# Thesis abstracts

*This section presents the abstract of most recent Master or PhD thesis related to aerospace technology and management*

## Launch vehicle guidance algorithm insensitive to the dispersion of burnout time

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**Keywords:** Guidance, Solid Propulsion, Orbit injection.

**Abstract:** This work describes a study of guidance of solid propelled space vehicles like the VLS – the Brazilian satellite launcher. Such vehicles do not have control over the thrust level, then its trajectory must be controlled through the attitude angles. The VLS guidance is based on the instantaneous velocity and position, the remaining propulsive energy and the nominal trajectory required for the satellite orbit injection. However, the current guidance algorithm does not take into account the actual thrust profile, leading to uncertainty over several propulsive parameters, mainly in the burnout time of the engines. To provide better guidance performance, an algorithm insensible to the dispersion in the burnout time was developed. This is achieved through an additional guidance condition that leads the vehicle to perform a trajectory which is tangent to a surface solution defined by some orbital parameters at the injection time. Thus, the vehicle will reach the desired surface solution independently of the burnout time of the 3rd stage. Obviously, this new condition must not violate the injection condition, so the algorithm was built in accordance with both requirements.

## Numerical simulation of the flow field over sounding rockets

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**Keywords:** Numerical simulation, Computational fluid dynamics, Aerodynamics.

**Abstract:** The characterization of aerodynamics of rockets is prerequisite for the design and operation of these vehicles. Knowledge of the aerodynamic forces acting determines the loading to which the structure is subjected and thus guides the structural design. Similarly, in order to determine its trajectory, it is necessary to know the aerodynamic characteristics in all phases of flight. One way to obtain the aerodynamic characteristics of a rocket is by means of numerical simulations of the flow over the rocket. In order to do that, the region around the rocket is discretized in a computational mesh that is then used for the numerical solution of the governing equations of the flow. The objective of this dissertation is to generate computational meshes in rockets and assess their suitability for the simulation of flow in different regimes of velocity. These simulations will be made using the program NS3D of the Aerodynamic subdivision of ASE, which numerically solves the 3-D Navier-Stokes equations of turbulent flows. These simulations will be validated by comparing the results computed with experimental data.

## Analysis of fabrication and insulations of an S-30 motor case in composite

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**Keywords:** Motor case in composite, Rocket motor insulations, Filament winding, Computational simulation.

**Abstract:** The rocket motor S-30 is used in the sounding vehicles VSB-30, VS-30 and Sonda III, of the Institute of Aeronautics and Space (IAE), such motor uses solid propellant and the motor case is manufactured in steel SAE 4140. The present work has the objective of analyzing the filament winding and the internal and external insulations of a composite motor case S-30 that can be used in the vehicles VSB-30 and VS-30 of IAE. The composite motor case aims at maintaining the interfaces with qualified parts of the vehicle, as tail can, igniter, nozzle and devices of propellant shipment with the objective of replacing the metallic motor case preserving the propulsive characteristics of the motor S-30. In this work, the geometry design and the thickness design of the domes and cylindrical part were performed. Also, the analysis of filament winding using the software *CadWind* and analysis of the internal and external insulations were performed. The analyses were performed for two configurations: the first for a motor case with same polar holes using an isotensoidal geodesic helical winding, and the second for a motor case with different polar holes, using a non-geodesic winding. The main conclusion based on analysis obtained from the two studied configurations indicates a composite motor S-30 with a better performance than a motor S-30 with metallic motor case, due to its smaller mass. This implies that a higher apogee may be reached for a same payload or a larger payload is possible for the same apogee.

## Characterization and simulation of resin flow of VARTM process in the carbon/epoxy composites manufacture

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**Keywords:** VARTM, Unidirectional permeability, Resin flow simulation, Composite.

**Abstract:** The present work comprises the VARTM (Vacuum Assisted Resin Transfer Molding) process for manufacturing carbon/epoxy composites combined with the previous resin flow simulation into the preform by using the commercial software known as RTM-Worx. The use of this software aimed to help the complex task of determining the resin inlet and vacuum outlet predicting possible dry spots on composite part. The simulation of the resin flow through porous preforms was performed to obtain one plate and one C spar. In order to run the simulation, the viscosity resin and the permeability and fiber volume fraction of the carbon preform were previously determined by experimental trials. Using the resin flow simulation to obtain a C spar, three strategies for positioning the resin inlet and vacuum outlet on the mold were evaluated. Once the simulation had led to the best proposal of infusion, the C spar was manufactured. The experimental results showed that the unidirectional permeability was suitable for the application in this work, with a good linear fitting of points. The comparison between the experimental and simulated infusion times for the permeability plate (6%) and for the C spar (11%), even though some inputs of software were estimated, shows slight deviations and they are within an acceptable range according to the literature.

## Development and characterization of radar absorbing materials based on polypyrrole/epoxy

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**Keywords:** Polypyrrole, (Chemical) Synthesis, Absorbing (Materials), Electromagnetic radiation, Epoxy resin, Engineering of materials.

**Abstract:** This work shows the study performed in the dielectric radar absorbing material area based on the polypyrrole (PPy) conducting polymer use. Six different PPy samples were synthesized by chemical route using different combinations of two oxidants ($FeCl_3$ e $Fe_2(SO_4)_3$) and two anionic surfactants (sodium dodecylbenzenesulfonate – DBSNa e 4-dodecylbenzenesulfonic acid – DBSA). Blends of the synthesized polymers with epoxy resin were obtained. Infrared spectroscopy (FT-IR) analyses of the obtained conducting

polymers confirm the success of the syntheses made. Electrical conductivity and scanning electron microscopy analyses show clearly the influence of the oxidant and surfactant used on the final characteristics of the obtained polymers. In this way, it is also observed that the sulfonate oxidant and the DBSNa surfactant favor the production of more conducting samples (13 $S.cm^{-1}$) and the PPy/epoxy blends with the best behavior as radar absorbing materials (95% of attenuation, near 11 GHz).

## Synthesis of poly(o-methoxyaniline) *in situ* with carbon black and its use as radar absorbing materials

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**Keywords:** Conducting polymers, Radar absorbing materials, Synthesis (Chemistry), Polymer matrix composites, Absorbers (materials), Material engineering.

**Abstract:** The main objective of this study was to investigate and produce radar absorbing materials (RAM) using conductive composites. These composites were produced using carbon black (CB) impregnated *in situ* with poly(o-methoxyaniline) (POMA)polymerized by chemical route using o-anisidine in an acid solution. Fourier transforms infrared spectroscopy (FT-IR), Raman spectroscopy, and X-ray diffraction confirmed that POMA was successfully obtained in its conductive form. After determining the chemical route to POMA, the production of the conductive composites combining CB and POMA was studied. Scanning electron microscopy (SEM), FTIR and Raman spectroscopy confirmed that CB/POMA composites were also successfully prepared. The comparison of RAMs prepared using POMA with those using CB/POMA (both dispersed in epoxy resin) for electric conductivity and attenuation of electromagnetic radiation showed that CB/POMA/epoxy RAMs were better absorbers of electromagnetic radiation than POMA/epoxy RAMs. The electric conductivity of CB/POMA/epoxy composites was up to 100 times smaller than POMA/epoxy composites. RAM materials produced with CB/POMA/epoxy composites attenuated the energy of microwaves (8 to 12 GHz) up to 99.5%.

## DSC methodology developing for high heating rate experiments

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**Keywords:** DSC, High heating rates, Calibration, Thermal analysis, Polymer processing.

**Abstract:** The present work aims to purpose a DSC (differential scanning calorimeter) thermal analysis methodology under high heating rates (>36$^{o}$ $C.min^{-1}$). To reach such purpose, an instrument calibration method is established utilizing traceable metallic materials as indium, zinc, tin and lead, in order to evaluate the DSC furnace symmetry and linearity. Indium masses with different weights, from 0.570 to 20.9 in the milligrams range, are submitted to several heating rates (4 to 324 $^{o}C.min^{-1}$). Experimental results of melting temperature and enthalpy of fusion values are very close when compared with literature data. The polypropylene and polyamide 66 melting and crystallization thermal events are also studied using the conventional DSC method and the high heating rate method. The experimental results show that the indicated methodology is able to characterize traditional thermodynamic events as melting temperature, crystallinity and heat of fusion, based on the DSC instrument under high heating rate. In a short period of time, it is possible to characterize thermal events in a faster way, thus increasing the sensitive and resolution in just one shot and attending the ASTM specifications, with a great advantage of using actual DSC already available into the laboratories.

## Study of convergence of parameters permittivity and permeability of RAM for X-Band and experimentally obtained from simulation

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**Keywords:** Scattering parameters, Nicolson-Ross-Weir method, Inverse problem, Electromagnetic simulation of rectangular guides, Electromagnetic absorber.

**Abstract:** Widely used for retrieving complex permittivity and permeability from scattering S parameters over a broad frequency range, the transmission-reflection method diverges for low-loss electromagnetic materials at frequencies corresponding to integer multiples of one-half wavelength guided in the sample. In addition, S-parameter measurements produce multi-valued solutions for the complex wave number when the electrical length of the sample exceeds a wavelength. These effects lead to uncertainty in the phase of the reflection coefficient Γ, thereby producing undesirable ripples in the retrieved quantities. To resolve such drawbacks in the inverse problem, the present work proposes a non-iterative method based on the Nicolson-Ross-Weir (NRW) algorithm by properly accounting the algebraically unstable term (1+Γ)/(1-Γ). Using S parameters obtained from a 3-D electromagnetic field simulation of a waveguide setup, the method shows to be stable over the whole frequency range considered (8,20-12,40 GHz) with no divergence at half-wavelength resonant frequencies for either dielectric or magnetic materials. Consistent with results in the literature, effective complex magnetic permeability and dielectric permittivity spectra are given for slab samples of Teflon, nylon, epoxy, and carbonyl iron with arbitrary lengths.

## Correction of the launcher vehicle attitude profile as function of the apparent velocity

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**Keywords:** Apparent velocity, Attitude control, Guidance.

**Abstract:** The attitude profile of the Brazilian Satellite Launcher - *VLS* is based on a nominal thrust used as reference during the execution of flight. Many propulsive and atmospheric dispersions can occur during the flight so that the launcher can deflect from the nominal trajectory. This work presents two approaches to compensate the propulsive dispersions of a satellite launcher through the attitude control system, increasing the nominal trajectory tracking along the flight. These methodologies are particularly useful for *VLS*, a four-stage solid propelled vehicle. Initially, an attitude correction through the apparent velocity feedback is proposed; it produces an attitude angle reference that is a function of the linear velocity. The other correction technique is based upon the creation of an off-line attitude table as a function of apparent velocity. Since the apparent velocity is related to the propulsive profile, a corrective action over this variable should perform a better treatment of the thrust dispersion. In both cases, specific software called *ADAGA* was used to produce several propulsive scenarios for the *VLS* flight. This software is also able to perform stochastic simulations through a Monte Carlo routine that produces dispersive profiles expected to occur in a real flight.

## Real time energy estimation of the third stage of the Brazilian Satellite Launch Vehicle (VLS-1)

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**Keywords:** Guidance, Solid propulsion, Energy estimation.

**Abstract:** The control system design of a satellite launcher is done based on an algorithm that takes into account, among other parameters, the propulsion generated by the rocket motor and the mass consumption of propellant, given in the form of three curves, called the nominal, superior and inferior. These curves are used as limiters among which the actual curve of thrust and mass must remain. Currently, the algorithm uses a constant thrust profile and a mass profile that depends on the rate of mass consumption, though the algorithm using these data, they do not match the profile of thrust and mass real, because during the burning of the propellant, these data can vary

considerably. The simulations of the algorithm takes into account the nominal profile of thrust and mass. The ideal case occurs when the actual profile is equal to nominal, but it is not due to variations occurring in the rocket engine. So it needs a good estimate for the profile of thrust and mass so that it closely matches the actual profile. This work presents an on-line estimation, during the vehicle flight, which estimates the values for the profile of thrust and mass closer to the actual values, thus obtaining an algorithm with results that are more consistent with reality.

## Vision-based control of fixed-wing Unmanned Aerial Vehicle for autonomous road-following

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**Keywords:** Unmanned Air Vehicles, Tracking trajectory, Lateral visual guidance.

**Abstract:** Navigation and control techniques using the GPS signals have problems in areas where obstacles can block the satellite signal. In some applications, an alternative is using navigation systems based on vision, for they do not emit signals, are passive and have low cost. This work aims to investigate the navigation of a fixed-wing unmanned aerial vehicle (UAV) for road-following through computer vision and inertial sensors. Simulation of the computer vision algorithms were also used to generate the waypoints after the road search as well as to project them from the image reference frame to the world reference one. With this procedure, it is possible to implement lateral and altitude controllers. The performance evaluation was carried out with a realistic UAV model and virtual scenarios using the FlightGear Flight Simulator. Two approaches for lateral control were implemented. Their behaviors were similar and presented satisfactory tracking performance. The simulator provides visualization of the three-dimensional aircraft models, which is updated in accordance with the information of position and attitude received from the control algorithms implemented in MatLab®.

## Development and simulation of the embedded logic to the SARA recoverable orbital platform rendezvous and docking maneuvers

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**Keywords:** Attitude and Orbit Control Systems (AOCS), Embedded logic, Embedded software, Rendezvous and docking, Recoverable orbital platforms, Distributed simulation environments.

**Abstract:** In this work, the possibilities of making computationally viable the space rendezvous and docking maneuvers implementation between the recoverable SARA satellite and another permanent orbital segment are analyzed. More specifically, the software needs and the flight algorithms that have to be developed to accomplish procedures like these were raised. Besides the reviews about procedures and technologies approaches involving this kind of maneuver, we developed a simulation of architecture made by a distributed virtual environment, which was capable to supply integrated simulation in near real time, together with another environment for controlling and monitoring which was implemented by interpreted language, in order to ease its using as a software tool for space engineers and space software engineers. Based on that virtual simulation environment, some algorithms that simulate the embedded logic in each vehicle acting on the scenario were also developed, as well as the remote operation and monitoring routines that reside on tracking ground stations. That communication methodology between two simulated environments can run a simulation scenario in a totally interactive and easy-understanding way to the user, because 3-D graphical outputs are generated showing all the simulation execution evolution. The results showed that the rendezvous and docking scenario development inside that kind of architecture turns the embedded software procedure analysis more precise and dynamic, without the need to develop simulators or virtual environments from scratch. All of those subjects were related to their respective applications within the SARA Project, addressing to the development principles of an embedded software prototype to be implemented onboard the mission vehicles computational subsystems that will accomplish the referred maneuvers.