RESEARCH PROJECT:

REPORT FRAMEWORK

This document describes the approach to document your research project in a systematic way by linking certain sections to specific assignments (be it theoretical or practical assignments). This allows for continuous evaluation of and feedback on the research criteria. The document further aims to clarify the links between the ECSA GAs, the particular assignments and the evaluation criteria/rubric.

Students should use this document in conjunction with the document describing the research project topic. Students are reminded that all assignments related to this project, with the exception of Practical 2, should be done on an individual basis and work submitted is the student's own.

1. ECSA GRADUATE ATTRIBUTES

The link between the ECSA GA, the specific GA components for assessment and the particular evaluation event where these components are assessed is tabulated below. The specific evaluation rubrics used during the assessment evaluation to evaluate these components follow later in the document.

GA 4: Investigations, experiments and data analysis

Assessment Components:

GA	Description of component to be assessed	Where is this assessed?
4.1	Effective planning of investigations and experiments and execution of investigations.	Assignment 2
4.2	Critical evaluation of pertinent literature.	Assignment 1
4.3	Application of correct research methodology and analysis.	Practical 2
4.4	Experimental execution, interpretations, analyses and conclusions emanating from results and data.	Practical 1 and 2 should be successfully completed. Implemented in Practical 3 and demonstration used for feedback, but formally assessed in the examination assignment
4.5	Documentation of investigations, experiments, data, results and conclusions in a technical report.	Examination assignment

GA 5: Engineering methods, skills and tools, including information technology

Assessment Components

GA	Description of component to be assessed	Where is this assessed?
5.1	Application of appropriate engineering methods.	Practical 2
5.2	Using appropriate engineering skills and tools.	Practical 2
5.3	Assessment of outcome from engineering methods, skills and tools.	Implemented in Practicals 1-3, but assessed in the examination assignment

2. REPORT FRAMEWORK

Documenting and reporting on your research and findings are just as important as the research work itself, as it is the only way to communicate your work to most of your audience. The actual approach of conveying your thoughts in writing in itself is the topic of many chapters in textbooks related to research (see Brynardt, Chapters 12-14, Mouton Chapters 8, 11). Many of these texts are written for social sciences and, although generally applicable as well, when conducting scientific and engineering research, a somewhat modified framework is preferable. When writing your research report, start out with the following headings for the different sections that will be populated with content during the course of the research project:

- Abstract
- Part A: Literature review
    - Introduction
    - Literature survey
- Part B: Research proposal
    - Research plan
- Part C: Research methodology
    - Simulation methodology and verification
    - Addendum: Application of appropriate engineering methods.
    - Addendum: Using appropriate engineering skills and tools.

Part D:

- Research methodology (continued)
    - Experimental methodology and verification
- Data collection
- Results
- Conclusion
- References

- Addendum (software)
    - Assessment of outcome from engineering methods, skills and tools.
    - Optional: Flow charts or diagrams of software implementations
    - Optional: Additional results

2.1 Writing an abstract

The abstract is a summary of your research project and contains the most important information from most of the other sections in your report. It should very briefly (i.e. in one or two sentence(s) for each point to follow) i) convey what the project aims to achieve (context), ii) why you want to achieve that (motivation), iii) how you achieved it (method), iv) the most important result (or two) and v) what you concluded. Considering the actual content presented in this section, it should make sense that you will complete this section last, even if it is presented first in your report.

Recall that this is the section that all readers will start with when your report comes up in a search, and this section will be scanned briefly in order to make the decision on whether your report is worthwhile to read in detail, or not (for that particular reader). It is extremely important that this section creates a good impression with the reader. This is relatively easy to accomplish by presenting high quality writing (being both in terms of content and writing style). Make sure that the points highlighted above are very clear and concise, since those are exactly the question your "speed" readers will ask. The reader does not expect masses of information here, so be sure not to fall victim to that mistake.

Reader (and evaluator) questions:

Is the research project description clear, yet concise? I.e.

- Is it clear where in the body of knowledge this project fits?
- Is it clear why this research was conducted?
- Is it clear (granted, from just a few sentences) how this researcher approaches the problem?
- Are the results comparable to those of other papers/reports I have read?
- Is the conclusion meaningful?

Part A: Literature review

This section is submitted as Assignment 1

2.2 Writing your introduction

As the name suggests, the introduction section is used to introduce the work. The purpose of the section is to provide *context by demarcating the problem*, (translating roughly to the "what has been done" by others). This typically requires that you provide context:

- *in general terms*, i.e. what is the "real-world" problem that will be studied, and
- in *specific terms*, i.e. what is the engineering problem that will be studied.

Context: When reading introductions (and writing your own), one should realise that the section is used to demarcate your research work. Normally we would like to create an overview of where this work will fit in, but you are cautioned and reminded that the literature review in a research plan is a

short document and, therefore, you should not tally too long on context that is only somewhat appropriate. Your observation should be about something specific, and not generic. The introduction serves as the initial demarcation of the project, and it is recommended to write the first two/three paragraphs with demarcation in mind. The first paragraph is used to paint the general picture, to create the general context of where the work will apply. This is still generic and written in such a way that most undergraduate engineers will be able to understand without any additional reading required. It is often also not necessarily phrased in engineering terminology. It can be a "real world" problem.

The next paragraph(s) should already be much more specific to the work that you plan to do. A good hint is to have this in engineering terms and these problems will typically be problems solved by engineers (only, or mostly). Here you should briefly introduce other work already published in literature that is very closely related to what you intend to do, but the focus is exclusively on what these authors did/contributed and the limitations of their implementation (i.e. the "what" of their research projects), rather than their detailed implementation and methodology (the "how" of their research projects, more suited for the next section covering your literature review). Finding this information can be done from a variety of angles. You should look for work where the authors address the exact same problem or a problem that is very close in nature to the one you are addressing, and based on this present their existing solutions, or very similar solutions. These solutions will almost always allow room for improvement since authors in general are honest about implementation limitations, which can directly lead to research questions and hypotheses. This is the most intuitive approach and follows the principle that research leads to more research. Alternatively, one could look at an out of context solution of a completely different problem, where the solution could be modified and tailored to solve the problem you would like to address.

In a nutshell: This section aims to provide context only (i.e. not detailed content) of the research problem and how it is related to that of others, from generic to very specific, i.e. what was done by others.

Limitation: *This section should be restricted to one page.*

Some extra thoughts/notes:

Potential pitfalls: What should also be very clear at this stage is that an initial literature survey needs to be done before writing up a research plan. The introduction to the research plan ***is not*** a summary of a *generic observation* and *a promise of a future literature survey* for a future report or later in this report, but rather an already very specific observation to what you will be doing in your project and supported by a context stemming from a concrete literature survey already conducted.

Reader (and evaluator) questions:

Is it clear where in the body of knowledge this project fits / Is the problem well demarcated? I.e.

- Is the research problem placed in the context of a broad/general field/area?
- Is the research problem narrowed down to a very specific problem?
- Is it clear from the content within the context of the very specific field:
    - What others have done and the relevance of that to this research project/report?
    - Why have they done it / their contribution?

- What limitations their approach has?

2.3 Writing your literature survey

This section of the report is used to elaborate on the problem context presented in the first section by providing a much more critical evaluation of the work of other authors that you consider related to your project. It is an important skill to consider and evaluate the content of literature sources, especially when considering just how much literature is available publicly and in academic environments. Therefore, in this section you need to demonstrate your ability to critically evaluate literature. Keep in mind that literature can be related to your work in one or many ways. Although most of the papers you will read will contain most of the elements to follow (to some degree), you are likely to find that some work may be related theoretically and show similar models, some published work may focus more on a simulation methodology, some work might focus and emphasize experimental methodology. All of these elements are important to consider.

For each article you review, conduct and illustrate your skill of critical evaluation. This means that for published work you need to demonstrate that you can both *interpret* the content of an article, i.e. explain that content to your reader in your own words, and *synthesise* content, i.e. combining content (interpreted versions) from many articles in a single report for a cohesive understanding of the topic. In class techniques were discussed (recall speed/scan reading, comprehensive reading and critical reading methods) covering how to quickly narrow down on potentially useful articles. At this stage of the reporting, you need to have compiled a list of articles that you consider worthwhile to read in more detail. When reading the articles, find the following key points and present them in your literature review:

- What is the main problem that the author(s) addressed?
- How is that work related to yours?
- What is the main, i.e. new/novel contribution of the author(s) to the field?
- What were the main assumptions of the author(s) and what limitations do that impose on the research?
- What is/are the main conclusion(s)?

The order in which work is presented in this section can follow many forms. It is often either chronological in terms of when the work was done (i.e. historically), or in order of importance of developing and repeating the work. The latter approach is preferred as it follows the research phases and considers theoretical modelling, simulation modelling and experimental methods. However, as we have to evaluate and assess a student's skill to critically evaluate the relevance of work, you need to present the literature survey by ordering the referenced work by relevance from most relevant to least relevant for each of the three categories. This is not to say that you should present irrelevant work. All referenced work in the literature survey should be relevant, and you should have at least five (5) closely related papers to your research project. However, note that it is considered poor synthesis to present work article for article.

Finally, ensure that these references are from good academic sources, and not merely Wikipedia pages or general webpages from the internet. You may wonder why such a restriction exists, and the answer is simple. Academic sources pass through the process of peer review, so you can be (mostly)

assured that the content has been considered and evaluated by experts in the field and is not merely the opinion of a hobbyist placed on the internet (anyone can do that). Having said that, be cautioned that not all sources from academic journals and conference proceedings are guaranteed to be of high quality. Even the peer review process is fallible.

In a nutshell: This section aims to provide content from existing knowledge related to your research problem. It should be clear that you can critically evaluate content available to you by demonstrating your ability to interpret elements like problem identification, relation to your work, contribution of authors, assumptions and limitations of research work and conclusions of other authors.

Limitation: *It is advised to restrict this assignment to four pages. However a strict limitation of five pages will be enforced (i.e. content on pages six and onwards will not be evaluated, as if it wasn't there).*

Reader (and evaluator) questions:

Does the student demonstrate the skill to critically evaluate pertinent literature? I.e.

- Is each article considered *relevant* to the research topic?
- Is the *content order* presented by the student a true representation of the content relevance (from most relevant to least) to this topic?
- Has the student demonstrated that he/she can correctly *interpret* content (problem identification, relation, contribution, assumptions and limitations, and conclusions) presented by others?
- Has the student demonstrated that he/she can *synthesise* content from multiple sources in a coherent and useful way for the reader?

Part B: Research proposal

This section is submitted as Assignment 2

2.4 Writing your research plan section

Research statements: This section revisits the problem statement where you considered the problem in the context of what others have done. The goal of this section is to paint a clear picture about *your* research project and how your project fits into the context provided earlier, i.e. *"What others have done?"* for assignment 1 versus *"What you plan to do?"* for this assignment. This means that you will have to provide two crucial elements:

- a *problem statement* of your research project
- a formal *research statement(s)* for your research project

The goal of the problem statement is to inform the reader of exactly which research problem *you* will be addressing (recall previous parts already highlight what has been done and not done in literature), i.e. "what problem will you be addressing". The problem statement should be brief, concise and succinct. This means that you should try and use as few as possible words to describe the problem, yet still provide sufficient detail that the reader will know exactly/clearly what you will do in you research project. A clear description will allow you to focus your research plan and final report to exactly what is important to be accomplished in your project, and what is not important. Generic

statements should be avoided at all costs. How would you identify if a statement is generic? Ask yourself if the answer is already known, i.e. is the answer to your question considered general knowledge and known? If yes, why would anyone pursue months of work to answer that question? Ideally, you are looking for a question without an existing answer, other than perhaps a 'gut feeling'. In this course, however, given the time limitation, a question where the answer is only known after a detailed and thorough literature review is acceptable. There is not sufficient time to actually contribute to the body of knowledge, except for perhaps a few very gifted students.

The goal of the research statement is to clearly highlight to the reader what you intend to investigate and how you propose to solve the problem stated. This can be in the form of a research question and/or a hypothesis. Once again, your approach should be clear and very specific, as general questions lead to general conclusions; neither are very helpful. Your research statement needs to highlight your unique approach and how it differs from that of others, i.e. your contribution, and the research gap addressed should be clear. Note that for an undergraduate module, it is not required to come up with a completely novel implementation. It will be acceptable to showcase that you understand these concepts by implementing a unique implementation from literature.

<u>Reader (and evaluator) questions:</u>

Is it clear why this research was conducted? I.e.

- Is it clear exactly what research problem will be investigated (problem statement is clear)?
- Is a formal research statement(s) presented (either as a research question and/or hypothesis)?
- Is the research statement(s) posed correctly:
    - Is it a statement that will lead to a research contribution, or merely a generic question with the answer already known as general knowledge? (The latter is bad, e.g. "Will the resolution increase if the number of bits increase?")
    - Is the statement about the work or the researcher (The latter is bad, e.g. "Can I implement a … ?")

Research model: The next part of the research plan gives the reader (in this section it helps to consider your reader as a potential investor or supervisor) an *overview* of what you intend to do in your research project. You should carefully consider what this means. Keep in mind your research project is/should be designed and is supposed to answer your research question. You should provide an overview (like a roadmap) of what you intend to do and how you intend to do it during this project, i.e. your planned research methodology to answer your research question. The overview should provide sufficient clarity to your reader about your proposed method, but the intention here is not to provide the detailed methodology and implementations. Those will follow in the next sections (assignments). Here you demonstrate that you had developed sufficient insight from your literature review to realise what needs to be done and how it needs to be evaluated relative to what is available in literature.

In order for this section to successfully present the above, it should include the following elements:

- Details of *your model* (it is reasonable to expect a detailed model, as the model planning should be conducted prior to the detailed implementation for the next section) showing:

    - a clear illustration of your proposed method and how it fits within a reference model from your literature review, i.e. how does your method modify/change the base model, since this change highlights your contribution,
    - the important variables of your model, i.e. describe the parameters playing a role in your model and highlight whether they are constant, independent variables, dependent variables or intermediate variables, and
    - clarify the assumptions made and the limitations of the model/method. Keep in mind limitations are not only things to potentially 'break' the research model, but also which aspects you do not consider to focus the research more.
- Your *data collection* strategy, i.e. how will your data be collected?
- Your planned *experimental method*, especially the analysis approach of the data. Identify from literature how this is typically done for your particular research topic, without worrying at this stage about the actual detailed implementation (which will be presented in the next section and considered during another assignment). Think of this as demonstrating your ability to identify how others have collected and interpreted the data, why they do it that way, and you planning on doing the same in your project when the time comes.
- A *timeline* to assist you to stay focused and keep your research project on track, often in the form of a Gantt diagram. This should show critical milestones for your research project and when you intend to have completed those milestones.

It is crucially important to realise at this stage that all of the components above should be included. The report is not considered as 'most sections were done, i.e. it is acceptable'. Skipping just one component highlighted in italics in the list is cause for failure of the report. Consider the above as the minimum acceptable standard. To highlight that each aspect was addressed, you should consider creating a clear section for each.

In a nutshell: This section aims to tell the reader what you plan on doing during your research project and contains a detailed model description, as well as your proposed methodology to conduct the experimental work and data analysis based on literature. Finally also give a planned timeline with important milestones.

Limitation: *It is advised to restrict this assignment to three pages. However a strict limitation of four pages will be enforced (i.e. content on pages five and onwards will not be evaluated, as if it wasn't there).*

Some extra thoughts/notes:

Potential pitfalls: It has been quite common in the past that students do not complete every item in the bullet list above, with the planned experimental method being the most popular to leave out. This is not a '3/4 = 75% and is good enough' situation. It is a minimum requirement to have these items included. Omitting it is a guaranteed way of failing the assignment and having to resubmit.

Reader (and evaluator) questions:

Does the student demonstrate the skill to effectively plan their investigation and experiments? I.e.

- By considering the presented model

    - Did the student demonstrate how he/she plans to establish a reference / baseline for their research work with reference / citation to that model in literature?
    - Did the student demonstrate the ability to coherently present a research model (modified from the reference) that is suitable to answer the research question(s)?
    - Did the student demonstrate how he/she plans to consider parameters and the relevance of these parameters?
    - Did the student demonstrate how he/she plans to restrict the research problem with assumptions and how these will influence the research output?
- By considering the proposed experimental methodology
    - Did the student demonstrate that he/she already considered a data collection methodology (experimental setup)?
    - Did the student demonstrate that he/she already identified relevant parameters used in literature to measure the success of the research method (in the context of the research topic)?
    - Did the student demonstrate that he/she already knows how the relevant parameters can be extracted from the collected data (analysis methodology)?
- Did the student demonstrate that they can effectively plan a research timeline?

Part C: Research methodology (simulation study)

This section is submitted as the Practical 2 report.

2.5 Writing your methodology section

This section is actually fairly similar to your research plan, with the major difference being that you should now describe to your reader the actual research methodology followed to implement your model (from which you will later answer your research question), rather than the originally proposed methodology of the research plan. Recall that your research plan was a proposal or a promise on how you intend to answer your research question, while this section now explores how you deliver on that promise with the details of your actual implemented approach. This also means that previous questions of evaluators with the basic form "*How will you … ?*" now change to "*How did you …?*".

Your main goal with this section will be to demonstrate how you implemented and verified your base and reference models. Verification here refers to testing that the system is working and performing the required functionality, but not an analysis of the results that leads to your research question being answered. That follows later. Here you answer the question "*Does the implementation work / deliver the correct outputs?*", and not the question "*How well/efficient/fast/etc. does the system…"*.

You will notice that the content of your research plan section now forms a very good foundation or starting point for this section, but at the time of documenting this section, you have gained significant additional insight and experience into the actual implementation methodology. This needs to be reflected here with a thorough (yet concise), detailed discussion of your methodology. The details should be sufficient to *enable the reader to repeat your work*. This does not mean you have to write a step by step instruction manual (or 'spoon feed'), but all the information needs to be there. In order to conserve some space, one sometimes presents standard methods or some of the less relevant aspects with statements like "The calibration procedure is detailed in [8]." (granted this example is a little vague). Notice how this statement still enables the reader to repeat that aspect of the work, since he/she can easily follow your method, but using the citation. Your methodology can

often be best described by a block diagram, flow diagram or pseudocode, *but avoid actual source code to explain your method at all cost*. It is often hard to read, especially for a language like VHDL, and your main focus is always to provide clarity to your reader on your contribution.

It is also perfectly reasonable that you may have identified some problems in your originally planned methodology and have since adjusted your methods to correct these problem areas. Research is an iterative process, so this is natural. Once again, you need to detail your actual implemented approach. If there are changes, highlight them clearly (for the internal and external examiners' benefit in this case). Keep in mind your evaluators in this course will consider both the research plan and final methodology, so be sure that the flow of the combined reports make sense. In practice, it is usually just the final methodology that is published and there this is less of a concern.

Your methodology needs to cover 3 major themes. These themes are general and applicable to all research, and you will also notice them in most research reports/papers by looking at the section headings. In short, they are *your approach followed to*:

- implement the research model,
- collect data, and
- analyse the data

Notice that these three themes very closely correspond to the three practical assignments, and as such, each particular theme should be the focus of that practical assignment report. These three themes can directly map to the practical assignments.

- The Practical 1 report needs to convey the information applicable to data collection, i.e. your methodology towards establishing and implementing your data collection strategy. It is important that you clearly describe your methodology/approach towards
    - the simulation implementation of each of the subsystems
    - the hardware implementation of the subsystems
    - the system integration in hardware
    - the simulation verification of each subsystem
    - the hardware verification of each subsystem
    - the verification of the system integration (a systematic approach should be clear)

  Also refer to verification, and the details thereof, in the next bullet point covering Practical 2, where verification is discussed in detail. Your methods for Practical 1 must be documented in a practical report that follows the standard Departmental template (refer to the Undergraduate ClickUP page), since the practical is completed in a group format. This report will be used internally and forms part of your semester mark, but is not provided to the external examiner and does not form part of your final report. Handle this report as a completely separate report.

  However, in your final report (that does go to the external examiner), you have to summarise your methodology towards collecting the data. *See section 2.6.*

- You identified and investigated an analytic/theoretical model previously and implemented it within simulation environments (Practical 2). The two most important questions that you should answer here are:

- How did I implement my *research model/system*? This gives the details of how your theoretical model was implemented into a simulation model. These simulation models should be implemented in a high level simulation language, as well as VHDL, and carefully scrutinised.
- How did I verify that *my research system/platform is working / giving expected outputs*? This gives the details of your initial verification, which would typically be informal, say looking at waveforms and comparing them with a few analytic results calculated by hand. This is then followed by a formal verification methodology testing your system against a range of parameters, which is typically a full digital simulation experimental setup itself (you could consider it an automated verification software platform), ensuring that your system will continue to produce useful and predictable results over the entire range of operating conditions / variable changes (and not just the few you visually inspected).

  This is the section that students usually struggle with the most and, therefore, some additional details are provided. Take note of this final and very important point: This verification method is intended to ensure that your research platform is working correctly, i.e. that you have complete faith that the output data corresponds to that which you intended for your research model. You have to be absolutely sure that the generated data is correct, else there is no point continuing to the next sections. This section is not about analysing the data to answer your research question, but rather to ensure that you have authentic and verified data to start your analysis on. The common mistake here is to think that the analysis methods are used for verification here. The analysis methods are the ones from your literature review and research proposal. You should design experiments to measure if your system works successfully ***before*** continuing to the analysis of the data generated by your system. Imagine this scenario: you implement an algorithm, but make one or a few small mistakes that you don't pick up, since you only inspected a few test vectors by inspection and your outputs correspond relatively well to your test cases. Other test cases could potentially be dramatically influenced, but you won't know without exhaustive formal testing over potentially thousands of cases. It can also happen that these small errors accumulate and become a major problem after tens/hundreds/ thousands of iterations only, and are not immediately apparent. This could be due to memory leaks or number precision. This can not be determined merely by looking at a couple of test vectors only. This means that if you decide to continue with your research, all of the data in your data set will be tainted with this small mistake, and all of the parameters extracted by your data analysis will be impacted by this as well. This could also lead to wrong conclusions of better/worse than expected system performance.

  A very interesting research project is discussed in the video at the link below. After watching it, consider again what the actual research was, and how the AI agents 'broke' the game. The video does not discuss the verification of the system and game engine, but in this context, it should be clear that there were certain parameters that were not successfully tested and verified by the developers before the research was conducted using that engine. It turns out that the AI agents discovered these

problematic areas in the engine by themselves and exploited it. In a 'perfect world' the verification process would be so thorough that all of these problems/'bugs' were discovered before the research was conducted. That at least should be the aim and is what we try to achieve. Given the scope of some research, it is not always possible. However, in this module, you should demonstrate how you considered and implemented a thorough verification strategy.

https://www.youtube.com/watch?v=Lu56xVlZ40M

- Practical 2 also covers and partially assesses ECSA GA 5. As such, you should also submit a partially completed Addendum for Practical 2 that covers the subcomponents GA 5.1 and 5.2. Refer to section 2.10 of this document for details. When the assignments and practical reports are combined into the final document, this partial addendum can be included as part of the addendum of the final document.

- *Practical 3 (and examination report): see next section*

Part D: Research methodology (experiments), results and conclusion

This section is submitted as an examination report during the November examination period based on work that was completed and successfully demonstrated in Practical 3. It will contain a minor section with content related to Practical 1, but mostly focus on the experimental methodology of Practical 3 and some additional work completed after the final practical.

2.5 Writing your methodology section (continued)

Note from the previous section that you have met only half of the requirements of your complete research methodology. This methodology section focuses on the experimental work and your writing follows exactly the same principles as for Part C, merely considering different content (designing, implementing and verifying your *experiments*, rather than the *simulation implementation* of the software model).

Similar to the simulation method, for this section

- you identified and investigated at least 2 analytic/theoretical experimental methods and implemented it within a simulation environment (developed in Practical 3) that gathers raw data generated by a hardware platform (developed in Practical 1 and modified with the Practical 2 models). The two most important questions that you should answer here are the same as above:
  - How did I implement my research *experiments*? This gives the details on your theoretical experiments; what are their relevance and what do they measure, how are the performance parameters extracted from the collected data, how do we interpret these parameters and how was the experiment implemented in software (motivation for your software tool selection).
  - How did I verify that my research experiments are working as expected? Keep in mind that when we implement algorithms in software from first principles, people are prone to making mistakes. We need to ensure that these mistakes were

eliminated or drastically minimised. As for the simulation model, any implementation needs to be verified first to ensure it is working correctly before it can be used for analysis. This gives the details of your initial verification, which would typically be informal, say looking at waveforms and comparing them with a few analytic results calculated by hand. This is then followed by a formal verification methodology testing your system against a range of parameters, which is typically a full digital simulation experimental setup itself, ensuring that your system will continue to produce useful and predictable results over a range of operating conditions / variable changes.

Since your data set will initially not have it's performance metrics characterised, using an unverified experiment will provide an output value that has uncertainty and too many unknowns exist (unknowns from the input and from the implementation prior to verification). To remove that uncertainty, you need to devise a strategy of eliminating unknowns by means of a more formal verification method than merely checking a few test vectors. You will often set up and design a specific input / data / set that will give a predictable output for a given experimental setup. This is used to analyse this data set in order to ensure that the predictable output is obtained and that the experimental setup is implemented correctly. Alternatively, an already characterised data set from a public source can often be used to eliminate the first unknown and verify the experimental setup. Other strategies also exist and are discussed in class.

2.6 Data collection

You should briefly describe your methodology towards collecting the data. This section need not be long for this module, although this is not always the case. For interest sake, in other research areas, notably social sciences, this section could be the major component of the research report, as a lot of care is needed to collect data, say with questionnaires that need to be compiled very carefully, but through initial probing or testing, etc.

2.7 Conveying your results

Now that you finally have i) collected *verified data* (verified by your verification strategy) that you are sure is authentic to what you expect from your research model, and ii) an experimental platform that has been verified to extract authentic performance parameters, you are in a position to generate a set of extracted metrics that can be used to gauge the performance of your research system based on the variables identified in your research proposal.

Before you start with this section, it is highly recommended to download a few (say 5) journal articles on your favourite topic, but you can also diversify and cover a few vastly different electrical/ electronic/computer engineering topics. The importance and focus of this exercise is not on the actual content presented, but rather on the format of how researchers present their results. By carefully considering the format of the respective results sections, you should realise from the exercise that when the detailed content is mostly ignored, (almost) all of these papers follow the same pattern (format). You should, with some practice, identify that the researchers present three critical components in their writing, being

- *actual results from their experiments*: The presented results are typically either tabulated or plotted in a graph. Typically tables are used to present exact results, while graphs are used to highlight trends in results. What one should also realise is that most research projects have massive amounts of collected data. This data sometimes/often needs to transition to an intermediate form (representation) to reduce cluttering and demonstrate trends more clearly. However, even intermediate steps may have so much data, and the actual data *relevant to answering your research question* gets hidden in the 'clutter'. Remember the golden rule, the reader should never wonder about your contribution! And this is *your* responsibility to ensure. Less is more, more often than not. Nothing prevents you from presenting intermediate data in an appendix if writing a report, dissertation or thesis, but you'll notice from research papers that you do not find pages and pages of results, only the most important ones directly related to the research and useful for answering the research question(s).
- *a discussion of these results*: Results by themselves are just numbers or graphs and as such, they require some interpretation. You will normally consider these numbers and critically evaluate them by asking questions like whether the numbers fall within expected ranges, and if not, what could possibly be the explanation of the deviation (Poor measurement? Poor experiment? Poor modelling of the phenomena? Noise? Manufacturing deviation? etc.). Do we observe the expected trends, and what is the cause for outliers? You are expected to show insight into the interpretation of the results. You can not expect the reader to do it on your behalf.
- *a comparison of results*: Here we have a number of factors that play a role and could be compared. How does the performance of your proposed research model compare to that of the reference model? This reference model can either be a generalised, standard model used for the application by all researchers in the field (how does your model compare to the industry standard), or a specific implementation that you have modified (how does your modified model compare to the unmodified version), or both of these cases.

  Furthermore, depending on the research topic, you have likely also developed a theoretical model, a simulation model (Practical 1) and a hardware implementation with measured results (Practical 2 and 3). In the digital domain, with sufficient verification, one would not be entirely wrong to assume that, at least in terms of functionality, the theoretical, simulation and hardware implementation offers the same functional results, unless of course one starts looking at timing and gate delays as well (which can be significantly different in FPGA and ASIC, for example). As such a comparison of these often ends up with the same result. However, in the analogue domain, one will always measure in the presence of noise and component tolerance will always influence the experimental results. As such, these results should always be compared as the differences will be apparent (and hopefully not significant).

  Considering all of the above, in this module you should at the very least compare the extracted FPGA results of your research model implementation with that of a reference model proposed in your research plan, i.e. a similar/same model from literature. The second minimum requirement is to compare your results from at least one published result from literature.

A word of caution: A very common mistake made by students in the results section is to include results that are irrelevant to this particular section. Hardware/software results that *verifies* your system operation and functionality **should not be part** of this section. The results included here are aimed at answering your research question. Your verification results need to form part of your verification methodology section in an earlier part of the report.

A second common mistake is the wrong impression that many results are better than few. This is also not the case. You should be very concise in your presentation. As such, you should avoid anything that removes focus from your contribution. You want to very clearly highlight the results that support your contribution and answer your research question(s).

2.8 Writing your conclusion

The conclusion section is one of the most important sections to write well when one considers that it is often read much sooner than what the order / it's position in a research report suggests. It is used to tie all of your components together in a very concise manner. Recall that you identified a problem that is supported with your literature review, which in turn led to a research question worth investigating. You completed an entire research project by developing and verifying (a) research model(s) and experiments in pursuit of the answer to this question. As such, you need to dedicate this section towards drawing *honest and realistic* conclusions about your proposed method.

You can repeat the exercise mentioned earlier by once again considering the articles you have selected and analysing their respective conclusion sections. You should identify the following (or most) components present in a well written conclusion:

- A reminder of what the author(s) wishes to prove, either in the form of a paraphrased version of the problem addressed, the research question, the hypothesis or even the suggested research model. What you should read into this is that the contribution of the research project should be highlighted.
- The most notable result demonstrating the improvement / contribution of the research approach. Keep in mind, the most notable result will be the one that actually answers your research question, so there should be clear evidence of you doing just that. You've asked the question and done the work to find the answer, so what is that answer? In summary, highlight
    - the improvements and advantages of your research model, and
    - the answer to your research question.
- You are very likely to have discovered disadvantages to your approach as well. If not, you probably did not investigate your method with sufficient vigour and depth. Although one may be inclined to think that you should not mention these, they absolutely need to be included. It supports your work and especially the fact that you objectively consider your results and present all your findings in an ethical manner. Not only that, you are reminded that research leads to more research. New research questions can often be discovered by considering these disadvantages in the context of the research work, and outside that context.

As a final note on the section, one needs to be brutally honest in your findings and the conclusion should be supported by your results. If it turns out that your results are subpar, you should report that your proposed method is not a good approach to solve the identified problem. Keep in mind

that the evaluator of the section needs to be convinced that you can critically think about results and draw meaningful conclusions from them. If your results are poor and you still decide to conclude that your suggested research approach is appropriate to solve the problem, it clearly demonstrates that you either can not draw meaningful conclusions, or that you are happy to report in an unethical manner. As you can imagine, neither of these approaches are acceptable.

2.9 Compiling and writing a references list

Both the IEEE and Harvard methods are acceptable, but you should select one and use it consistently.

2.10 Addendum

The addendum consists of additional information that does not necessarily highlight the contribution of the research, but was required to reach the end result. Although one would not normally include a discussion and demonstration of the required engineering skills to reach that end product, in this report a short essay needs to be included to demonstrate mastery of the required GA 5 skills. Before continuing, also consider the formal GA 5 description and range statement (especially points 1 and 2 are important for our specific discipline) included in Section 2.11. Using these three subheadings, write a section on each:

- Application of appropriate engineering methods.
- Using appropriate engineering skills and tools.
- Assessment of outcome from engineering methods, skills and tools.

Firstly, address the issue of engineering methods. You could ask yourself whether this refers to the actual engineering method for design, or rather the research method. Considering the report addresses GA 4 as well, the research method is more appropriate. A reminder (from the ECSA GA 4 definition) - An investigation differs from a design in that the objective is to produce knowledge and understanding of a phenomenon. There should already be a lot of evidence of you demonstrating correct methodology in the main report of your body. However, part of this methodology requires one to also investigate and consider as part of your approach which software tools will be utilised. As you can imagine, new projects (either design or research) often goes with a lot of uncertainty that needs to be clarified early in the project phases; and one such uncertainty is related to which software tools can be utilised to solve the problem.

The selection of the software tools applies to both the engineering and research methods. During the various phases of your research project (but also for any engineering problem), you encountered (and will encounter in future) decision making processes regarding which software tools to select and which tools (and often available libraries/add-ons) are the best to solve the problem (i.e. why you select them). What ECSA requires are that exit level engineers have the ability to look at *"any"* problem, apply the engineering or research method (like the research plan done in this course), and then for GA 5 identify all relevant software available, choose and motivate your specific selection and apply/demonstrate that you can use those software tools. Furthermore, you need to look at the outcome of the tool and assess the success of that outcome. These are usually niche tools specific to engineering and/or science, and usually more than one used in an integrated manner to solve the problem.

First, we address GA 5.1. Apply *your* specific research topic to the "*any*" problem above, i.e. ask the questions below, demonstrate critical thinking to answer these questions, and find/document the answers. Consider all aspects of the research project, i.e. modelling, data collection and experimentation. Which software tools could you have used? Compile a list. Which software did you select from that list and why is it either the best or at least suitable to solve the problem? What are the limitations of the software and considering those, how does it impact your approach (for example, a software may simulate a functional implementation, but not consider timing delays in the actual hardware implementation, etc.). Avoid including a long, detailed, separate discussion of each tool that was used, but rather a focus on a description of and motivation for the type of tool that was used to address sub-problems and the integration of tools to solve the overall problem.

GA 5.2 requires demonstration of skill to utilise specific engineering software suites. There should be ample proof of this from Parts C and D, both for simulation, hardware implementation, verification, data collection and analysis. For example, an output graph generated by specialist tools is hard to create if you did not actually use the tool and goes a lot further than merely stating 'Tool ABC was used to simulate …', etc. Therefore, in this section list or tabulate the software packages utilised relative to the various research phases / challenges with reference to figures in your report supporting that claim. Do not repeat figures. Also cover the topic of how you integrated the various software packages. Furthermore, how did you integrate the software with your hardware? This forms part of the required explanation of how you use the software tools.

GA 5.3 requires you to demonstrate how you assess the outcome of the tools. If the tool reports that you generate sequential logic, but you require combinational logic, you need to be able to interpret that (assess the outcome). This GA is evaluated in Parts C and D of the report, but you are encouraged to write at least a paragraph on the topic to assist the evaluator.

You may also include the following *optional* sections:

- Flow charts, diagrams and/or code snippets of software implementations
- Additional results

The following parts offer some additional insight, but should not be included in your report.

2.11 Frequently Asked Questions

These are some of the questions that have been asked by students:

Q1: With regards to the numbering (page, figure, table, etc.) for the examination report; will it be acceptable to keep the original numbers of each part i.e. the numbers originally given in assignments 1, 2 and report 1 or would it be preferable to recompile the entire final report to have the numbering corrected and in sequence for the whole report?

A: Consider the disclaimer in the example document:

" ... the content has not been changed to such an extent that it could be interpreted to mean something different from that as my final submission."

Changing the numbers will not change the interpretation of the content if it is done consistently (i.e. in the caption and the body/content). As such, you can change it should you wish, but you will not be penalised should you decide to leave it as in your previous submission. The advantage of the approach is that one presents a neat document for the external examiner with a sequential numbering scheme that makes more sense. The disadvantages of this approach is that internal examiner comments of the semester assignments might not make sense, and there is the risk of making a mistake and referring to figures incorrectly in the body if the links are not correctly set up. The choice remains yours.

Q2: Will it also be acceptable to leave the figure numbers assigned in the assignments 1, 2 and report 1 as they are?

A: The previous answer applies here.

Q3: Can/should we use the separations for each section provided exactly as they are or should we create our own representations of these pages?

A: Use the pages exactly as provided. Use the pages in the example exactly and merge/insert your reports into the appropriate placeholders. Do exactly what is expected in the example and framework documents. The example and framework documents should be considered instructions, not suggestions. Deviation results in unfortunate penalties that could easily be avoided.

Q4: But can we change … <interrupted>

A: No. See previous question (Q3).

Q5: Should I include a table of content / list of figures / abbreviation?

A: This would be a change. See Q4.

Q6: I am concerned that some of my earlier submissions will be interpreted as plagiarism. Will I fail the examination if I plagiarised someone else's work?

A: Yes. You have to fix this in your examination submission.

Q7: (Follow up on Q6) But I don’t want to fail the module after all this effort! What now?

A: You have to fix this in your examination submission.

Q8: (Follow up on Q7) But I am not allowed to change/modify my last submission(s)! See Q4!

A: Refer again to the disclaimer that you are required to submit for each of the previous reports:

" ... the content has not been changed to such an extent that it could be interpreted to mean something different from that as my final submission."

Only correct certain/definite plagiarism related problems without changing the meaning of what was said. This normally happens when you copy and paste directly from articles/reports. You are not allowed to do this without express permission from the publisher. As such, you can only include in your report your specific interpretation of what they published, and that goes with paraphrasing what they've done into your own words, i.e. synthesis. And of course, they still need the credit for the original work, so include a citation. Even if you redraw figures, always include in the caption a phrase similar to '(a modified implementation from [4])'.

Do not modify the meaning in any changes you make. If you promised in your method a model ABC, do not modify it now to model XYZ.

Q8: What format should I use for Parts A, B, C and D?

A: The format is not specified. However, it is expected that the document presents as a professionally prepared research document. You are encouraged to use a recognised standard like that of the IEEE.

Q9: I had an appendix in my report submitted for Part A, B and/or C. Where do I place that in the examination report?

A: Considering the goal to present a professional looking technical document, it is recommended that you move that appendix to the appendix of the examination report, i.e. keep the main body of the examination report as clean and concise as possible, with additional information (like the earlier appendix) placed in the appendix of the examination report.

2.12 Formal ECSA Exit Level Outcome Definitions

Graduate Attribute 4: Investigation

Conduct investigations of *well-defined* problems through locating and searching relevant codes and catalogues, conducting standard tests, experiments and measurements.

Range Statement: The balance of investigation should be appropriate to the discipline. An investigation should be typical of those in which the graduate would participate in an employment situation shortly after graduation.

Note: An investigation differs from a design in that the objective is to produce knowledge and understanding of a phenomenon.

Graduate Attribute 5: Engineering methods, skills, tools, including Information technology

Use appropriate techniques, resources, and modern engineering tools including information technology for the solution of *well-defined* engineering problems, with an awareness of the limitations, restrictions, premises, assumptions and constraints.

Range Statement: A range of methods, skills and tools appropriate to the discipline of the program including:

1. Sub-discipline-specific tools processes or procedures.
2. Computer packages for computation, simulation, and information handling.
3. Computers and networks and information infrastructures for accessing, processing, managing, and storing information to enhance personal productivity and teamwork.
4. Basic techniques from economics, management, and health, safety and environmental protection.