SMARTSAT
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Australian Government
Department of Defence
Science and Technology

University of South Australia

An Automated Method of Detecting, Characterising, and Responding to Radiation Events in Space

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Introduction

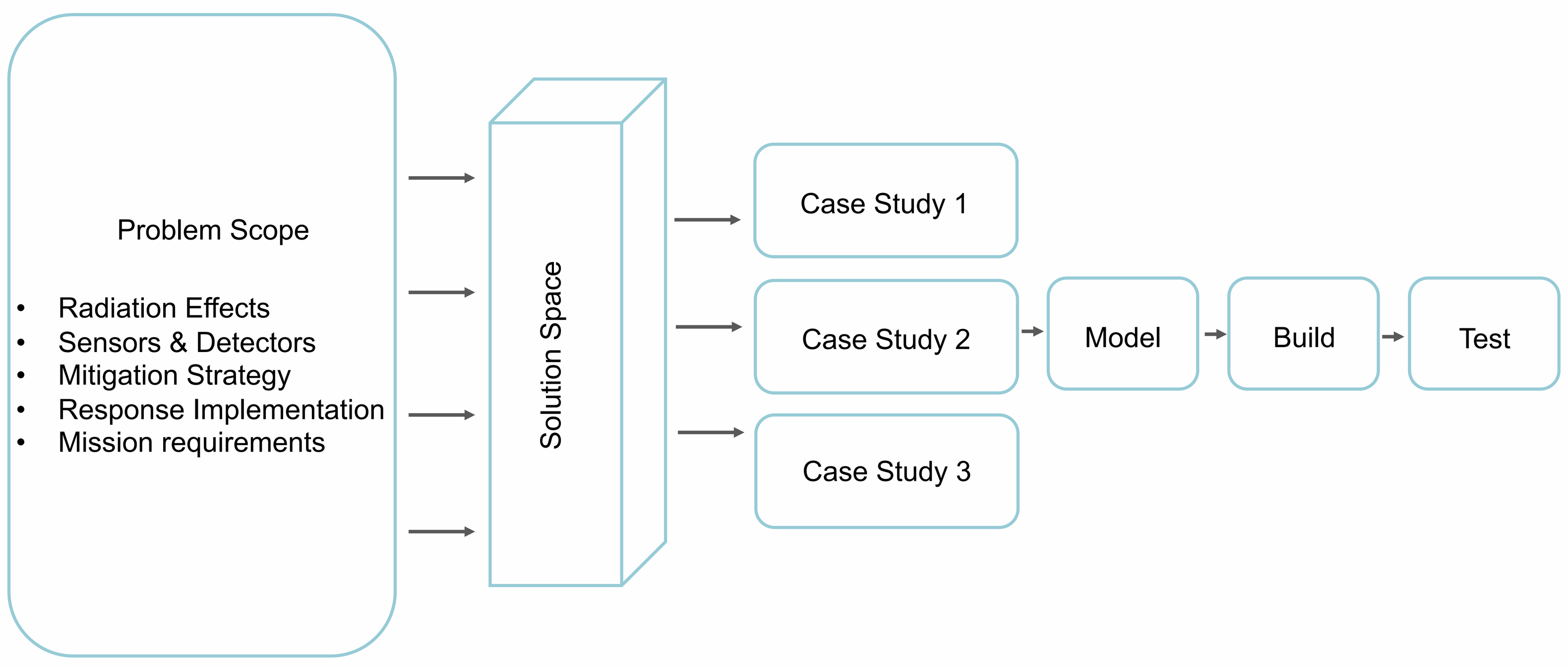
Satellites provide accurate weather data, internet access, the ability to bank anywhere, and GPS navigational capabilities amongst many other applications. Satellites are essential to our society and safety, however, between the years 2000 to 2016, 41.3% of all small satellites launched globally experienced total or partial mission failure (Jacklin 2019). With the shift in the space industry to small satellites using commercial-off-the-shelf products, the standards surrounding space resiliency have reduced, however, reduction in mission assurance has not reduced the operational mission expectation. To ensure a resilient spacecraft that meets the demand for Australian Defence capability, a spacecraft must be designed to survive in its environment and characterise and respond to threats in this changing environment. Of all the environmental challenges, radiation is arguably the most difficult to overcome; as space radiation has detrimental effects on electronic components. Currently spacecraft attempt to pre-emptively mitigate radiation events by using Earth-based space weather forecasting and preventive techniques. Gaining understanding and characterising radiation induced effects will be essential to real-time on-orbit mitigation.

Aims

This research will result in the design and build of a radiation detection and real-time response instrument, capable of pre-emptively avoiding radiation damage to system electronics.

Methods

The following diagram visually demonstrates the areas of considerations which form the problem scope for this project. The scope will be critically analysed to form a solution to the defined problem. This solution will be modular by nature, and will be demonstrated in a number of case studies. These case studies will encapsulate the details of the payload design for spacecraft of various size (weight and volume), orbital parameters, and budget. Based on the case study, a plethora of considerations will be revealed.

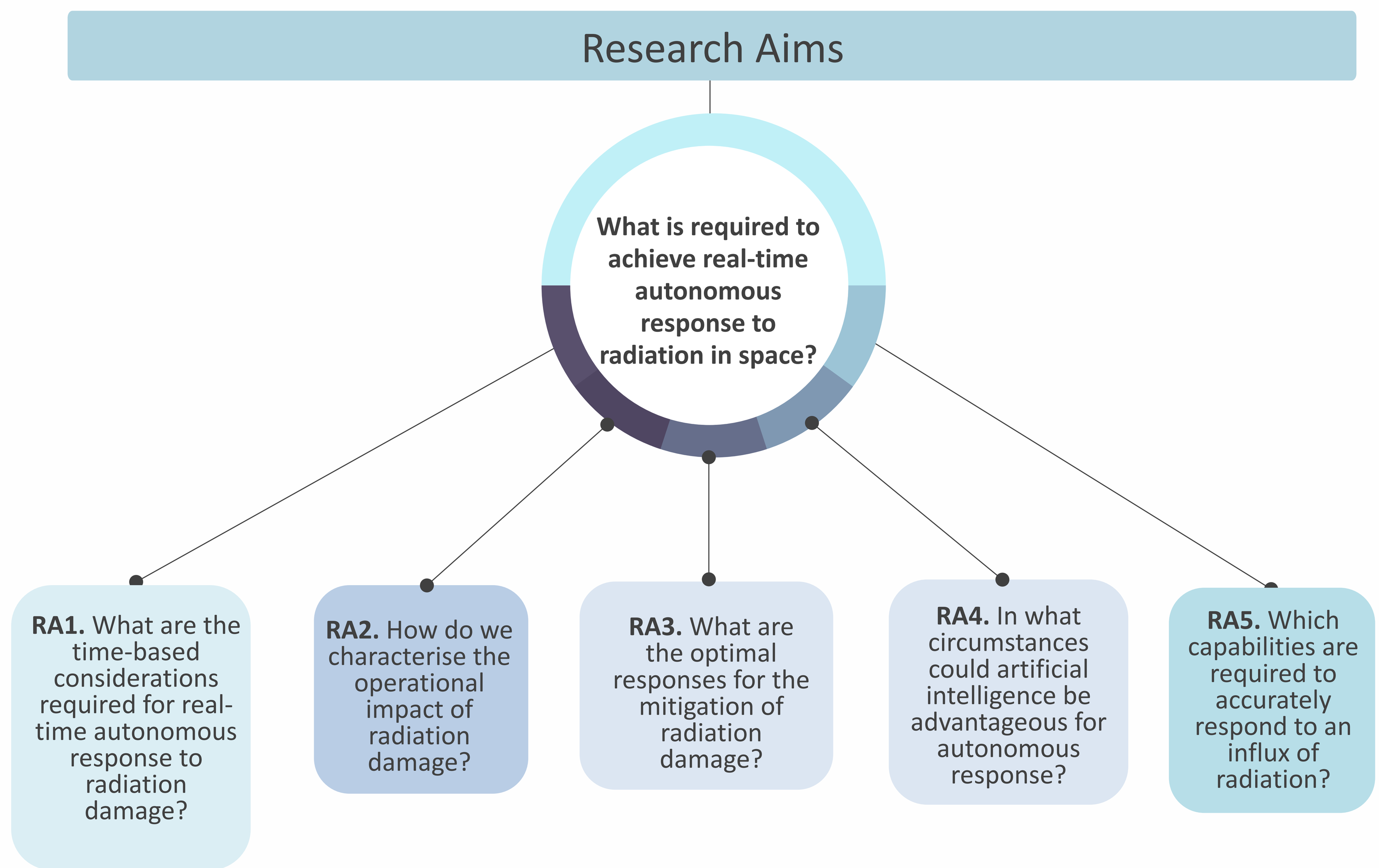


Existing data sets will be heavily utilised at the early stages of this project, to analyse the radiation environment anticipated for operation. Sensor and detector technology will be carefully investigated to determine the optimal selection for use onboard the payload, as will artificial intelligence algorithms capable of processing various sets of data (weather forecasting, sensor readings, existing orbital models, etc.). These findings will begin to form the basis of design for the payload, followed by deep analysis of optimal real-time response mechanisms. Once the payload software and hardware has been determined, the modular design will be adapted for a number of case studies. A singular case study will then be selected for prototyping/testing.

Research Gaps & Questions

Electrons and protons in space can cause cumulative and irreversible damage to spacecraft electronics, leading to operational failure. There are three key radiation effects to spacecraft; displacement damage, total ionising dose, and single-event effects.

Existing radiation damage mitigation strategies are typically preventative in nature, implemented prior to the launch of spacecraft. These avoidance, prevention, and protection measures include shielding, redundancy, and hardened/tolerant by design components. Whilst these strategies do protect components to a certain extent and all present valuable strengths, they all have various shortcomings. Shielding is limited by its effectiveness, mission weight/volume constraints, and its inability to protect instruments which must be exposed to the space environment. Redundancy is only as effective as the designer of the system allows it to be, which is often limited by lack of expertise and cost. Hardened and tolerant components are limited primarily by their exorbitant cost, making it infeasible for all electronic components to be substituted. Systematic reviews of existing literature have revealed the following preliminary aims and questions to be addressed through this research, which will result in a design solution capable of effectively preventing radiation damage:



Impact Statement

This project will benefit future Defence Spacecraft by providing resilient space-based services direct to war fighters, which will enable the Australian Defence Force to prevail in increasingly contested environments. Additionally, this research and design will be applicable to any future satellite, resulting in a reduction in mission failures globally.

References

Jacklin, SA 2019, *Small-Satellite Mission Failure Rates*, NASA, viewed 15 March 2023, <https://ntrs.nasa.gov/api/citations/20190002705/downloads/20190002705.pdf>

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