**Autonomous Rampaging Chariot Project Report**

**Background.**

The Autonomous Rampaging Chariot is a Scottish Secondary school coding project. This new ‘module’ delivers a comprehensive kit of parts and instructions to convert a radio controlled Rampaging Chariot Sporting Robot*, (previously constructed by Scottish Secondary pupils under an existing extra-curricular STEM initiative)*, into an Autonomous sporting and exploration Robot. Controlled by a Raspberry Pi computer programmed in Python, it is an exciting upgrade to an already successful project and focuses on teaching coding in a real-time environment The Project is delivered by Rampaging Chariot Guild STEM volunteers in partnership with Leonardo MW and the SCDI.

Digital Xtra funding has been used to manufacture and trial the Autonomous enhancement in four schools:

Johnstone High School, Renfrewshire,

Merchiston Castle School, Edinburgh

Sgoil Lionacleit, Benbecula,

The Glasgow Academy

The Autonomous trial targets the upper end of secondary school (S3,4,5) with teams consisting of between three and six members (total 19). Two female pupils were involved, and one school has two team members from (S2). All schools are doing the project as an extra-curricular activity in their STEM Club.

**Aim.**

The construction of the prototype autonomous kits by the school teams, useful feedback to improve the kit and successful modification by pupils of the Python Code in selected modules.

**Project Timescale and Milestones**

The project was due to start in mid July 2016 and had two phases and two associated milestones.

**Phase 1**

The initial phase involved the final design and procurement of all the hardware for the Autonomous Chariot evaluation kits including sensors, actuators, switches, cables, Raspberry Pi Computers, Printed Circuit Boards and 3D printed brackets for sensors.

**Milestone 1** was the completion of this phase and the delivery of kits to the selected schools. It was originally scheduled for 30th September 16, but a one month slippage to 31st October 16 was agreed by the Digital Extra Fund due to the late award of the contract and associated transfer of initial funding for procurement of parts. This revised date was achieved.

**Phase 2**

The second phase involved installing the sensors and autonomous system into the existing Rampaging Chariot chassis followed by testingthe motors and sensors using the Raspberry Pi and software modules coded in Python. A progressive approach in coding difficulty was employed with coding exercises supplied to extend the testing and to modify existing Python code. The final route-test programme enables the robot to travel round the classroom between sequential Waypoints defined by the pupils.

The purpose of the second and final phase of this project was to collect feedback from the pupils and teachers to ensure that teething problems are discovered and dealt with efficiently and with personal attention; including school visits. Positive feedback will lead to the project being rolled out on a larger scale.

**Milestone 2** was the delivery of this report containing feedback and schools assessment of the project to SDS. It was originally scheduled for 30th April 17 but, due to the school clubs not meeting during their exam period in April/May, meaningful feedback could not be obtained until late May 17.

*We have challenged the participating schools to demonstrate their autonomous Chariots undertaking the Assault Course event at the annual ‘Rampaging Chariots Scottish Robotic Games’. These Games are hosted by Leonardo in Edinburgh on 10th June 17 and all our schools have registered to attend.*

**Execution**

The Autumn term is generally free of exams and is the best time for extra-curricular STEM clubs to concentrate on a project of this description. Feedback from schools highlighted that whilst waiting for the autonomous kits, the STEM club had to provide another project to keep the designated pupils occupied. Two schools bought an additional standard subsidised Rampaging Chariot kit for this purpose and two schools provided coding exercises in Python for their teams. These new Rampaging Chariot kits had to be finished before the autonomous project could be started.

Due to the initial funding delays and unforeseen problems experienced by all schools in installing the odometers, the installation of sensors was not achieved by Christmas. The lead school started the Python sensor test programmes at the end of January 2017 and the last school in March.

During Phase 2, sixteen visits by one or two STEM Ambassadors from the Guild and Leonardo were made to the schools.

**Installing the Sensors and Autonomous Systems**

All four schools completed this section satisfactorily and said it was a popular and interesting task, particularly as they had to find solutions to some installation problems. Unfortunately progress has been slower than expected and feedback from schools identified several factors that contributed to this:

1. The initial SDS programme delays.
2. The installation of the odometers

All four schools had trouble lining up the odometer IC with the magnet on the drive wheel axles. Pupils recommended we improved this aspect and between us we have devised a design change that should overcome the difficulty.

1. Attaching the Infra-red sensor to the stepper motor shaft.

All four schools had problems with attaching the Infra-red sensor to the stepper motor shaft. When inserting and tightening the fixing screw, two schools split the 3D printed housing and two schools stripped the plastic thread in the housing. This should be easy to overcome by increasing the size and strength of the 3D printed housing in this area.

**Testing the Motors, Sensors and Scanning Actuators Using Raspberry Pi and Python Code**

Two schools have completed this section satisfactorily and one is almost complete, but progress has been much slower than expected and exams have had to take priority. Due to a recent wiring fault with one odometer, the remaining school has decided to operate its autonomous Rampaging Chariot in manual mode to ensure it’s pupils can compete at the Games in June.

1. All schools got the Chariot motors and wheels turning in the correct directions at varying speeds under Raspberry Pi computer control.
2. The coding exercises to modify the test modules were generally completed successfully.
3. When the odometer magnets were correctly aligned, all schools were able to get the odometers working and showing the correct readings.
4. Some schools had initial difficulty in getting two R-Pi’s to operate correctly as a Hotspot and WiFi to allow remote start/stop functions and telemetry. Leonardo provided advice and are making code modifications to make this set up easier and more reliable. One school experienced communication drop-outs. This was investigated by the Leonardo software specialist who was unable to cure the problem at the school. After some long distance discussion, further testing by a STEM ambassador at the school concludes that there is probably interference from the school WiFi network.
5. The odometer/chariot calibration tests have resulted in several questions from schools during visits. These are test sequences that would benefit from an instructional video which we are currently working on.
6. There were some issues with e-mail attachments containing code updates in Python being blocked and then not released by the school's Network Services.

Initial feedback from the pupils and staff show that the five test programs are well within the pupils ability to operate, but some pupils are not yet able to do simple modifications of the Python Code without help or accessing the ‘answers’ file provided. Nevertheless modification of existing code is a proven way to understand Python, and helps pupils understand the generally simple coding techniques employed in the test programs.

All the school pupils have been very helpful in pointing out areas in the manual that can be improved to assist their understanding of the installation of the sensors, the test programmes and the coding exercises. As a result we have identified several items that can be improved by simple design changes or improvements to the manual.

The inclusion of Sgoil Lionacleit on Benbecula has been very useful to the project due to its remote location and its involvement of the youngest participants. These two factors have resulted in a number of challenges, as visits required air travel and an overnight stay. This highlights the benefit of undertaking this development project, as a wider rollout will generally require questions to be answered by e-mail.

**Autonomous Chariot Project Questionnaire – Teachers**

**Statistics**

1. School/Club Name:

Johnstone High School STEM Club

Merchiston Castle School Senior Engineering Club

Sgoil Lionacleit STEM Club

The Glasgow Academy, Mark Andrew Engineering Club

1. Frequency of activity and average time spent at each meeting:

Weekly 1-1.5 hrs,

Weekly 1.5 hrs,

Weekly 1-2 hrs

Weekly 1.5 hrs

1. Number of pupils/year/gender involved in this project:

3 boys (S4),

3 boys (S5) (boys school) / 1 girl (S3) (teachers daughter involved),

6 boys (4 S3 & 2 S1)

5 boys (4 S3 & 1 S6 mentor) / 1 girl (S3)

**Please comment on the Suitability, Difficulty and Learning Outcome of this project for your pupils.**

1. **Installing and mounting the sensors and electronics provided.**
2. Easy to assemble sensors etc. but time consuming (around half of the year)
3. The students really relished this part of the project and undertook all the work independently, spending their own time to complete the work ahead of schedule.
4. Odometers proved to be most challenging sensors to mount accurately. Additionally, IR and Ultrasonic sensors easily detached.
5. The team seemed able to do this themselves, but it did take them quite a long time.
6. **Understanding the manual provided.**
7. Manual was well written though more diagrams and pictures were needed
8. The manual was very comprehensive
9. Some parts of manual caused confusion, but these were clarified with support from Teacher and Stem ambassador.
10. The pupils have not raised any concerns with this and the printed copy they were given.
11. **Undertaking the testing of the sensors and systems using the Python test programmes provided.**
12. Straight forward when things are working
13. This went very well and provided a good introduction to the style of programming expected. The test programs were easy to edit and the challenges to modify them were appropriate for the project brief.
14. Testing ran well up until right turn test – chariot would not turn and due to breakage in sensor, autonomous progress was halted.
15. The pupils have worked with a Computing teacher in terms of Python, which I know nothing about and did think was a type of snake until it was explained to me!!!
16. **What Experience of Coding Python and other languages did the pupils have prior to starting this project?**
17. Pupils had some experience of Scratch, App Inventor, Visual Basic and had dabbled in python (N5 Comp Sci )
18. All students had self-taught prior experience, none had any formal training or academic instruction.
19. Pupils had very limited experience of coding prior to starting. Some coding exercises were undertaken as an introduction to python and the raspberry pi
20. The pupils cover Python as part of their course during S4, but the Computing teacher has helped them with this a year early.
21. **Would pupils have benefited from some simple lead-in projects using the Raspberry Pi and Python to activate motors and LEDs before embarking on this project?**
22. No
23. Yes, I think so, especially if the personal support of the project mentors was not available.
24. Yes. However, STEM ambassador had developed some test equipment and used these with pupils as an introductory exercise for python.
25. I think the Computing teacher and S6 mentor mean this was not necessary/was provided in-school.
26. **Were pupils able to understand the Python code in the test programmes and make simple modifications.**
27. Yes – no problem
28. Yes, definitely
29. Pupils have made simple modifications so far with success following instructions provided.
30. I think they will be, but they're not at this stage yet.
31. **Were pupils able to get the Rampaging Chariot navigating round a planned route?**
32. Yes
33. Yes, to some extent, with a lot of work on the odometers in particular.
34. Pupils did not reach this stage due to problems with wi-fi connections.
35. This is still to be done.
36. **Pupils were not expected to undertake this project without some help from teachers and/or STEM** **ambassadors. How challenging was this project for your pupils and how much help did they require?**
37. Fairly difficult – I didn’t really give the pupils much help
38. The project kept the students motivated throughout the duration of the time available and, in reality, they required guidance rather than help.
39. Project was challenging for pupils. Pupils conducted all work with supervision.
40. They should have had two STEM Ambassadors, but due to the death of Mark only had Paul from 1730 until 1900 each Wednesday, which drastically impacted on their progress.
41. **Was the time allocated sufficient?**
42. More time was needed as the build was time consuming.
43. No, we are always chasing our tails
44. Time was an issue – this was mainly due to other factors impacting on club. Eg. Work on other projects, S3 pupils on work experience, school closures, long weekends – missing out on Friday sessions. Change in pupils attending club. Problems connecting raspberry pis without interference from school network proved to be biggest trouble.
45. It would have been if Mark had been available, as expected, from 1630 until 1830 each Wednesday.
46. **What was the learning outcome for pupils?**
47. The learning outcome was to take on a worthwhile challenge beyond the constraints of the traditional curriculum … and they did.
48. Pupils have learnt co-operation and team working skills. They have developed their understanding of electronics and programming.
49. The team had already worked on a Rampaging Chariot, which they entered at the Games, so the main learning was Python, working as a team and how to respond to a pilot/work independently with adults/professionals and to deadlines.

**The Future**

1. **Do you intend to demonstrate and test your autonomous Chariot at the Scottish Robotic Games in** June?
2. Yes
3. Yes, we have registered
4. Unfortunately due to sensor breakage, we will be unable to demonstrate autonomous aspect.
5. Yes
6. **Do you intend to continue/extend this project next school year?**
7. Yes – we feel like we are just at the start of this exciting project.
8. Yes, we are forming a specific activity to take on this challenge
9. Yes. Pupils are keen to continue and get autonomous chariot up and running.
10. Hopefully, if a new teacher will take on the Club following my departure
11. **What additional capabilities should this project provide?**

b. Knowledge of hardware integration – that is the best part – programming something real in the real world.

c.

**Highlights**

1. Really engaging and challenging project – suitable for older pupils. However, the brunt of the time in the academic year is between August and January. After this there are prelim exams and then final exams and time for extra-curricular activities.
2. The students have been thoroughly engaged throughout the course of the project. When we were behind schedule they came in to school and spent four hours of their Saturday morning – which was a leave out weekend for everyone else – working to catch up. They have definitely benefited from the encouragement and mentoring of the project engineers.
3. Pupils have really enjoyed working on the project, however, problems with local wi-fi connections caused problems with getting the project up and running.
4. I'm just grateful to the support and understanding of Peter and Josh and am sorry that this school year hasn't gone as hoped/expected in August when it started, which has made this harder for the pupils than it should have been. However, they have shown enthusiasm, dedication and certainly risen to the challenge, which I am delighted was provided for them.

**Pupils Testimonials**

**Charlie - S5 pupil:**  
I have been involved with the rampaging chariots guild since I built my first chariot in 2015. I thoroughly enjoyed participating in the games in 2016. As a consequence of our involvement we were lucky enough to be invited to trial the autonomous rampaging chariot. I have particularly enjoyed the coding aspects of the project. This challenge has allowed me to see real world applications of computing and has encouraged me to take computer science at A level along with maths, further maths, physics and mandarin and I hope to study computer science at university. This was not always the case but projects like this have reinforced my determination to do this.  
Charlie   
  
**Bassam – S5 pupil:**  
I chose to do this project because I was excited about getting to build and program an autonomous chariot. Autonomous systems interest me because they are closely related to computer science, a field I hope to go into professionally, particularly software engineering which is why this project appealed to me so much. I enjoyed the electrical engineering aspect of the project as well as this to interests me. I learned a great deal from this project. I learned that I can work well with a team. I learned how to build and assemble certain parts and systems of the chariot that I never knew how to assemble before. This project has helped me to confirm taking Computer Science as a subject at A-level and to peruse it as a degree at university as well as increasing my interest in electrical engineering. I am very grateful to Peter Bennett for allowing me to participate in this project.  
Bassam

**Ben – S5 pupil**  
I first decided to join the project as I was interested in getting more involved in engineering projects as they were something I found interesting - and the original chariot was certainly incredibly interesting, and is probably one of the most important factors that set me down the path of engineering. The autonomous project, however, gave me real word experience of what engineering can be and is like, and was invaluable in helping me develop my knowledge of electronics. I learned how to work as a team and to establish realistic and attainable goals within the parameters of a chosen task, and to solve real world problems with no original solutions as they come up, in parallel with the engineering team at Leonardo.   
This project has also taught me several valuable skills within computer science and coding, and as a result I have chosen to take computer science at A level, along with physics and maths with hopes to study a split course of physics and computer science, or one of electrical engineering and computer science at university. I have enjoyed the project thoroughly and hope to continue with its development to produce a fully autonomous robot capable of traversing an assault course for the next rampaging chariot competition.   
I am incredibly grateful for the mentorship and guidance of Peter Bennett and his team, as without them this project would have been impossible, and with whom it has been a great experience to work with, one which I have enjoyed thoroughly.

Ben

**Summary**

*Our biggest challenge has been to provide a coding project for upper school pupils that is within the capabilities of the majority of pupils and provides them with a real challenge that can stretch and enthuse them in the world of coding.*

We have provided a progressive approach to the coding aspects of this project that has enabled the majority of pupils attending the school STEM Clubs to understand what each test programme does and do simple modifications to these programmes and see what effect it has on the Chariot.

Schools have been very enthusiastic over their achievements so far and all schools are planning to continue the project next school year. The autonomous project has huge potential to stretch bright pupils as they will be able to integrate new sensors such as gyros, accelerometers, magnetometers, cameras, etc. and experiment with modifications of the main navigational programme to improve their performance round a defined course and to undertake other Games events such as Sumo and Football.

Progress has been slower than expected, but the aim of this development project has been achieved.

The school teams have successfully constructed their prototype autonomous kits and successfully modified the Python code in selected modules. Valuable feedback to improve the kit, the instruction manual and the coding exercises has been obtained.

The Rampaging Chariots Guild thank the Leonardo company and Joshua (Hull University sandwich student) for the software development of the main navigational programme.

We also thank the participating schools and their enthusiastic teams for their patience and helpful feedback. We look forward to welcoming them to the Scottish Robotic Games and working with them next school year.

Peter J Bennett

Manager,

Rampaging Chariots Guild

26th May 2017

Copies to:

Participating Schools

Debbie McCutcheon. Digital Extra Fund

Ketty Lawrence. Digital Extra Fund

Allan Colquhoun. Leonardo

Donald Taylor, Leonardo

Joshua Hessey, Leonardo

Jane Martin SCDI

**Attachments**

Video of the mcs Autonomous Rampaging Chariot during testing.

Photo of Sgoil Lionacleit Autonomous Robot