air Cargo Challenge – AERO@UBI

- UBI/DCA team participation on the “Design-Build-Fly” competition promoted by EUROAVIA.
- Full composite aircraft;
- Improvement on manufacturing techniques;
- Next competition on July 2021, at Munich, Germany;



Classification: 5th place

Best flight:

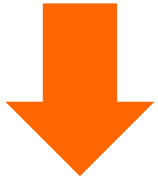
8.1 kg of payload

82 seconds

M.Sc.

Numerical modeling of freezing water droplets using a two-way coupling approach

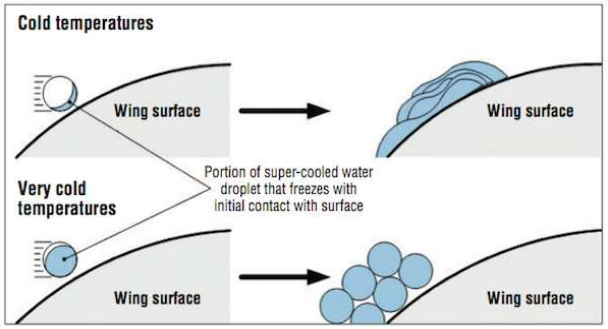
- FAA reports that, if the current accident rate holds constant and the airline transportation continues at the current rate, there will be **more than 4500 air travel fatalities** per year worldwide by **2025**.
- Between 1970 and 2010, **323 events**, concerning aircrafts with more than 2250 kg, were **found ice related**.
- **Due to ice**, drag increase is far larger than that of the lift decrease, where the increase in the **drag coefficient can be increased by 100% – 200%**.
- Most of the **aircraft cannot fly at altitudes beyond the icing risk**, icing possibility exists in their entire flight envelopes.

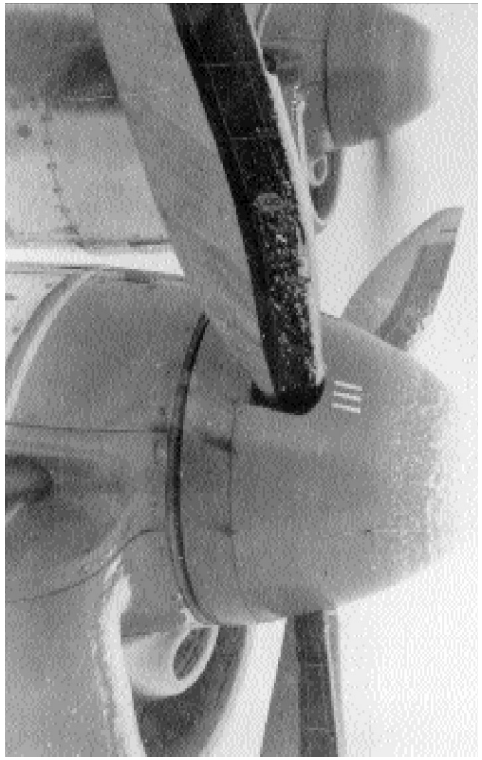


- **Highly important** to study aircraft aerodynamics, stability, control and flight **performance in icing conditions**.

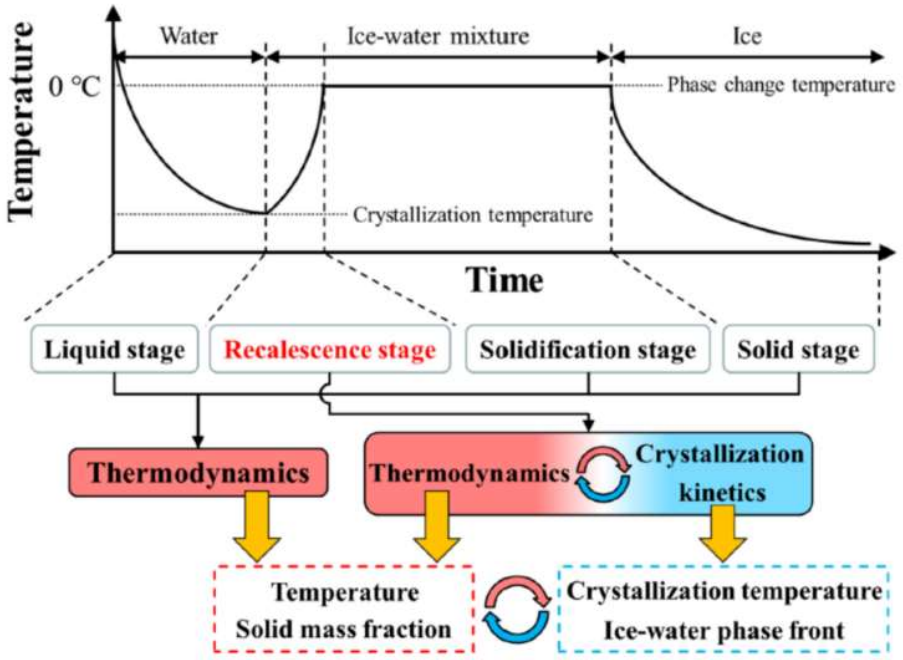
FOUR-STAGE FREEZING MODEL IMPLEMENTED







FOUR-STAGE FREEZING MODEL IMPLEMENTED



ISSUES ON OTHER SECTORS

- Accidents on roads and highways, during freezing rain events.
- Structural deformation of power and communications transmission towers due to ice accumulation.
- Offshore structures collapse due to accretion of sea spray droplets.
- Refrigeration on food supply chains and air conditioning issues, widely recognized problems, concerning energy consumption and efficiency of the devices.
- Shutdown of eolian plants due to a heightened load and stress as well as increased vibration and turbulence

OVERALL INTEREST OF THE STUDY

- Increase systems overall performance and efficiency.
- Mitigate structural and mechanical failures, enlarge components lifetime.
- Reduce economic damage via the loss of millions of euros in services and production, as well as injury and loss of human lives.

M.Sc.

Human Factors and Flight Safety – The Case of Cognitive Fatigue in Airline Pilots

Why the interest?

- Between 2010 and 2019, **more than 70%** of the **occurrences** recorded in Portugal by GPIAAF, in the air transport business, involved **human factors** and fatigue is one of them.

Currently, **pilots' fatigue** is acknowledged as a **hazard** that degrades human performance and can cause incidents or even accidents.

In a 24/7 industry, **fatigue is inevitable**. However, it should be **managed** and **mitigated**.

M.Sc.

Human Factors and Flight Safety – The Case of Cognitive Fatigue in Airline Pilots

According to ICAO, what is fatigue?

- A physiological state of **reduced mental** or physical **performance** capability resulting from sleep loss, extended wakefulness, circadian phase and/or workload that can impair a person's alertness and ability to adequately perform safety-related operational duties.

Consequences of cognitive/mental fatigue (examples):

- Loss of situational awareness;
- Poor judgement;
- Difficulties in concentrating;
- Difficulties with memory;
- Increased reaction times;
- Decrease in vigilance.

M.Sc.

Human Factors and Flight Safety – The Case of Cognitive Fatigue in Airline Pilots

Tools to evaluate airline pilots' fatigue

Subjective:

- **Sleep diary** -> To evaluate if there is any pattern that affects the possibility of having a restorative sleep, such as caffeine or alcohol consumption;
- **Samn-Perelli 7-Point Fatige Scale (SPS)** -> Fatigue severity classification using 1 of 7 points, from "Fully alert, wide awake" to "Completely exhausted, unable to function effectively".

Objective:

- **Psychomotor Vigilance Task (PVT)** -> Reaction time test;
- **Actigraphy** -> To estimate (using an actiwatch) the quantity and quality of sleep -> Sleep data is processed by a biomathematical model that provides fatigue scores -> This model can accurately predict changes in cognitive effectiveness throughout the course of the day or night.

It is possible to compare the fatigue experienced by the pilots (subjective data) and the real deterioration of their alertness (objective data).

M.Sc.

Human Factors and Flight Safety – The Case of Cognitive Fatigue in Airline Pilots

Experimental procedure

- **After waking up + Before going to bed:**
  - Filling the sleep diary;
  - SPS classification;
  - PVT test.

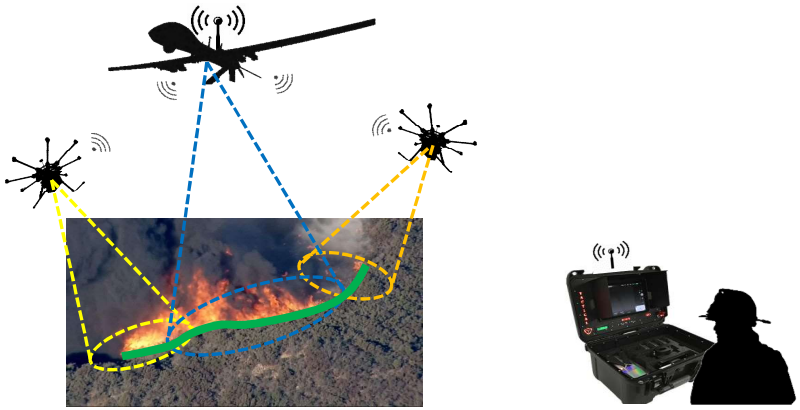
To evaluate how sleep quantity and quality affects the fatigue experienced by the pilots (SPS) and their reaction times (PVT).

- **Before + After each flight:**
  - SPS classification;
  - PVT test.

To **classify the risk of accident or serious error**, according to the level of fatigue experienced by the pilots (SPS), their reaction times (PVT) and fatigue scores produced by the biomathematical model.

Ph.D.

Development of an Unmanned Aerial Vehicles Cooperative System for Forest Fires Detection and Monitoring



- A UAV autonomous cooperative system provides a safer, more reliable and less expensive mean for detecting and monitoring the progress of a forest fire.
- This system provides to fire fighting crews a real-time and precise knowledge of several important parameters, for instance, the fire perimeter and rate of spread.

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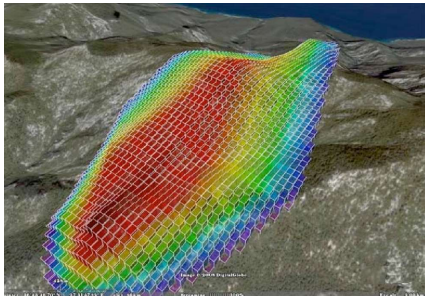
Ph.D.

Development of an Unmanned Aerial Vehicles Cooperative System for Forest Fires Detection and Monitoring

Stage 1 – Numerical Fire Propagation Models



- These models allow simulating several wildfire scenarios according to different atmospheric, topographical and fuel bed conditions.
- The dynamic fire perimeter will be extracted in order to specify the UAVs mission requirements.

- Different types of UAVs will be evaluated to determine their suitability for each mission phase.



Ph.D.

Development of an Unmanned Aerial Vehicles Cooperative System for Forest Fires Detection and Monitoring

Stage 2 – Fire Detection Algorithm

- The fire detection is performed using a visual camera as a sensor, and an onboard computer that applies a fire segmentation technique to the collected imagery.
- The fire segmentation technique consist of analysing each pixel RGB and YCbCr color space values, and applying a set of rules to distinguish a fire from a non-fire pixel.
- Several flight tests are being conducted to evaluate the effectiveness and detection range of the developed fire detection algorithm.





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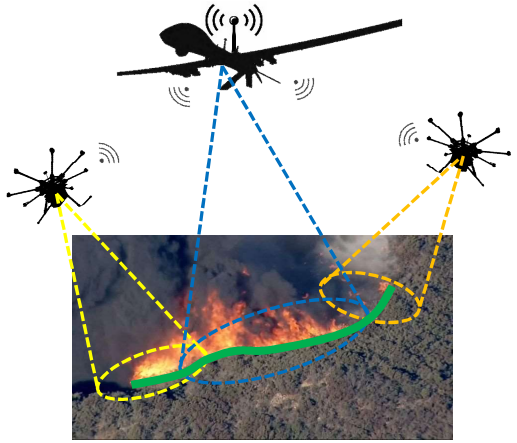
Development of an Unmanned Aerial Vehicles Cooperative System for Forest Fires Detection and Monitoring

Stage 3 – UAV Cooperation Algorithm

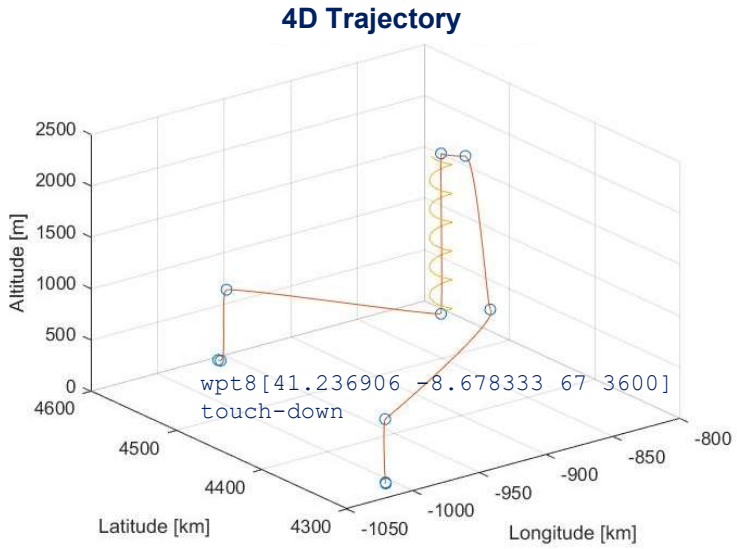


- This algorithm will define the flight path of a team of UAVs in order to maintain a fully autonomous and persistent aerial surveillance and should address several operational constraints such as:

- UAV's deployment times and order;
- UAVs' quantity and flight capabilities;
- Charging stations' number, location and charging characteristics;
- UAVs' fire detection range;
- Communications needs and limitations.

Ph.D.

Optimal Robust Trajectory Control of Atmospheric Flights



Objective:

4D time-constrained waypoint navigation with nonlinear flight controller and filter algorithm for improved flight operation

Advantages:

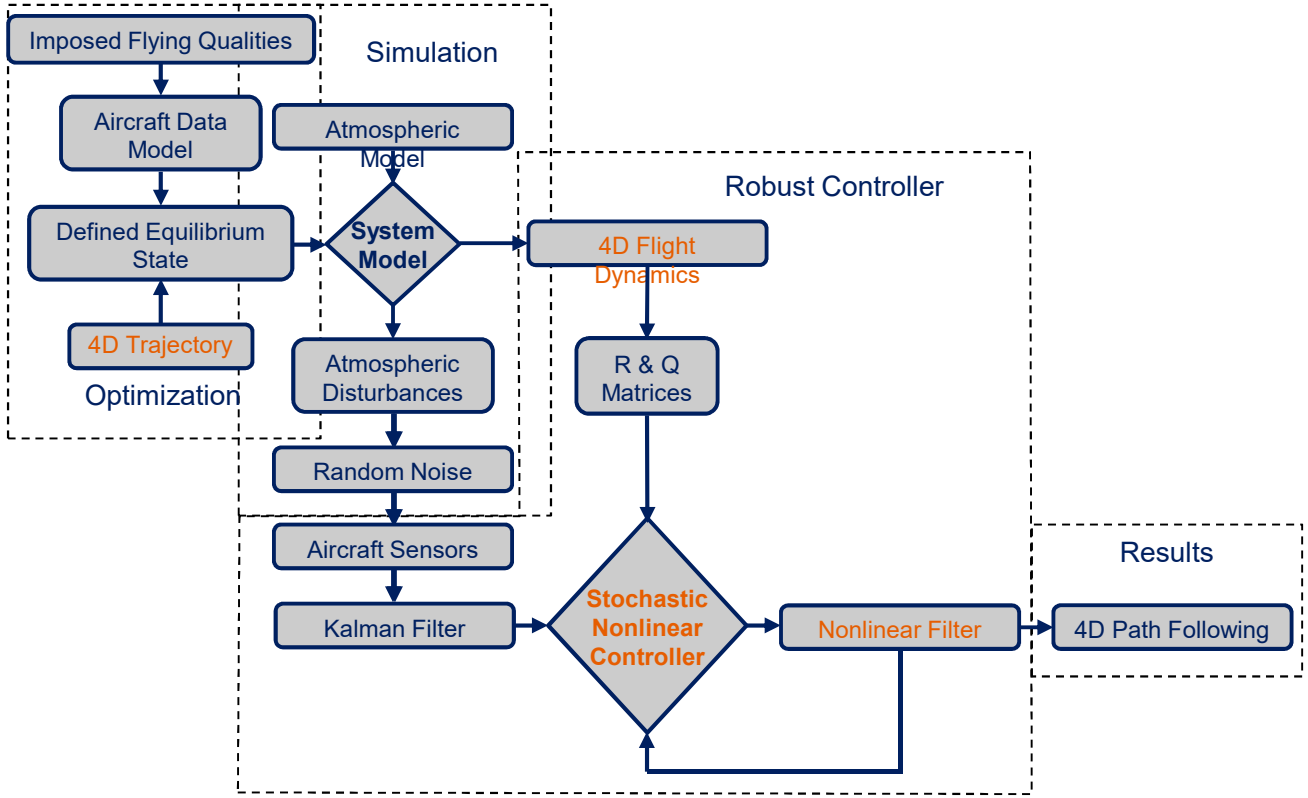
- On-schedule arrivals
  - Flight efficiency & profitability
  - Aviation safety
- Autonomous flights
  - SIGINT & cyberattack prevention
  - Aviation security
  - RVLOS operation

$$4Dwpt_i = (x_i, y_i, h_i, t_i)$$

Development → **Simulation** → **Testing**

Ph.D.

Optimal Robust Trajectory Control of Atmospheric Flights



Ph.D.

SECURIoTESIGN

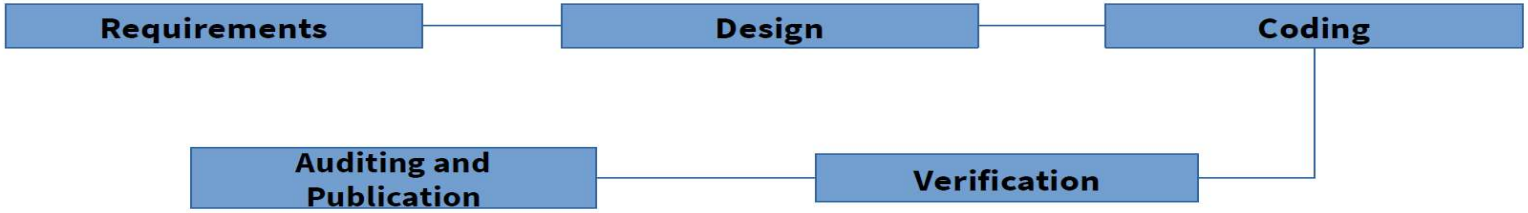
- IoT security;
- Guarantee that security is taken into account in the development process of an IoT system;
- Friendly for developers;
- Framework that encompasses several tools for this purpose;
- Tools communicate with the user through mainly a question-answer system, that gather the user information on its system, and outputs, among others, suggestions, mechanisms, models, test methodologies on the system to ensure it is secure and built with the best practices;
- Modular system capable of easily being expanded and built upon, to keep it up-to-date and relevant.

SECURIoTESIGN - Global Model

First Phase. Responsible for outlining security requirements, receives as its main inputs elements such as, e.g., chosen platform, stored data, transmitted data or authentication needs.

Second phase, it will use the security requirements to create threat models, and technical security requirements, as well as a proposal of security mechanisms to be implemented.

Third phase, it will receive the programming languages used as inputs, returning good practices, cares to have, mechanisms to implemented and configuration procedures.



Fifth and last phase, the application and source code will be analysed again, only this time with auditing tools, to ensure its correct functioning and monitor its behaviour, so that it can then be released to the community.

Fourth phase, it will receive the prototype and source code of the application, that will be analysed and tested to generate technical reports, that will assure which security requirements are fulfilled and potential vulnerabilities that still need to be adressed.

Ph.D.

SECURIoTESIGN
SAM - Security Advising Modules

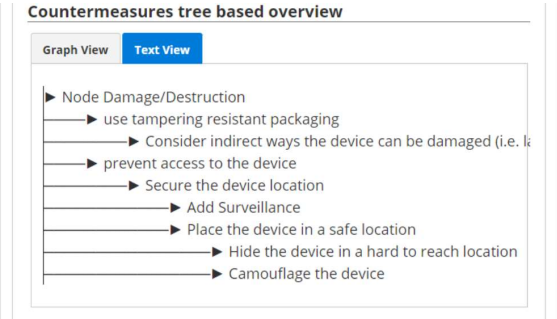


- Currently under development;
- API and front-end for interaction with tools;
- Modular, can be built upon;
- Easily updatable;
- Intends to create a more personal and relatable Security Assistant.

Ph.D.

SECURIoTESIGN
Attack Modeling Module

- Currently finalizing development;
- This module will design an attack tree to better allow the user to detect potentially sensitive points in their system, and to integrate into the system model to ensure mechanisms are implemented in the correct locations;



Ph.D.

SECURIoTESIGN
Currently Under Development

- System Modeling Module - This module will generate a system model/architecture, depending on the type of IoT system (e.g., Smart City, Smart Grid or Smart Environmental Monitoring), giving the user a better view on the system as a whole, each component and their interactions, as well as data and its flows;
- Module for Tests for Verification of implementation - This module will provide guidelines on how to design tests to ensure that previous recommendations and guidelines were followed and correctly implemented.
- System Requirements Module - This module will, from the data gathered from the user input, discern functional and non-functional requirements that the system should abide, depending on its characteristics. To extrapolate this information, the system will use machine learning to extract the main system characteristics and match it with the corresponding requirements.

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