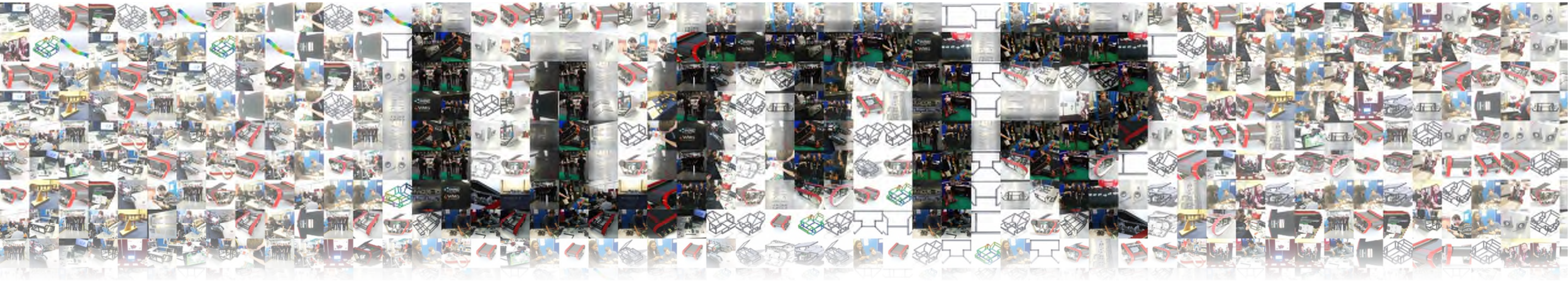


Warwick Mobile Robotics

2014/15

Design & Development of a Miniature Urban Search and Rescue (M-USAR) Robot

WMG Innovative Solutions | School of Engineering | MakerBeam | maxon motor driven by precision | Transdev

Contents

Sponsors:

WMG Innovative Solutions

School of Engineering

MakerBeam

maxon motor
driven by precision

Transdev

Warwick Mobile Robotics – Background

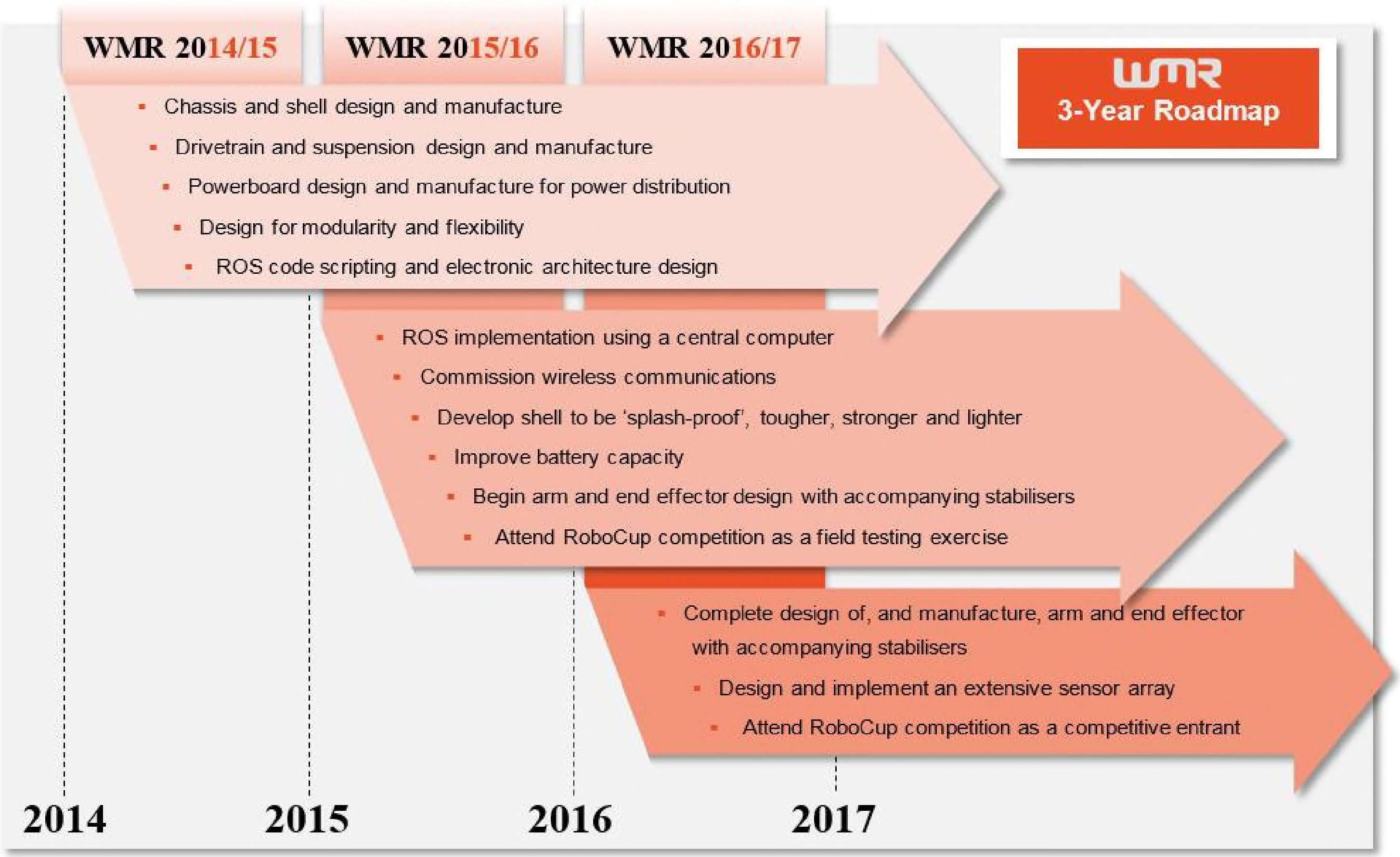






WMR Robots

Strategy – 3-Year Plan



Strategy – Project Aims

Aim 1:

Deliver a mechatronic framework for an innovative M-USAR robot by May 2015 as the first stage of a three-year plan

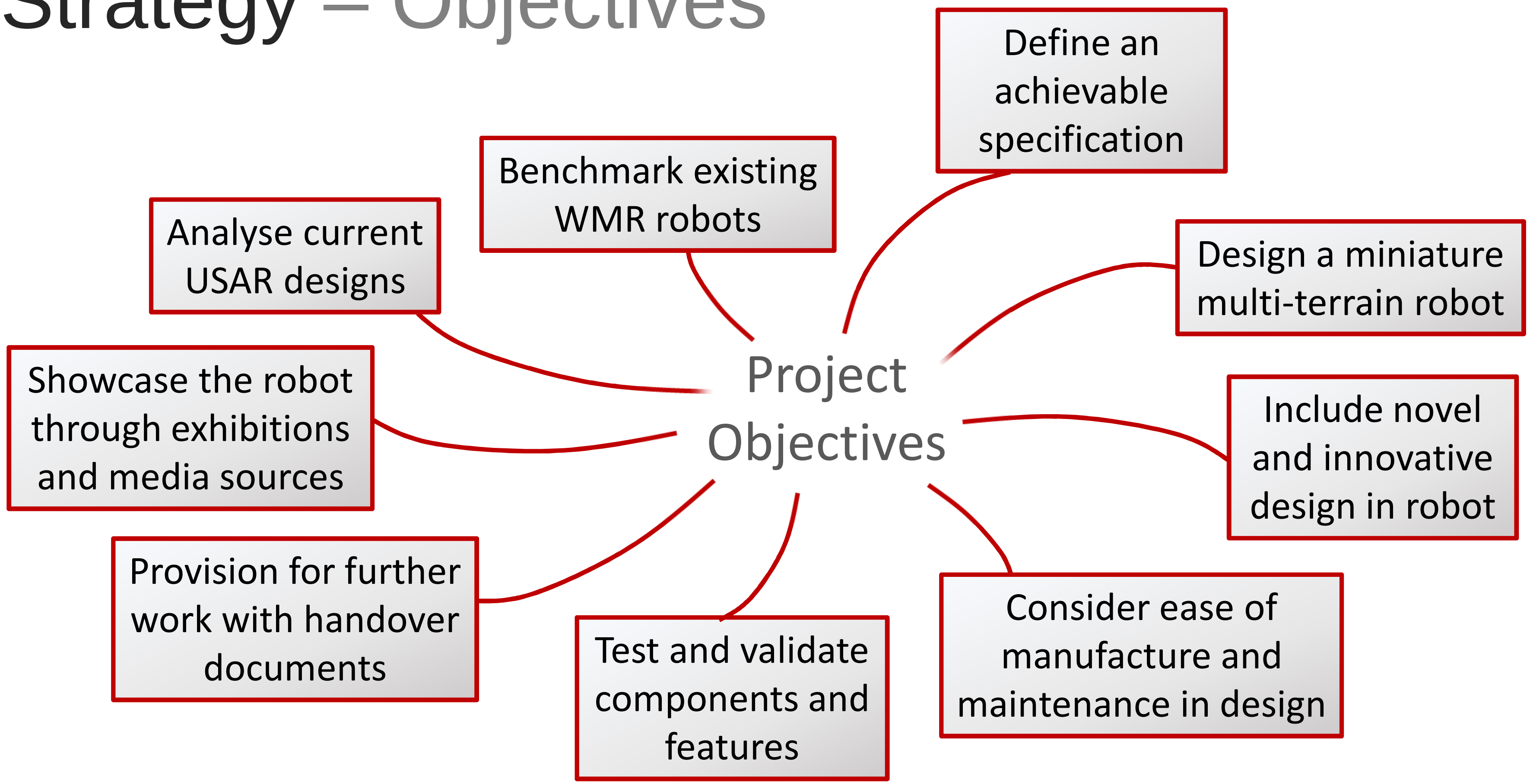
Aim 2:

Provision for design development by future WMR teams

Aim 3:

Exhibit the robot as an educational platform to inspire younger generations

Strategy – Objectives



Design Overview

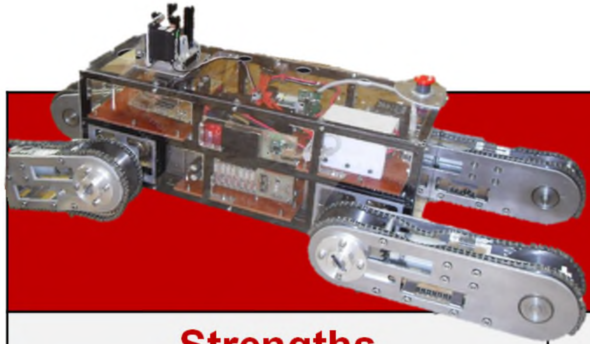
Presented by

Rebecca Saunders

Benchmarking

USAR

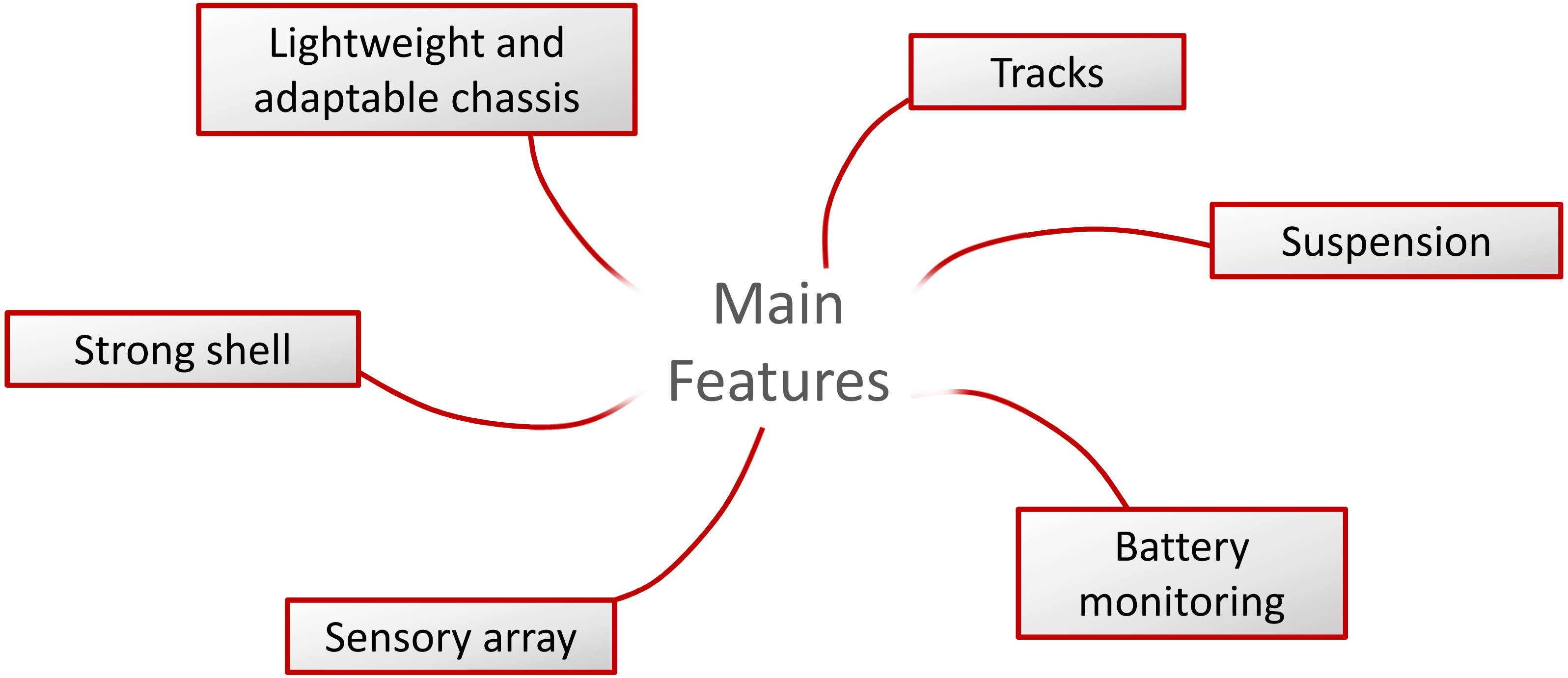
Strengths	Weaknesses
▪ Strong manipulator ▪ Mobile ▪ Wide range of sensors	▪ Very bespoke ▪ Difficult to diagnose and repair faults ▪ Unreliable drivetrain ▪ Heavy ▪ Large and unwieldy



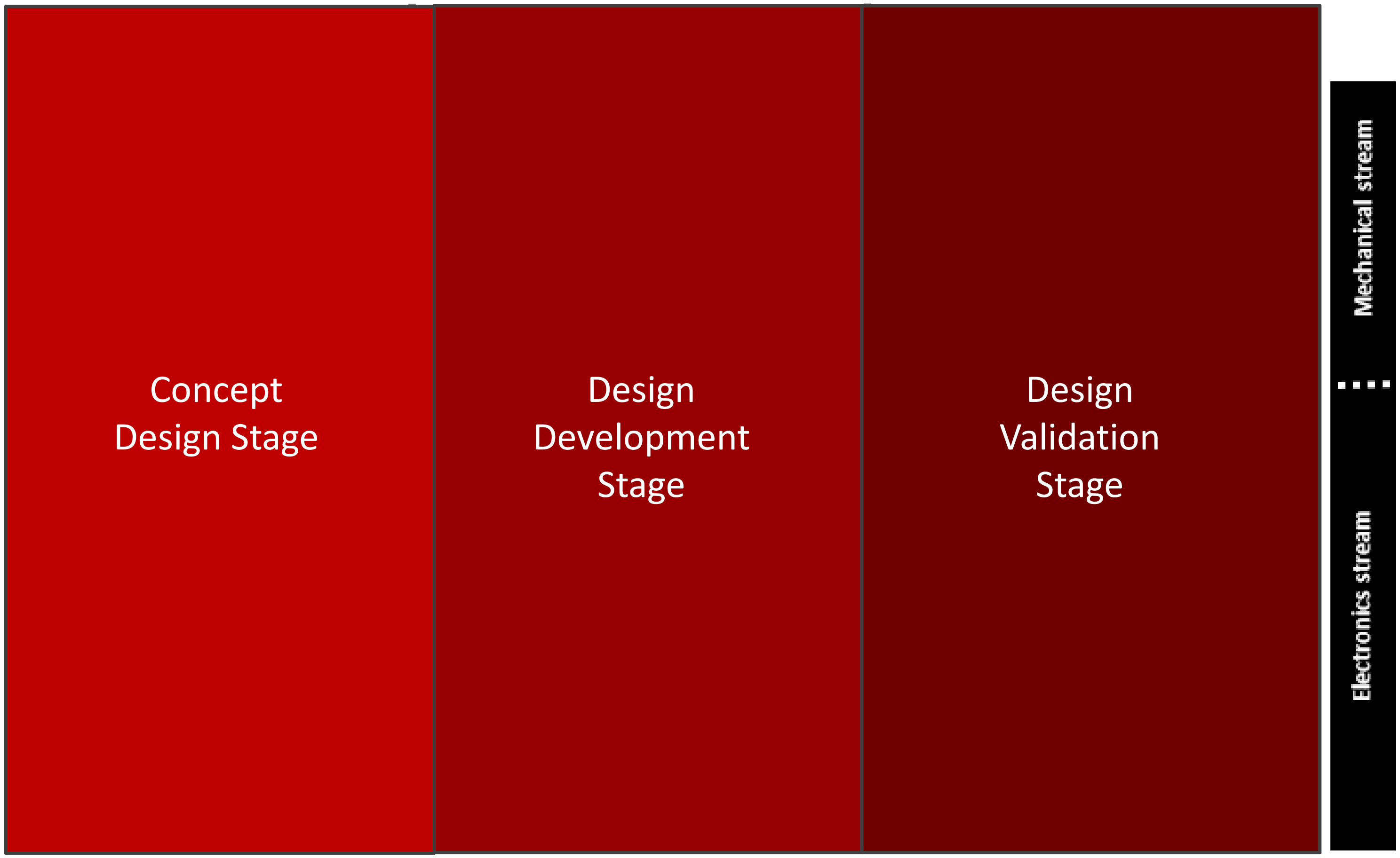
M-USAR

Strengths	Weaknesses
▪ Weight < 25kg ▪ Strong MakerBeam® chassis ▪ Small size ▪ Uses off-the-shelf components	▪ Long battery change time ▪ Difficult to access internal components ▪ Poor chassis clearance ▪ Exposed brushed motors ▪ Wiring through moving components ▪ Inadequate battery management ▪ Poor battery life

Specification Overview



Design Methodology

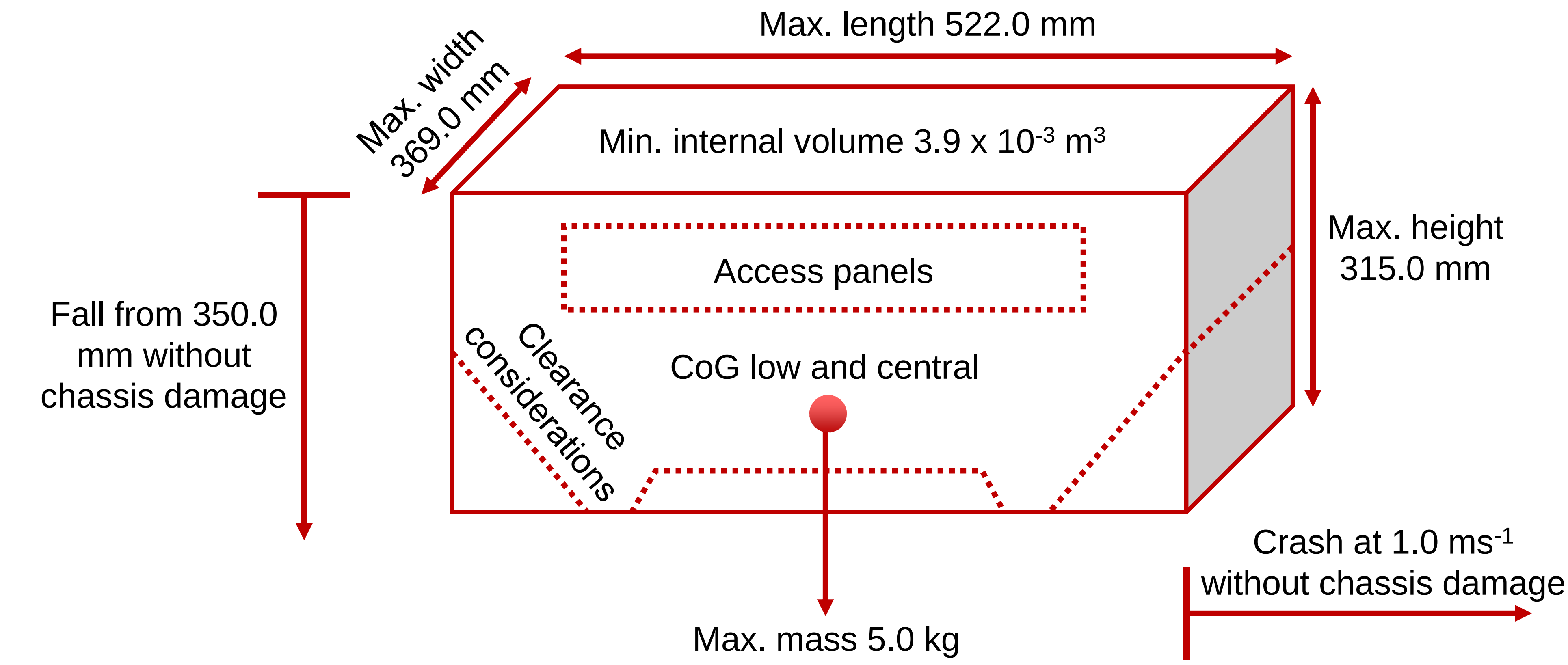


Chassis

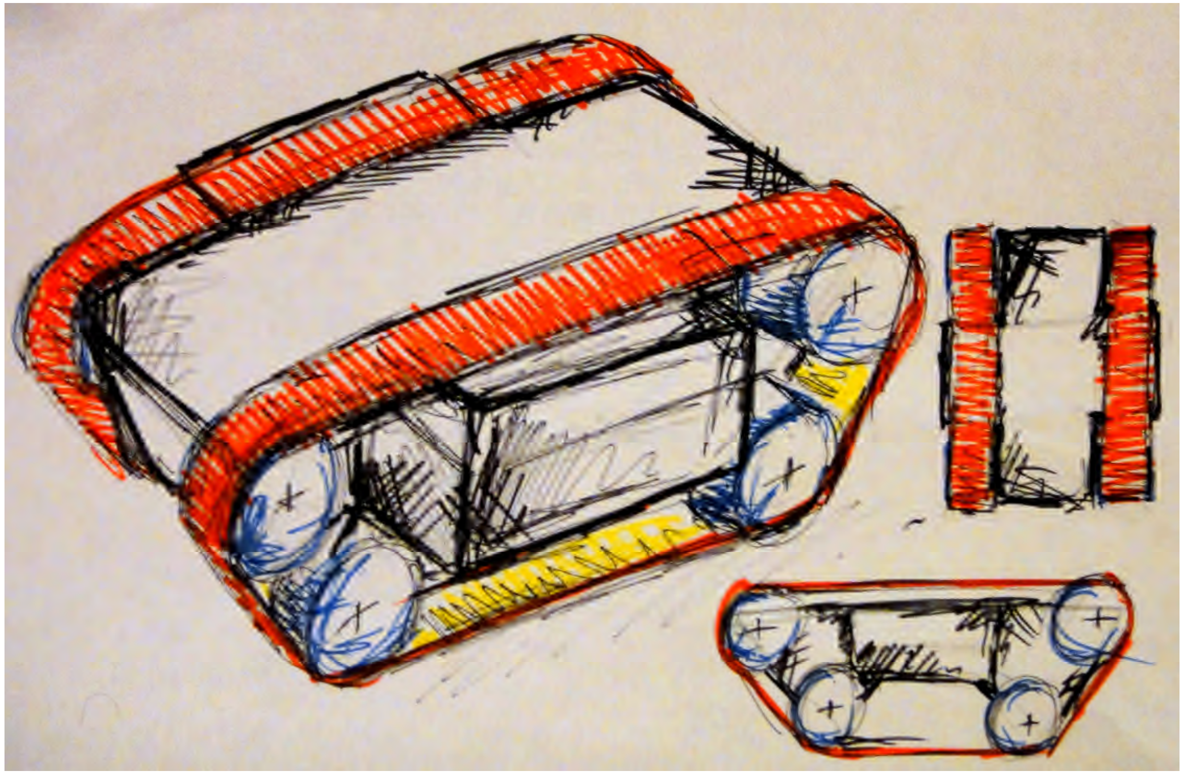
Presented by

Craig Fox

Chassis – Specification

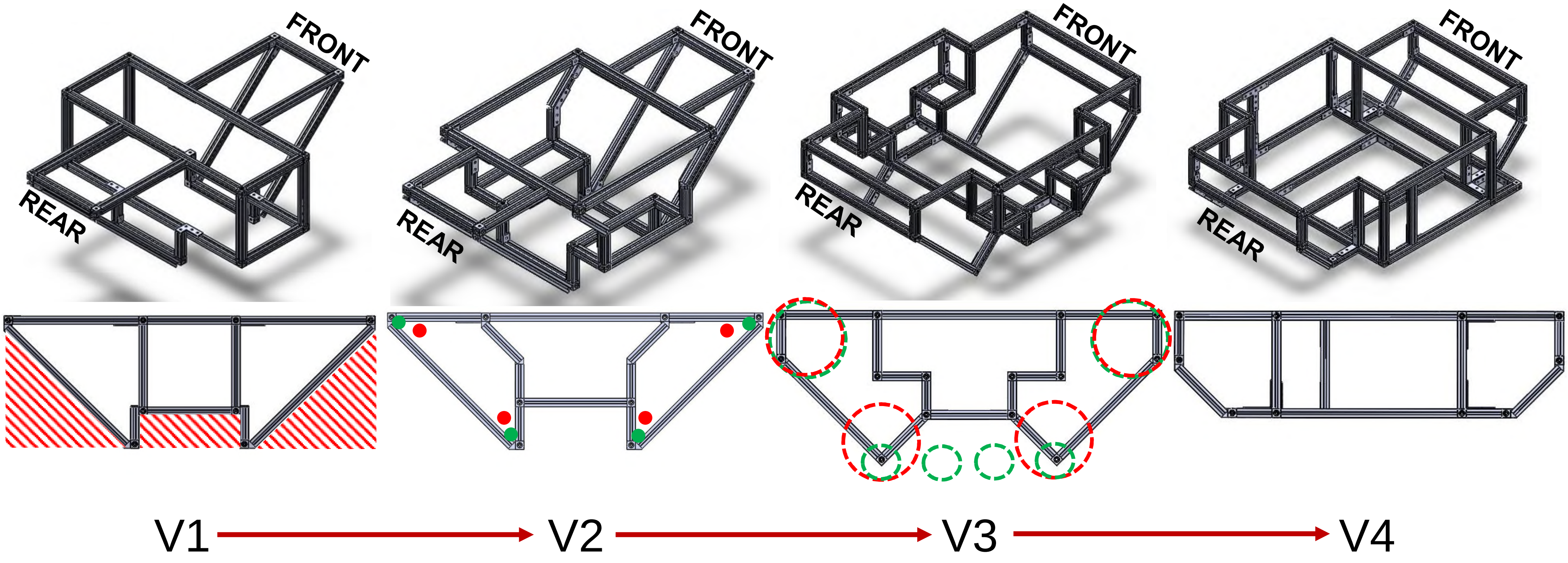


Chassis – Concept Design

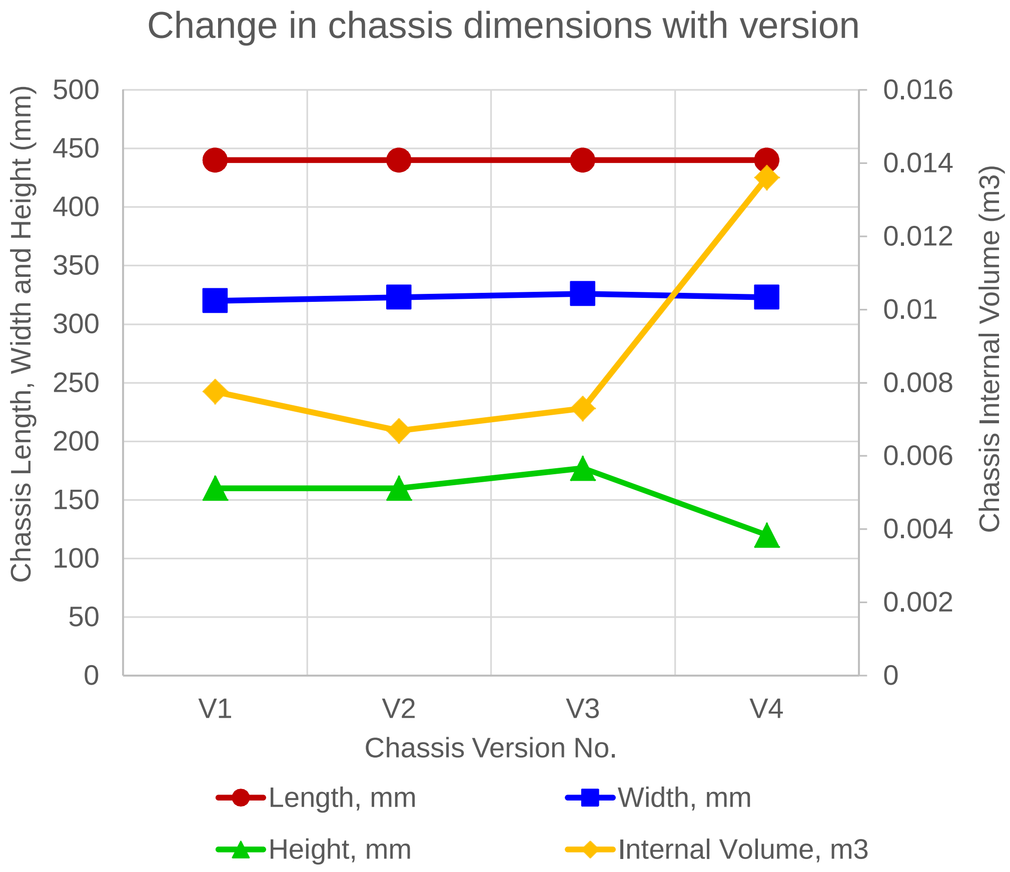


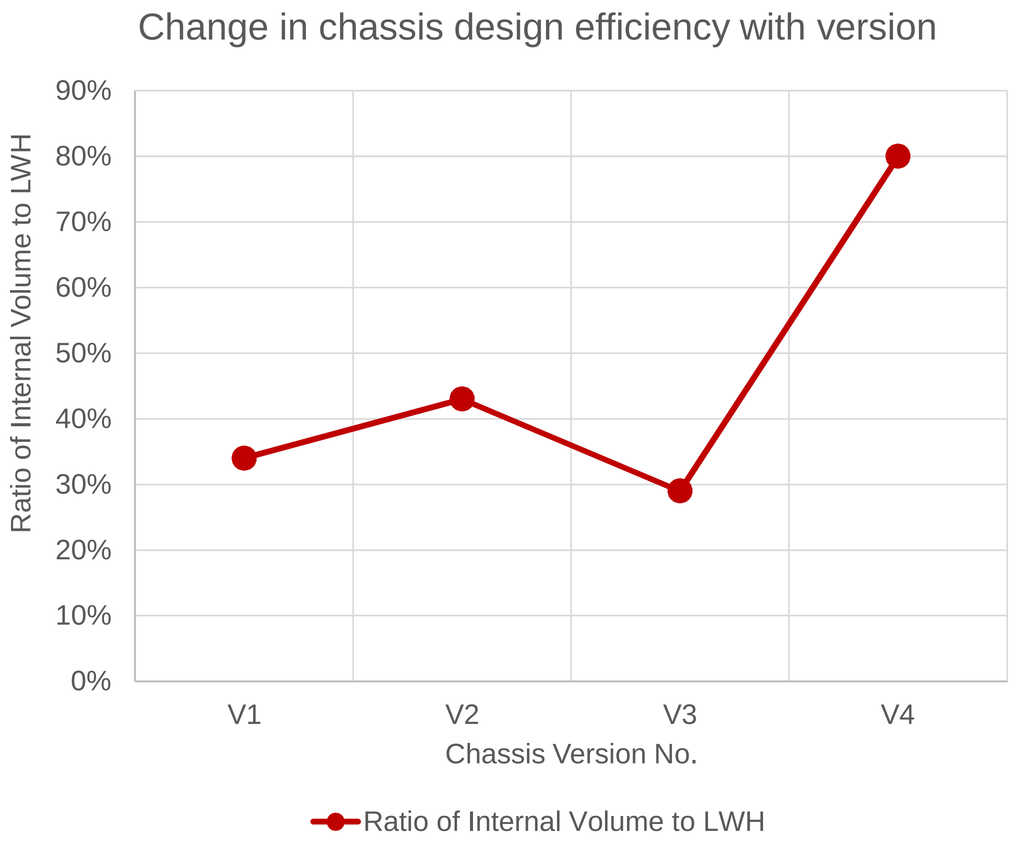
- **Chassis** – MakerBeam®
  - Extruded 6000 series aluminium beam
  - Good ease of assembly
  - Good specific strength
- **Shell** – 6082-T6 aluminium plate
  - Good thermal conductivity
  - Good machinability
  - Lightweight properties

Chassis – Design Iterations

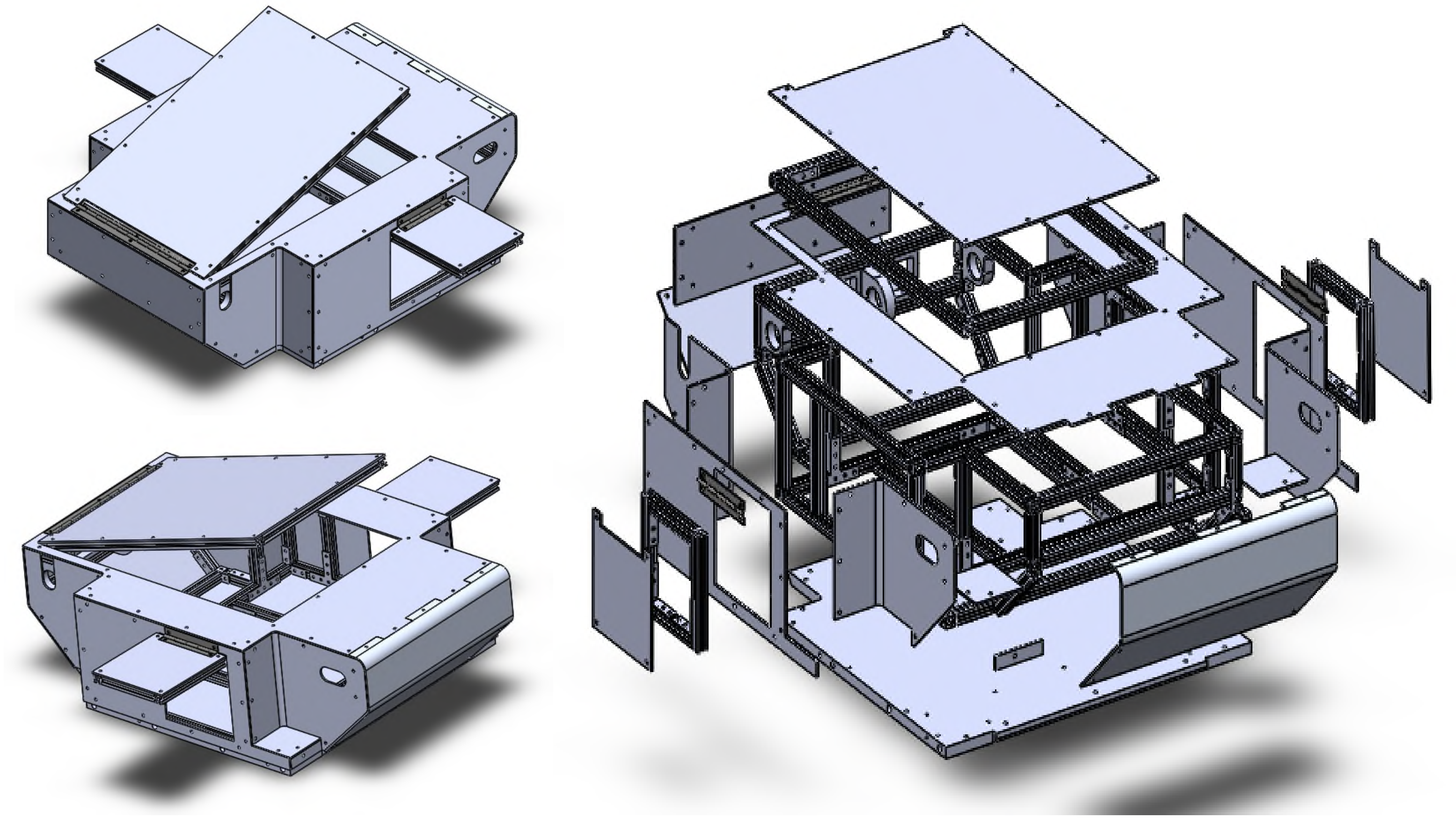


Chassis – Design Iteration Summary

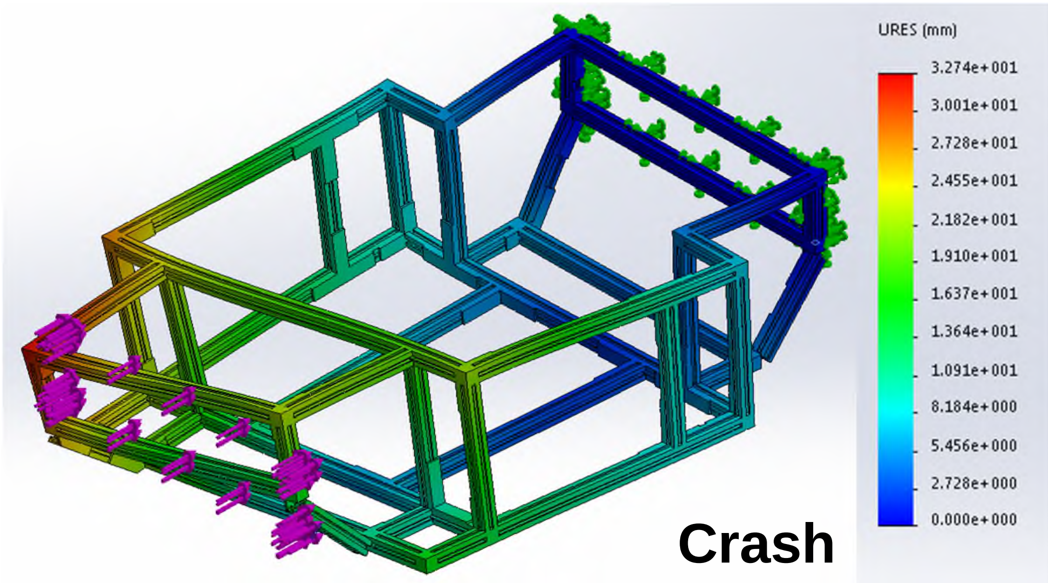


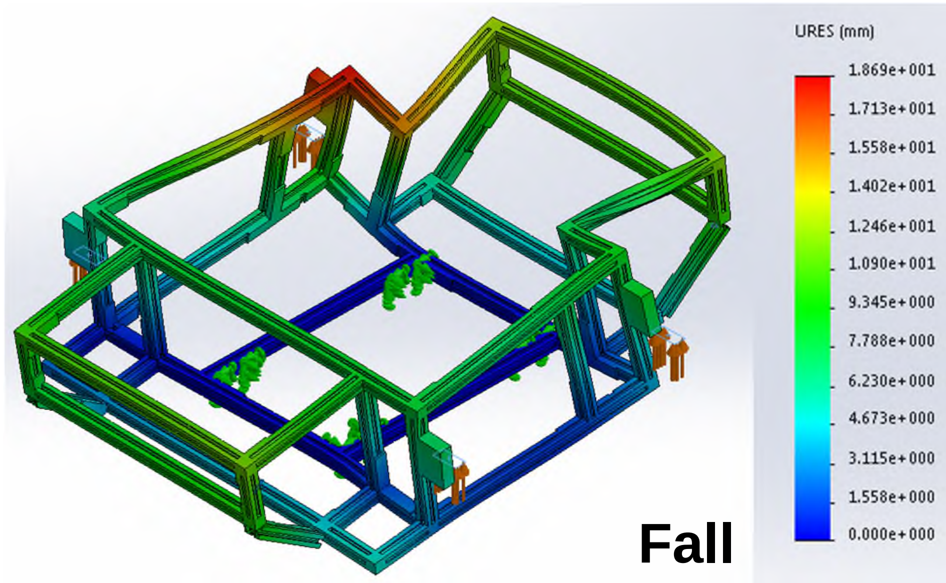


Chassis – Shell Design



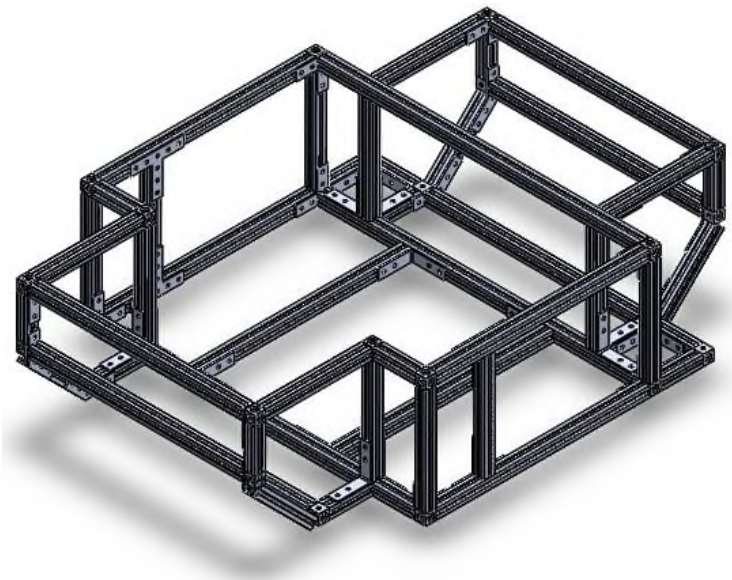
Chassis – Crash and Fall Resistance

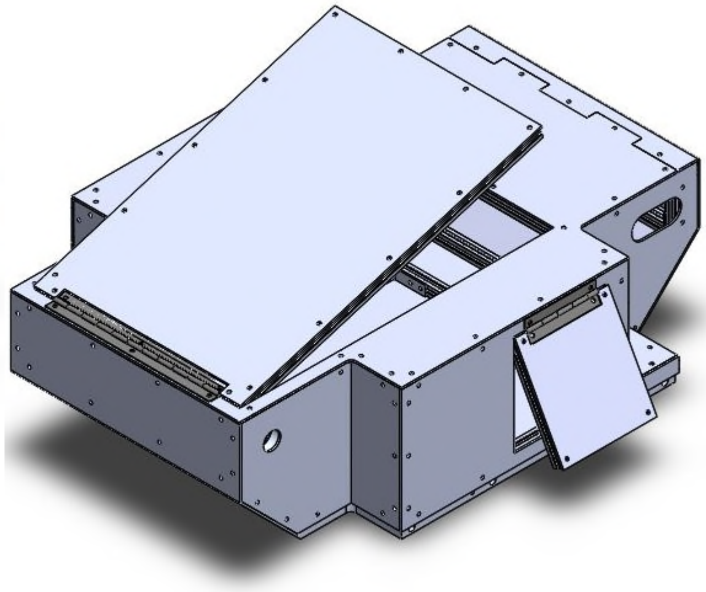


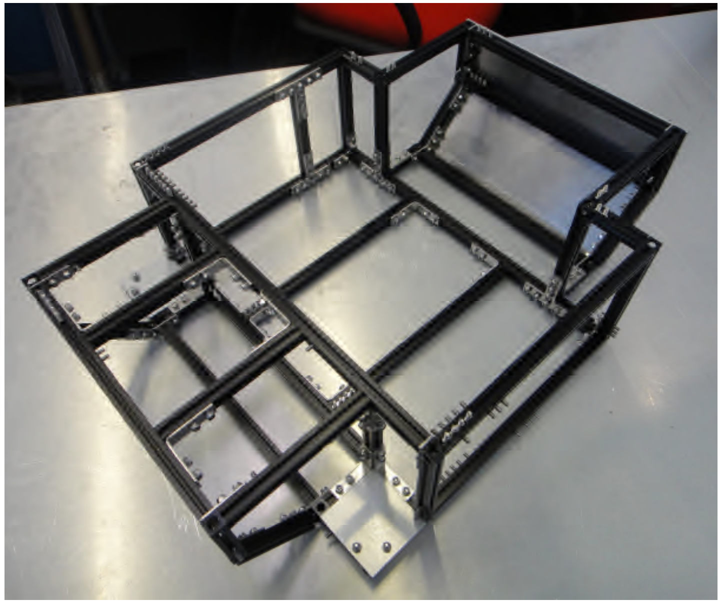


- SolidWorks buckling analyses of chassis response to a crash at 1.0 ms^{-1} and a fall height of 350.0 mm
- Maximum crash deflection of 32.7 mm and bending load factor of 41.4
- Maximum fall deflection of 18.7 mm and bending load factor of -70.4

Chassis – Final Design







Drivetrain

Presented by

Leigh Dawson

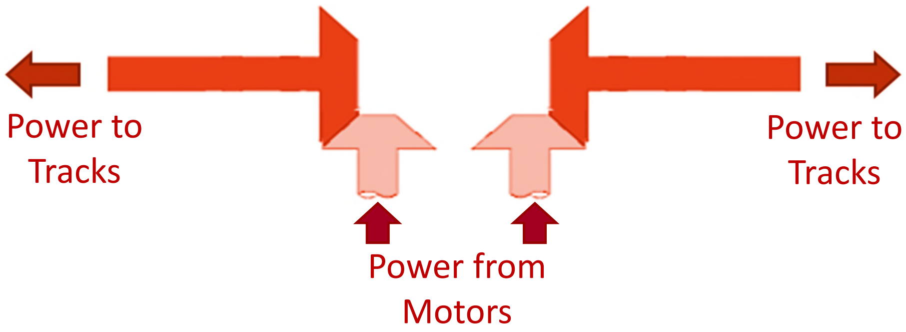
Drivetrain – Specification

- Lightweight
- Compact
- Durable
- Mobile

Criterion	Specification
Maximum Mass – 25kg	▪ Drivetrain to take up a maximum of 60% of overall mass: i.e. 15kg
External Dimension Restrictions	▪ Maximum dimensions - 580mm x 410mm x 350mm (length x width x height)
High Clearance	▪ [illegible] track radius required to enable stairs of step height 190mm and incline of 38° to be climbed
High Traction	▪ This parameter stemmed from the goal of producing a multi-terrain robot able to provide traction in various conditions: i.e travelling on mud, [illegible] floor[illegible], surface water etc.
Drive Requirements	▪ Invertible: arising from the goal of being able to still operate if the robot is turned over ▪ Able to achieve a range of speeds with standard operation at 1m/s – approximating average walking speed to avoid possible injury to survivors if an accidental collision were to occur ▪ Able to accelerate at 0.3 m/s² up a 38° slope – reduced from the previous year's design specification of 1m/s² up a 45° slope as this was decided to be unnecessarily rapid – requiring overpowered motors which would have to operate well below their rating for the majority of the time
Durability	▪ Able to survive a 350mm drop impact

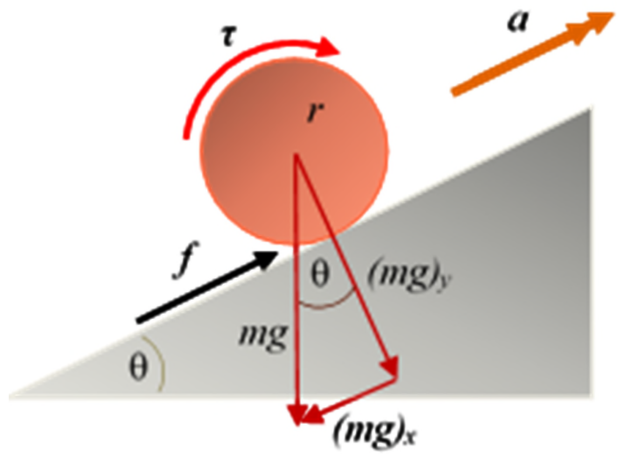
Drivetrain – Power & Transmission

- **Steering**: Dual drive



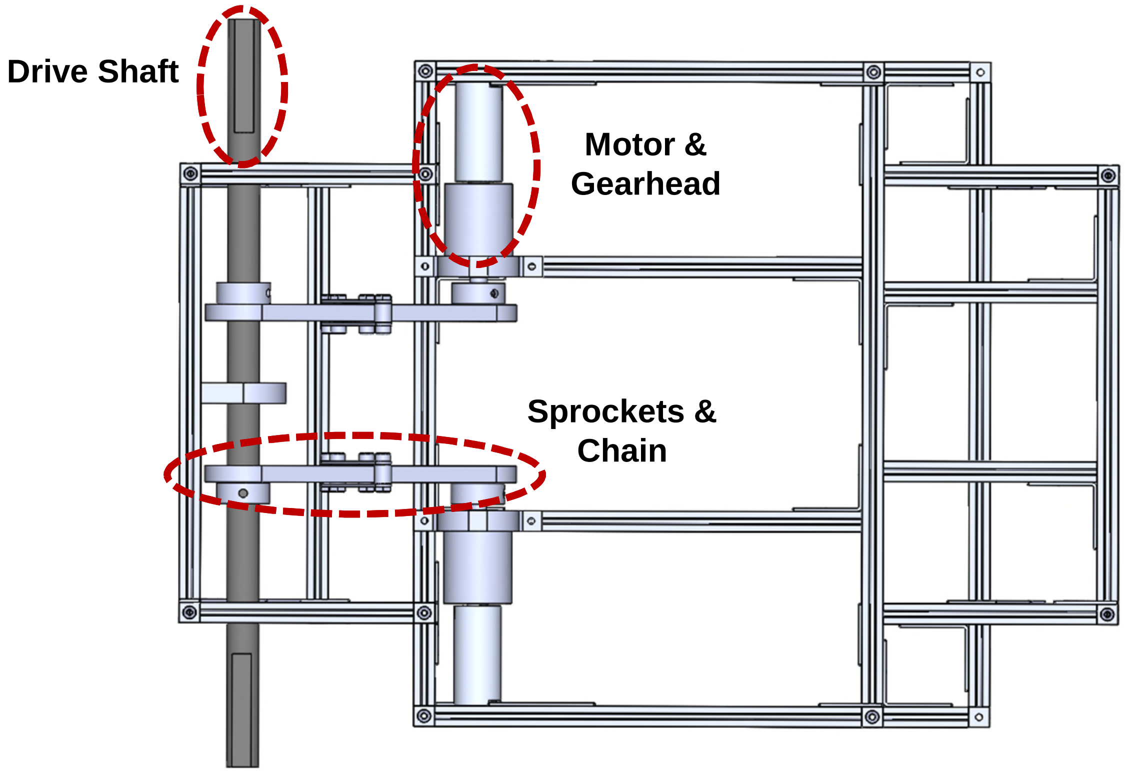
- **Motors**: Maxon Motor, EC-4pole

  Ø22 mm, brushless, 90 Watt motor



Drivetrain – Power & Transmission

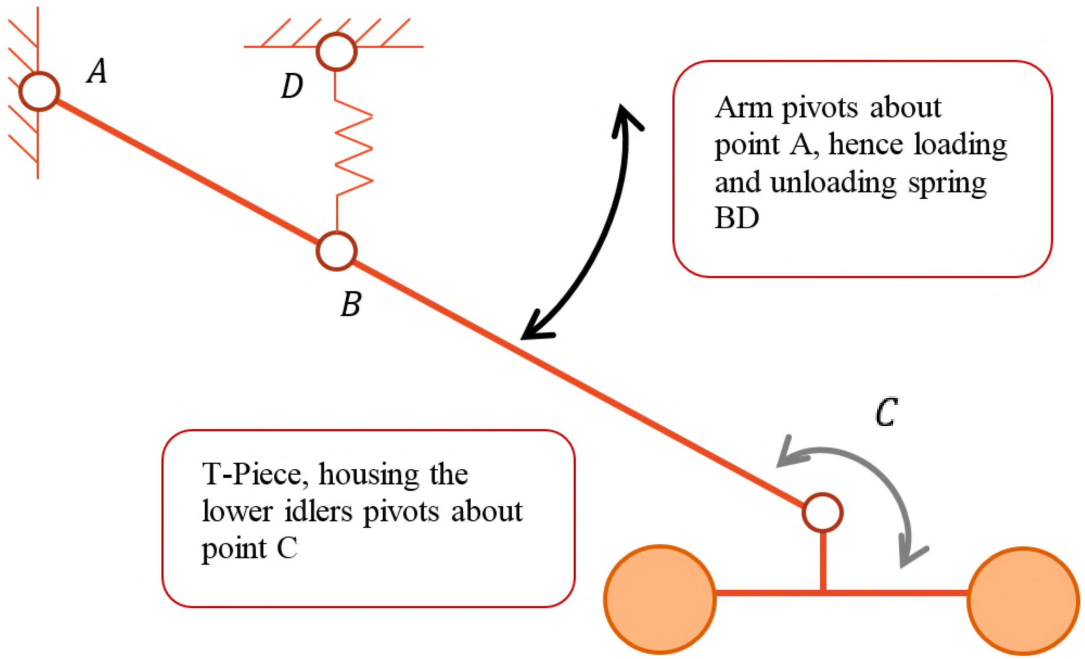
- **Internal Layout**: Sprocket & chain configuration turning drive shafts



Drivetrain – Suspension

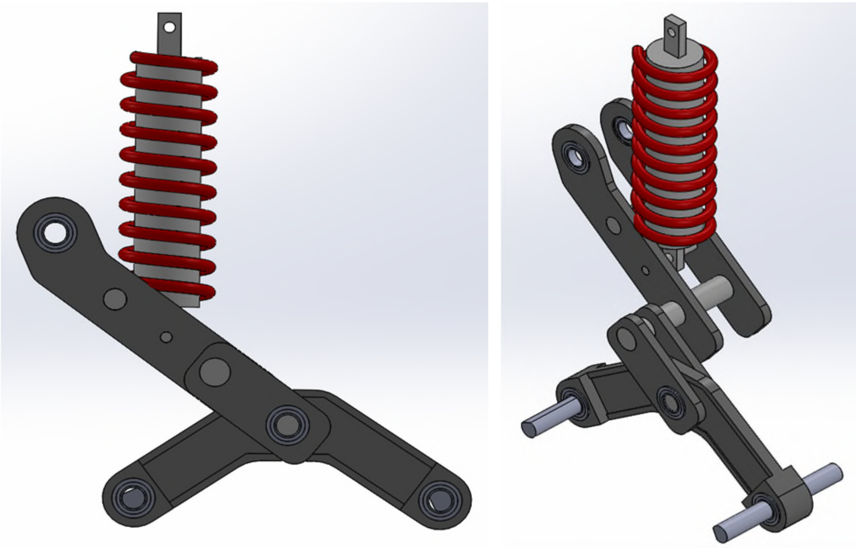
- **Increased Mobility:**
  Allows the M-USAR to easier traverse rough terrain

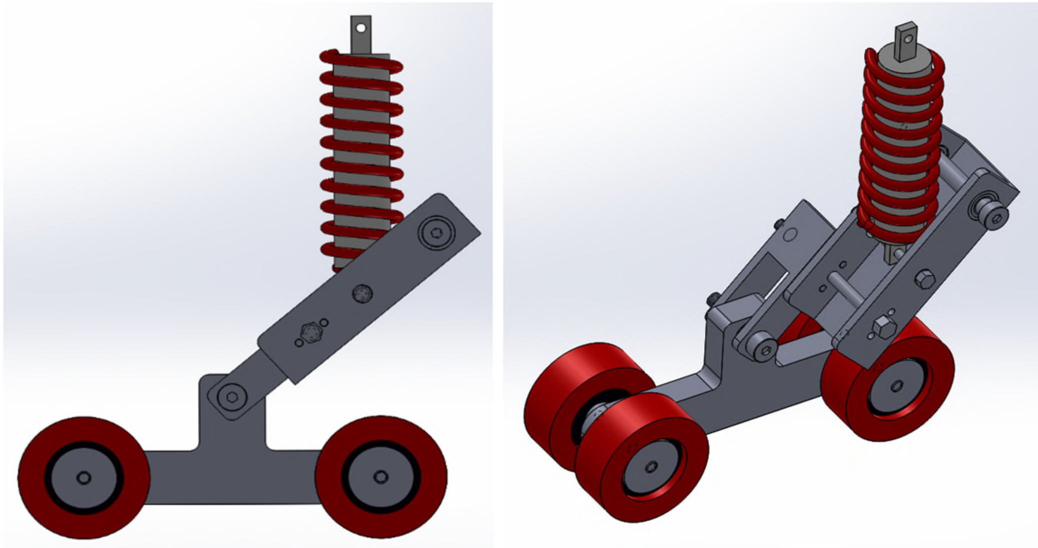
- **Dual Shock Absorption:**
  T-piece pivot handles small inconsistencies; larger variations activate arm pivot



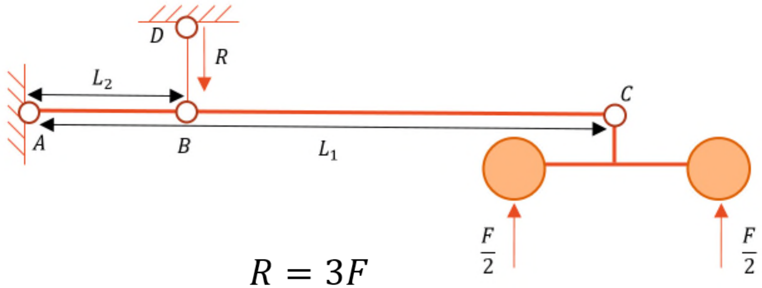
Drivetrain – Suspension Design Iterations

V2 → V3

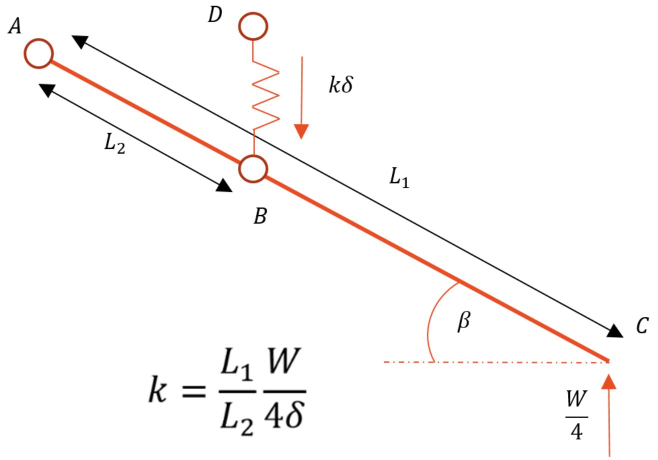




Drivetrain – Suspension Validation

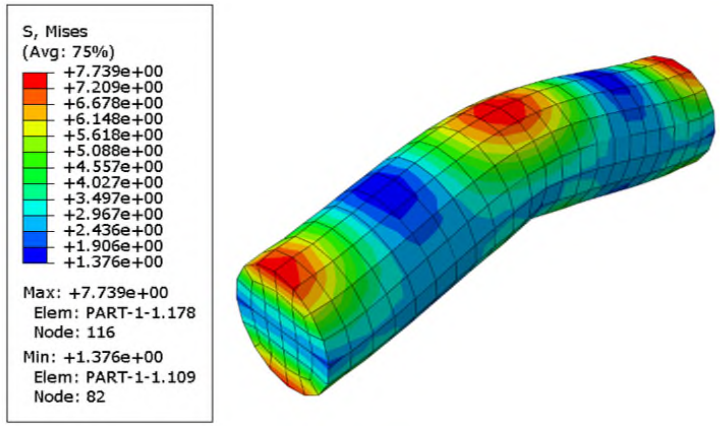


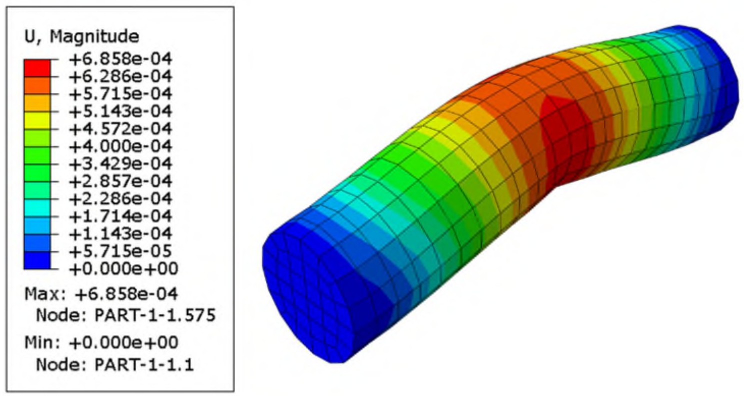
$$R = 3F$$



$$k = \frac{L_1}{L_2}\frac{W}{4\delta}$$

Theoretical Modelling

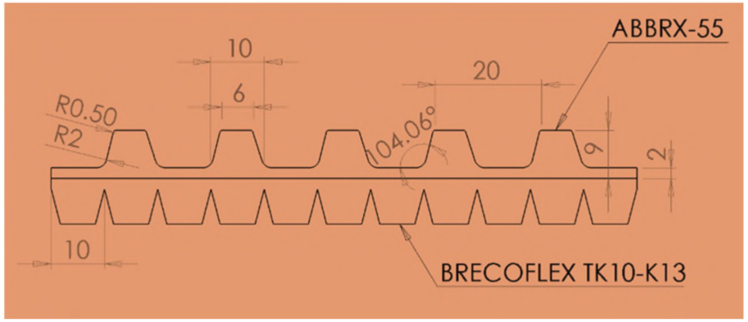


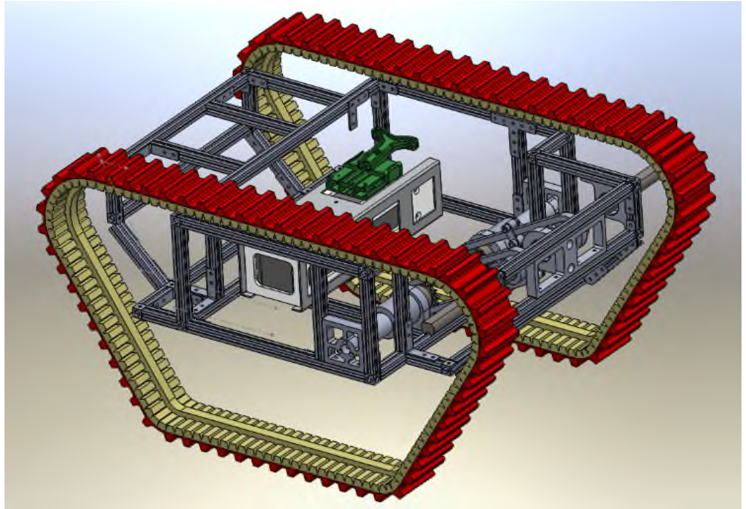


FEA Abaqus Simulations

Drivetrain – Tracks

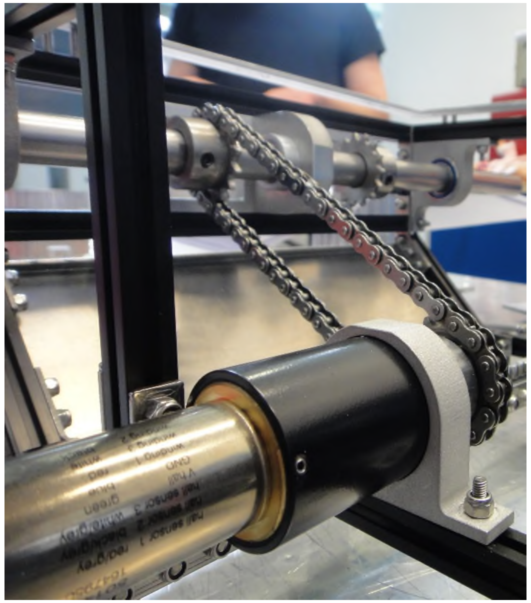
- **Tread Design:** 20mm spacing of 10mm rubber treads; 10mm backing tread
- **Material:** AbbrX 55 - silica-reinforced natural and synthetic rubber mix tread
- **Track Guidance & Tensioning:** 10mm raised guide on backing track to prevent lateral disengagement. Adjustable tensioning



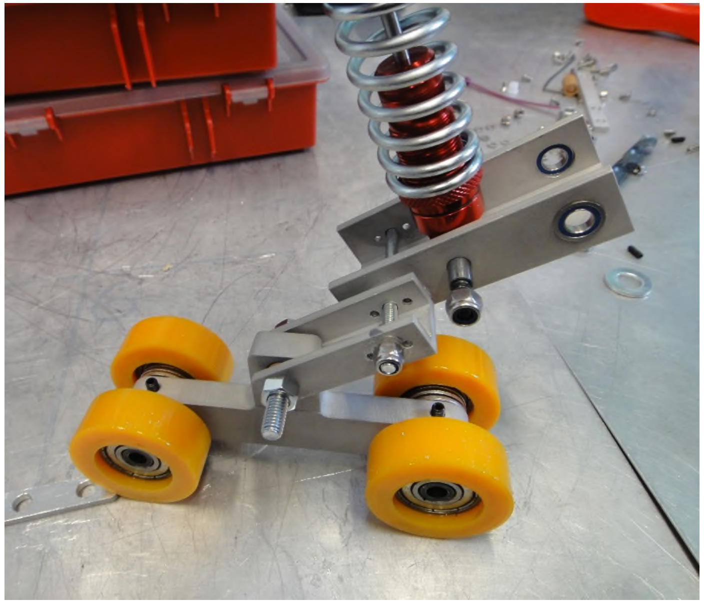


Drivetrain – Final Designs

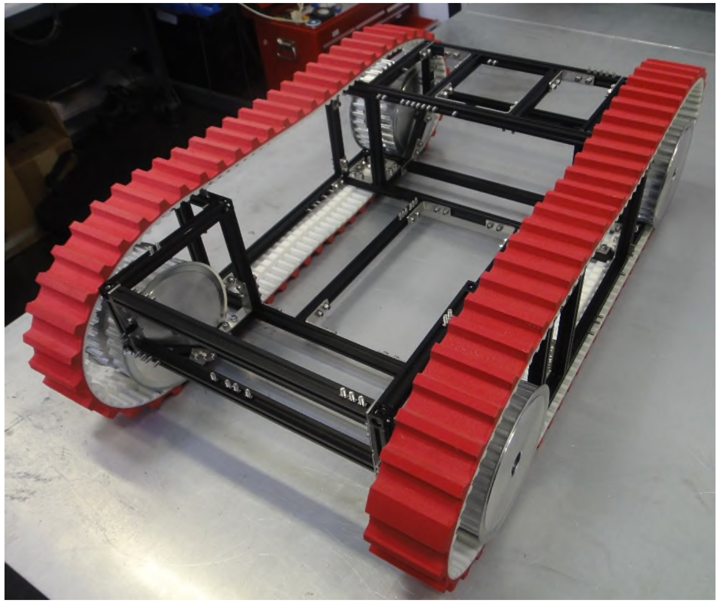
Power & Transmission



Suspension



Tracks

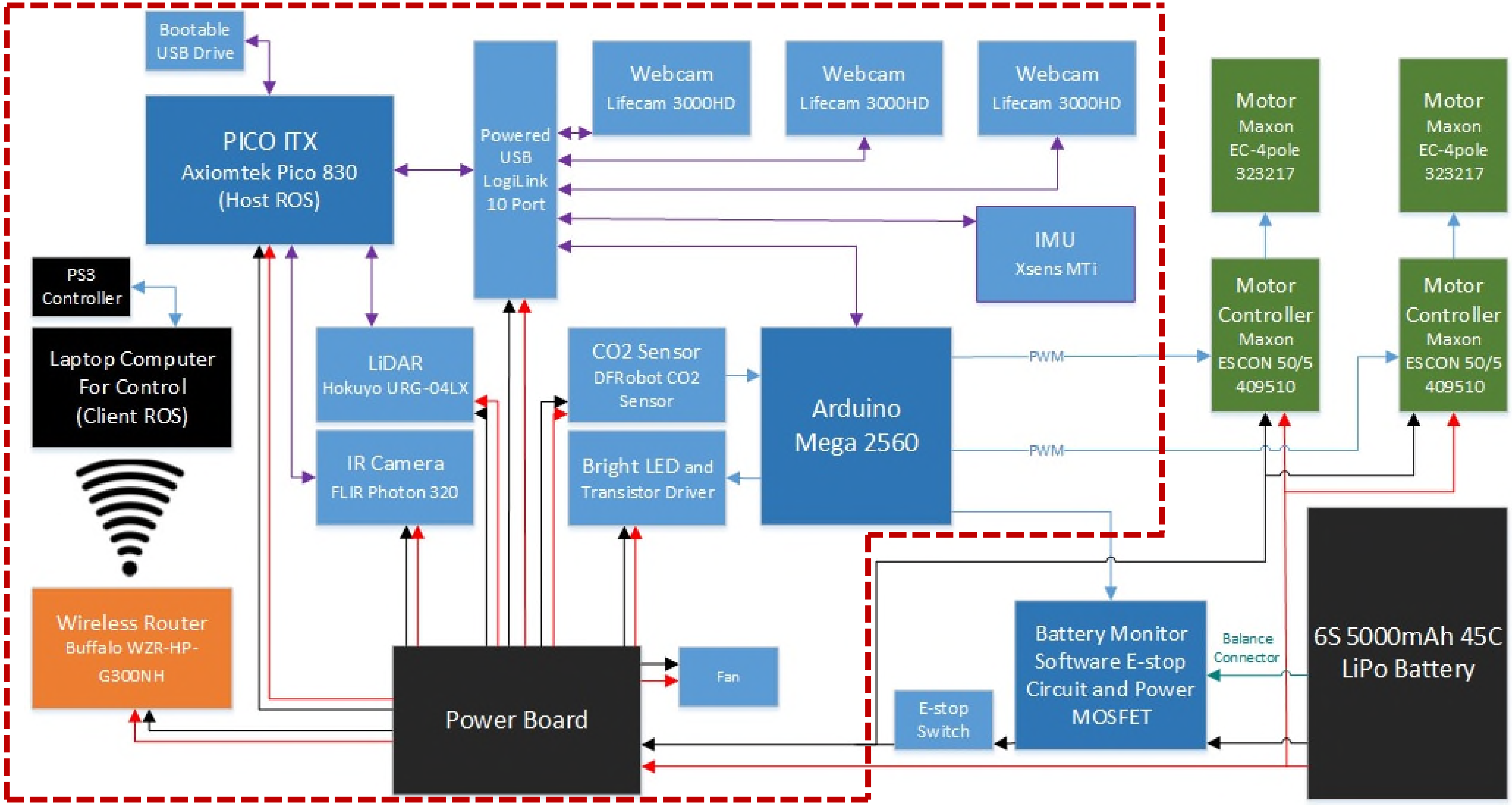


Electronics & Software

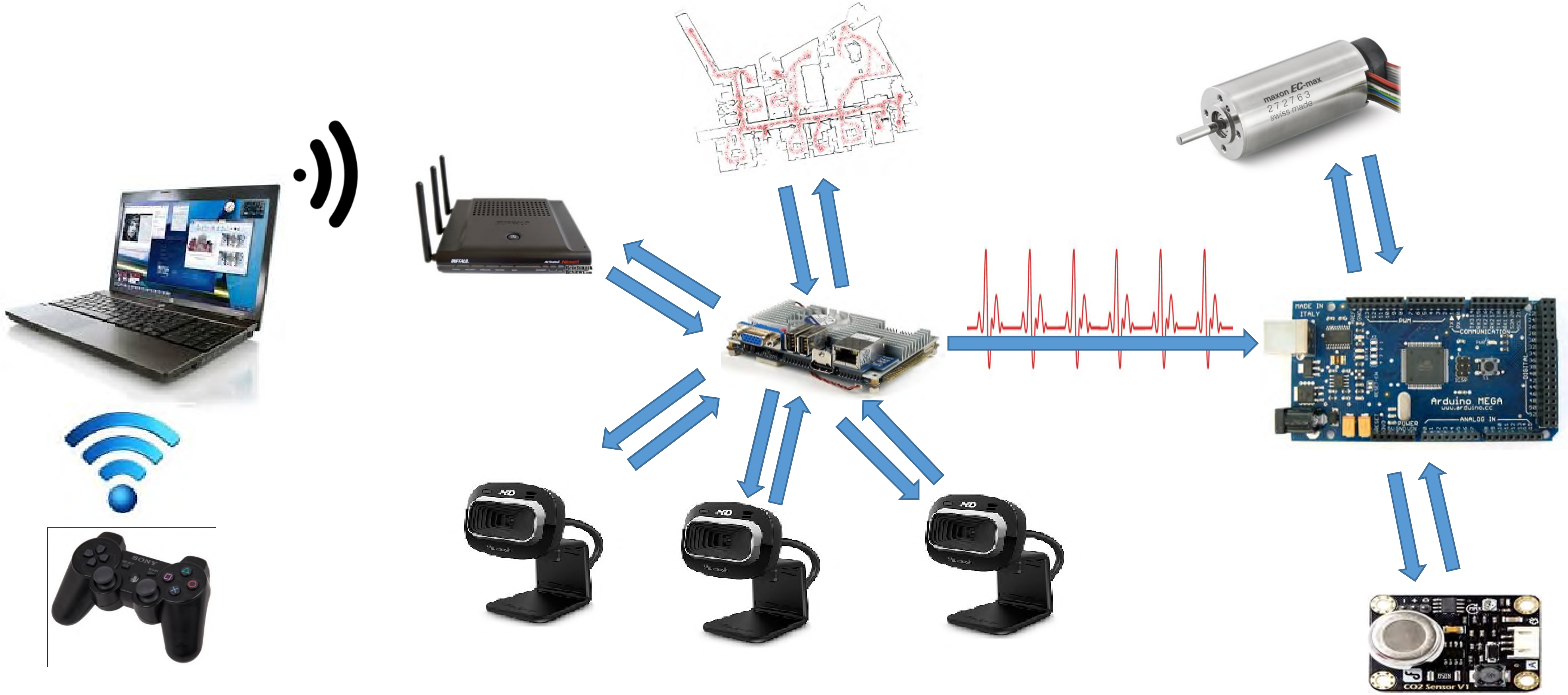
Presented by

Avnish Popat &
John Strutton

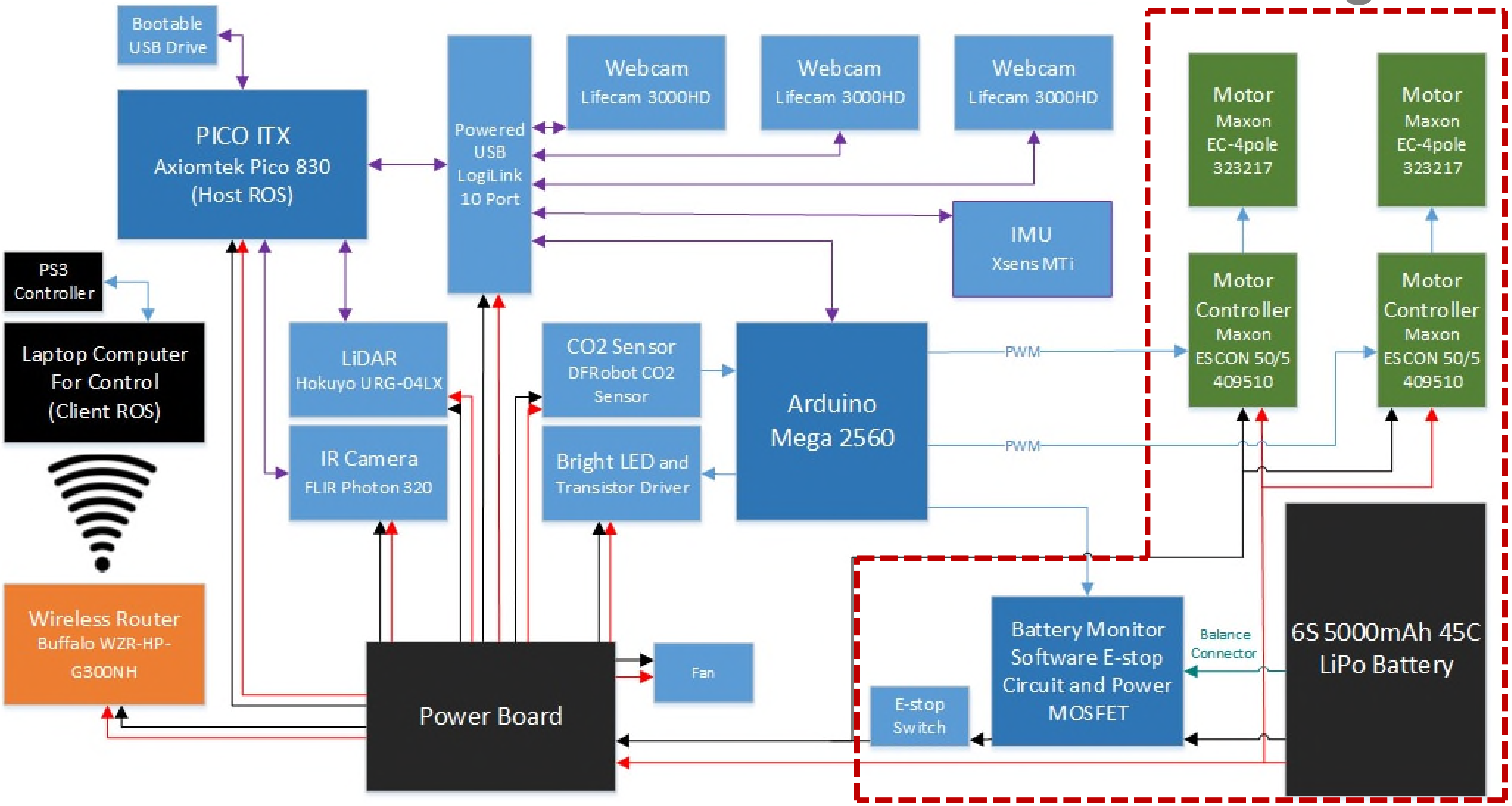
Electronics and Software – Architecture Overview



Electronics and Software – Computational Architecture



Electronics and Software – Architecture Diagram

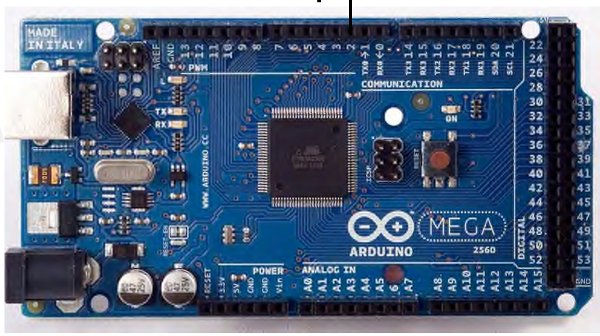


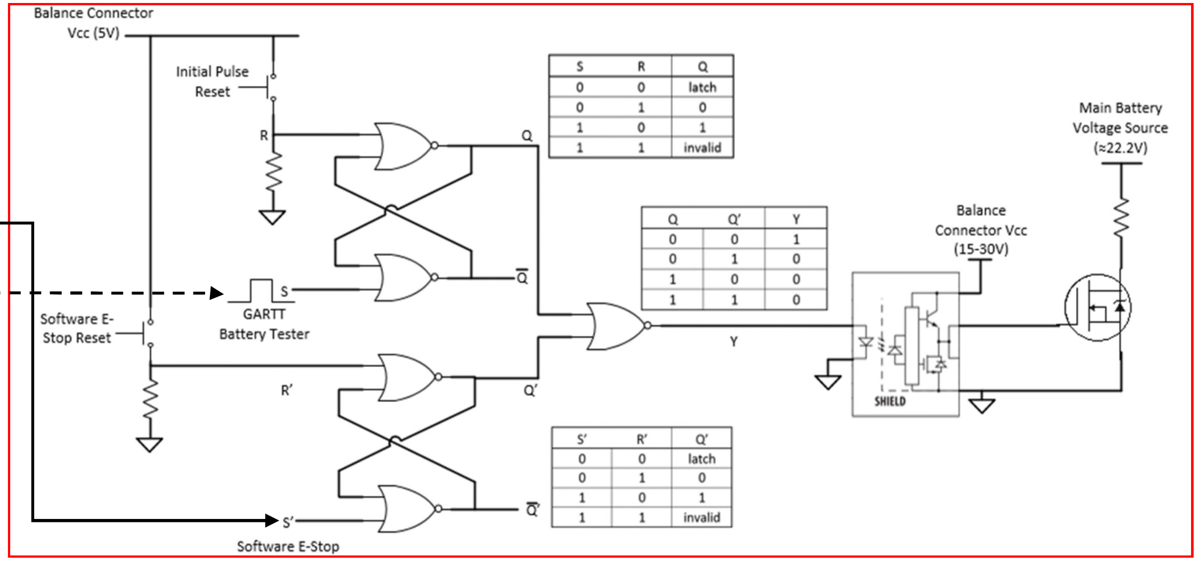
Electronics and Software – Safety System: Battery Master Switching

Battery Voltage Monitor

Software E-Stop

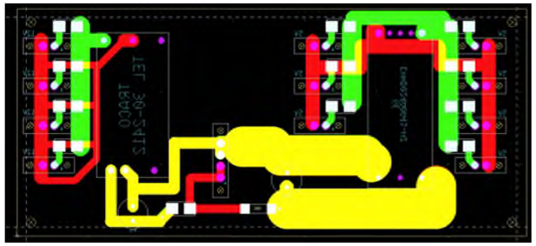
Pico-ITX comms.

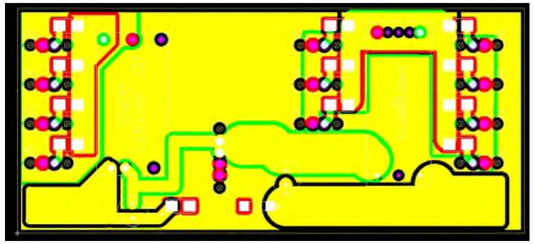


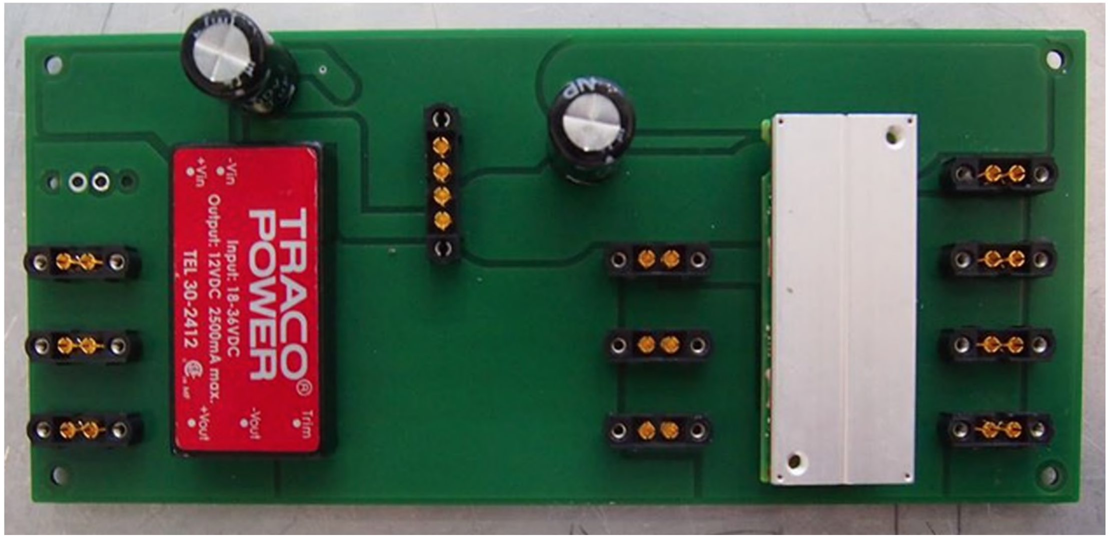


Electronics and Software – Power Distribution Board

- Additional outputs
- Thick Traces for flexibility
- High power DC-DC converters
- Interchangeable fuses
- Miniaturisation







Electronics and Software – Summary

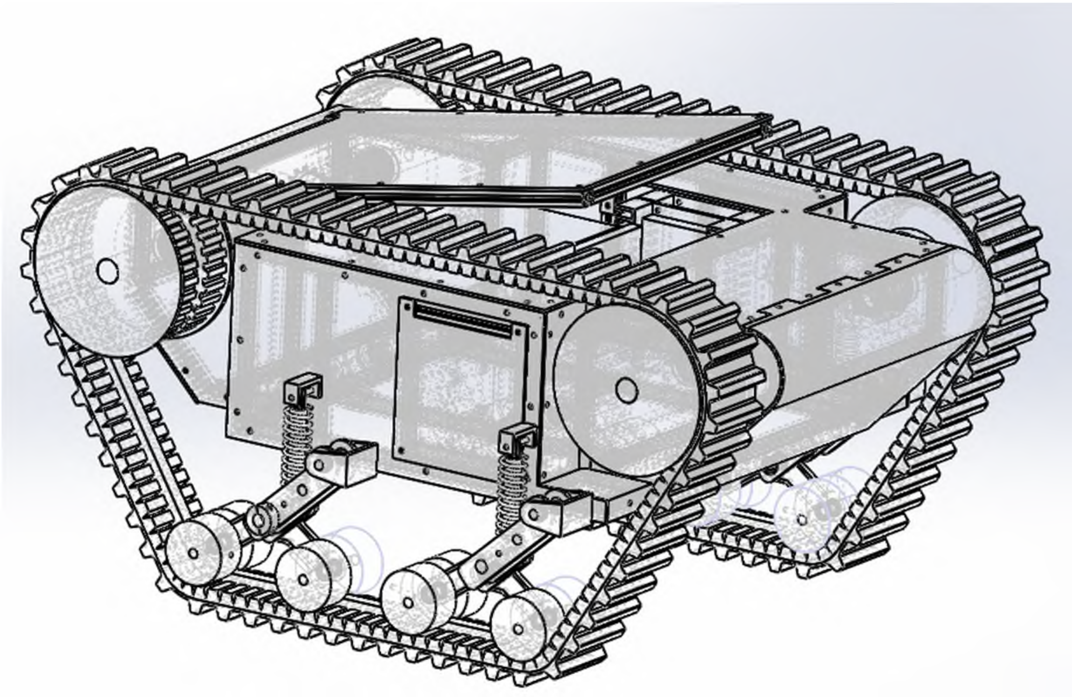
- Network and SLAM ✓
- Provision for reliable code, architecture and internal wiring ✓
- Test with singular motors prove capability and controllability ✓
- Modularity, power, and space for further expansion ✓

Final Design

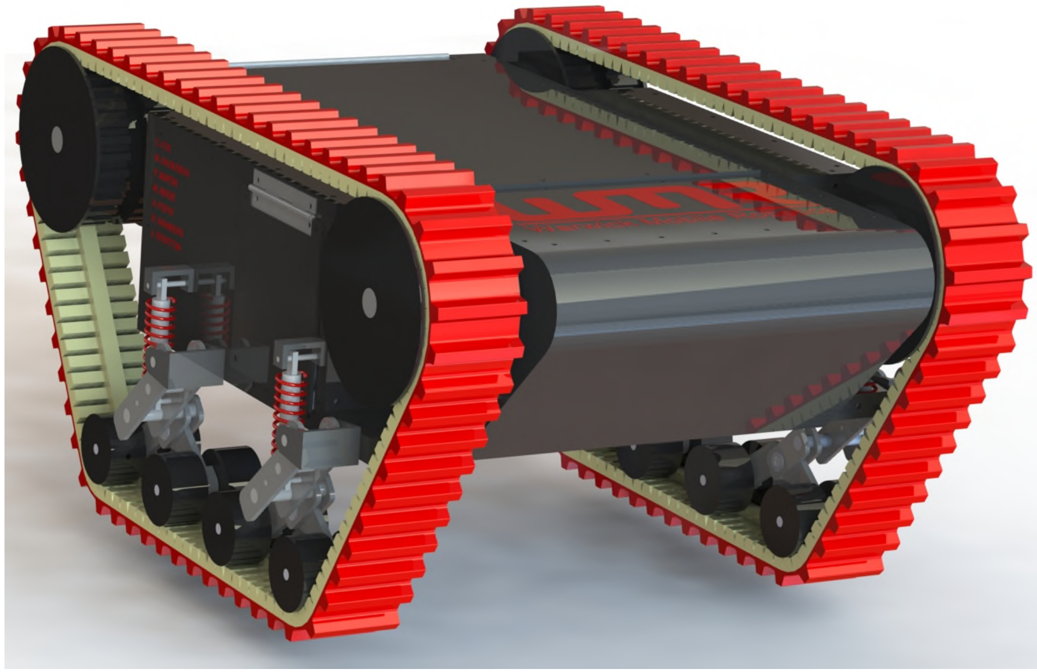
Presented by

Rebecca Saunders

Final CAD Design

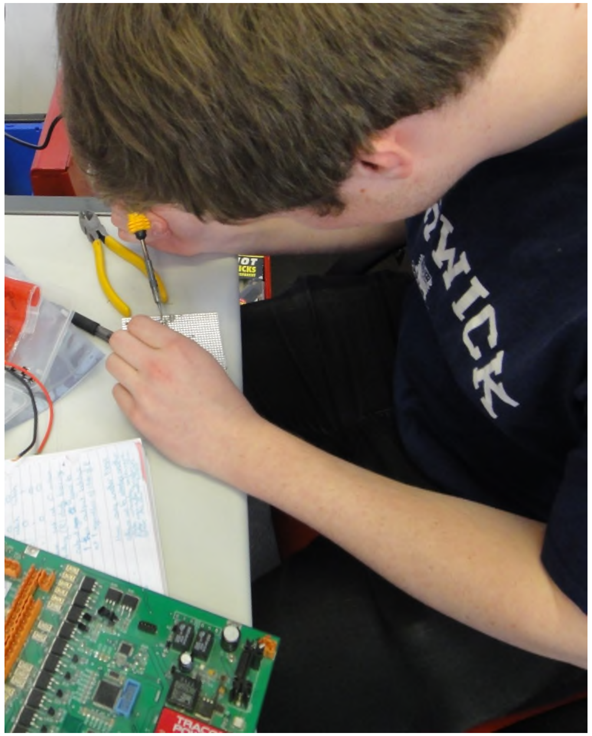


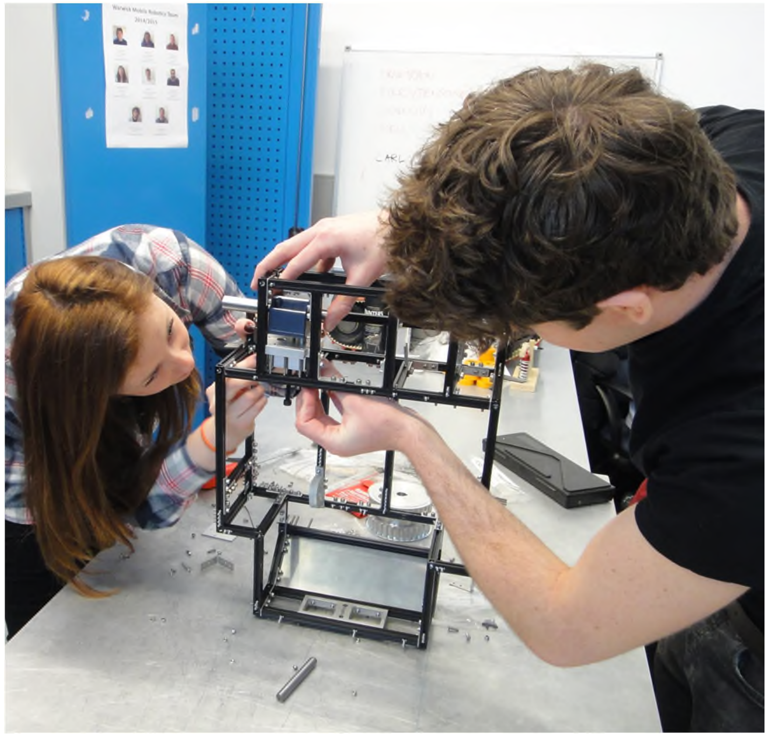
Wireframe Model



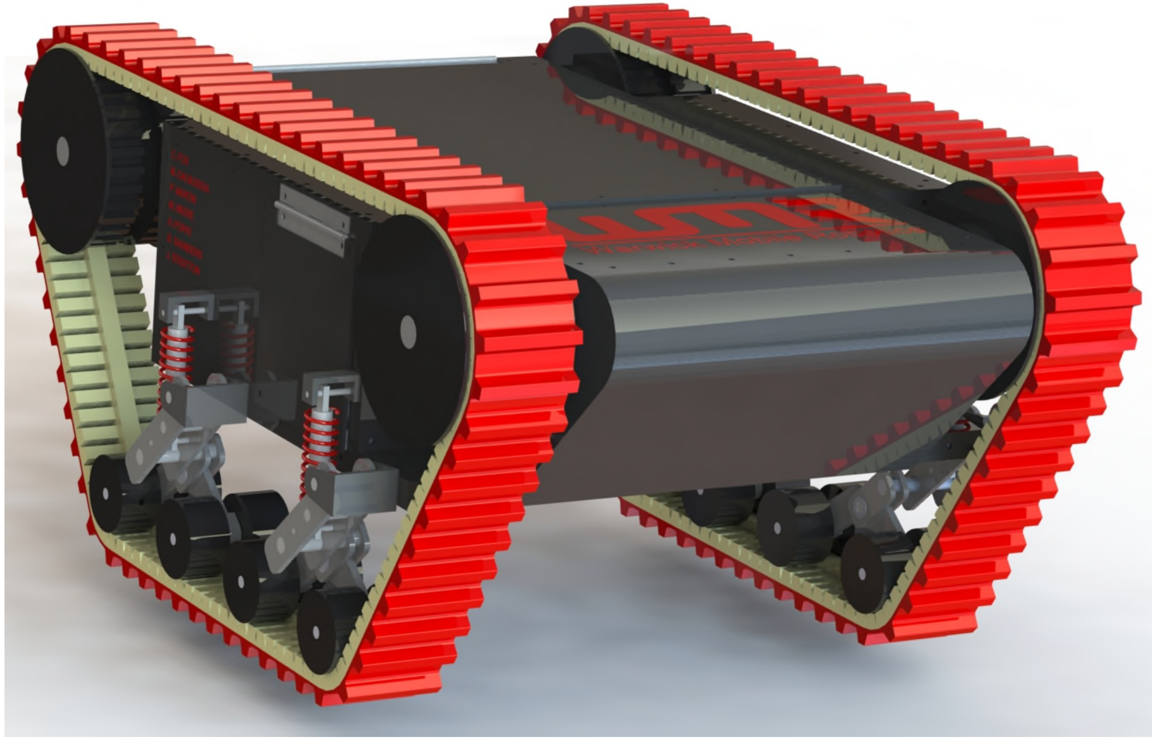
Fully Rendered Model

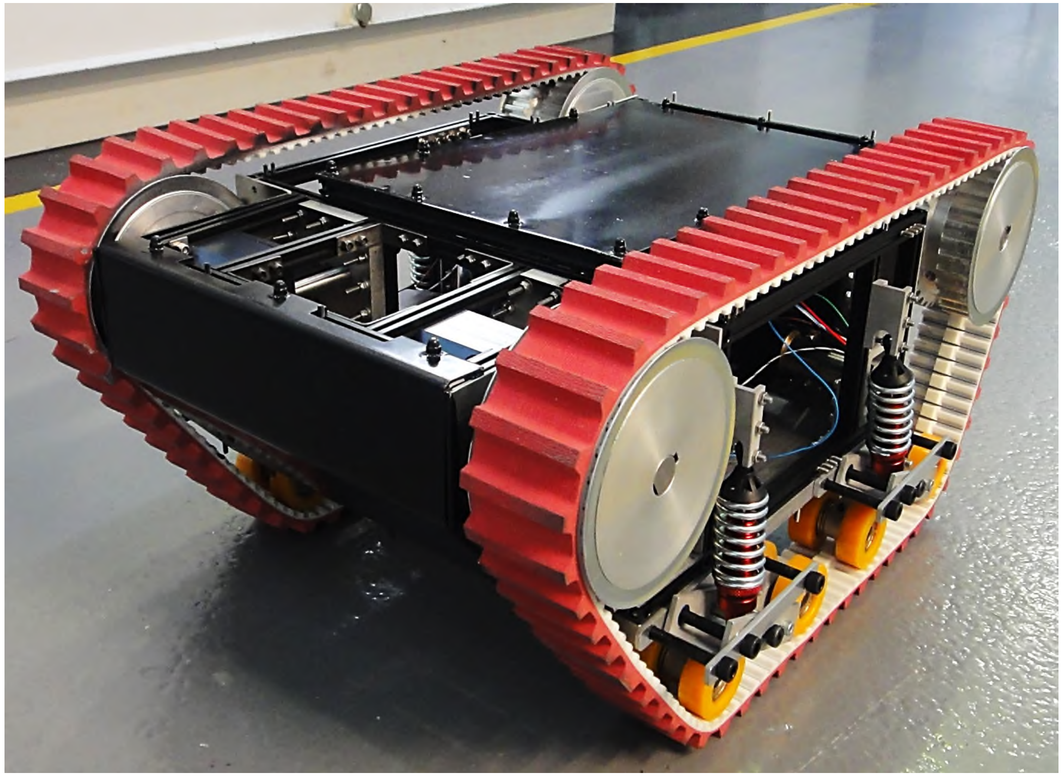
Manufacturing





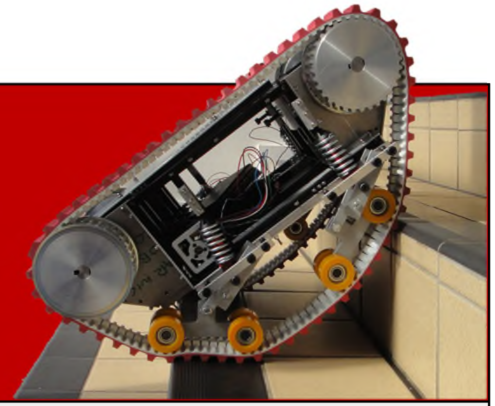
Orion M-USAR





Critical Review

Orion



Strengths	Weaknesses
▪ Optimised drivetrain with tracks and suspension to enable multi-terrain travel	▪ Internal use of space could be more efficient
▪ Strong & accessible chassis and shell	▪ Weight distribution
▪ Battery safety system through quick access and emergency stop	▪ Limited Battery Life
▪ Easily adaptable mechanical and electrical systems	▪ Suspension is vulnerable to side impacts

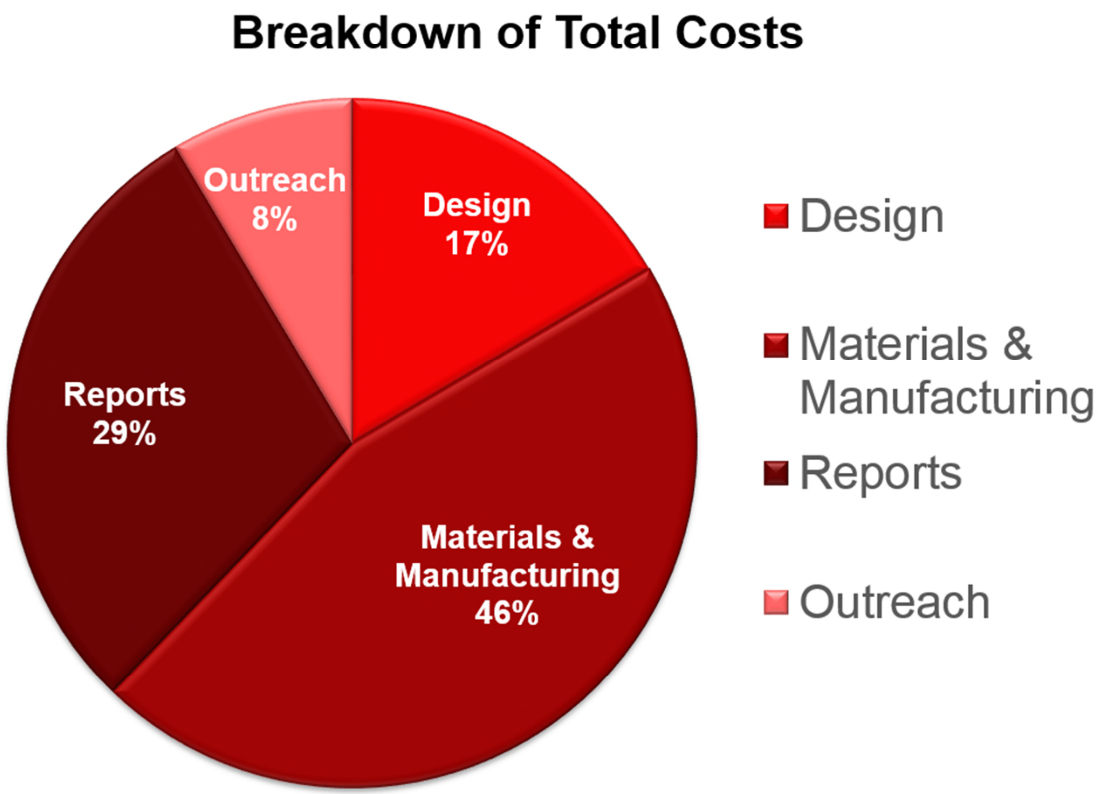
Conclusions

Presented by

Paul Martin

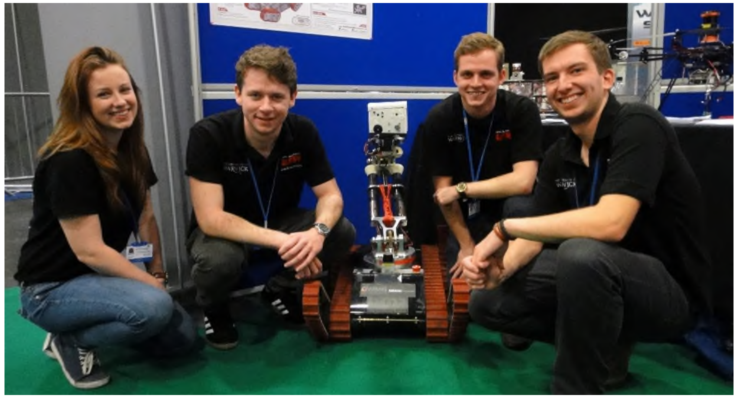
Costs

- Total Project Cost: £58,964.94
- Material Cost: £4,082.94
- Estimated Cost of Human Life: £6.1 million

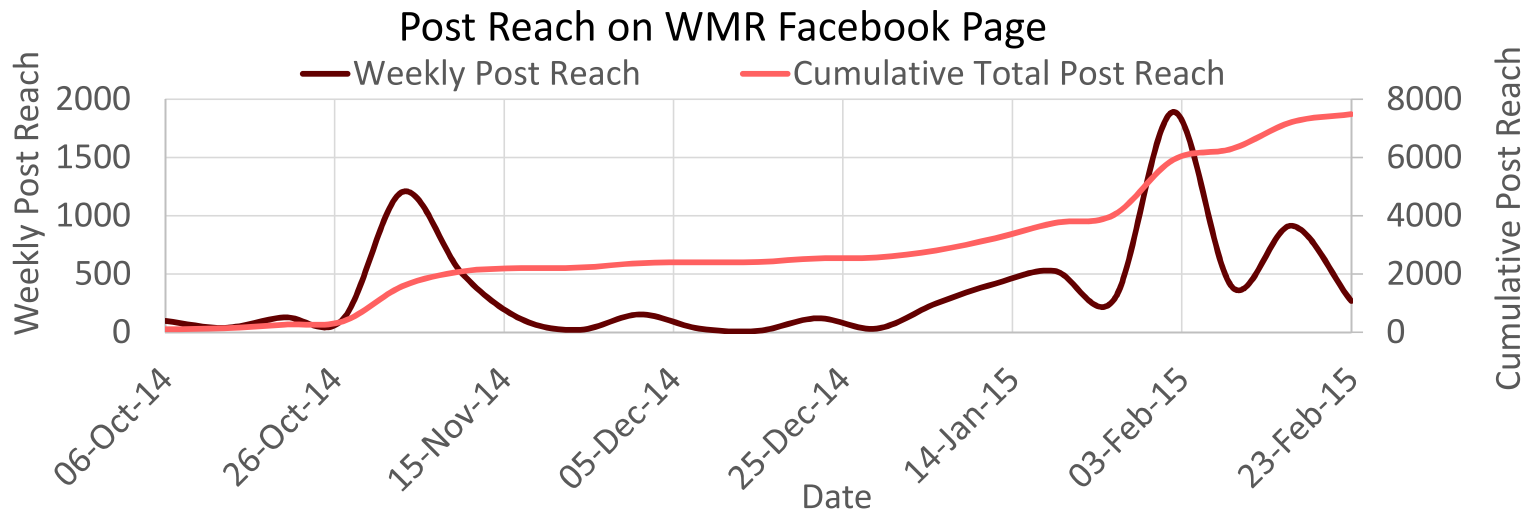


Outreach

- Imagineering Fair 2014
- 3D Printing in Schools Showcase at the Herbert Art Gallery
- WMG's "Thinking About University?" and other recruitment events
- School of Engineering Open Days
- Cheltenham Science Festival



Publicity



- Project featured in:
  - Eureka Magazine (website), January 2015
  - Control, Drives and Automation (website), January 2015 (Editor's Pick)
  - Maxon e-Newsletter, January and February 2015
  - Design Engineering News, February 2015 (Page 1)
  - The Engineer (website), February 2015
  - Motion Control Newsletter, March 2015
  - P&T Review (website), March 2015

Strategy – Objectives

1. Analyse Current USAR Designs ✓
2. Benchmark Existing WMR Robots ✓
3. Define an Achievable Specification ✓
4. Design a Miniature Multi-Terrain Robot ✓
5. Include Novel and Innovative Features ✓
6. Consider Ease of Manufacture and Assembly ✓
7. Test and Validate Components and Features ✓
8. Provision for Further Work with Handover Documents ✓
9. Showcase the Robot through Exhibitions and Media ✓

Strategy – Project Aims

Aim 1:

Deliver a mechatronic framework for an innovative M-USAR robot by May 2015 as the first stage of a three year plan ✓

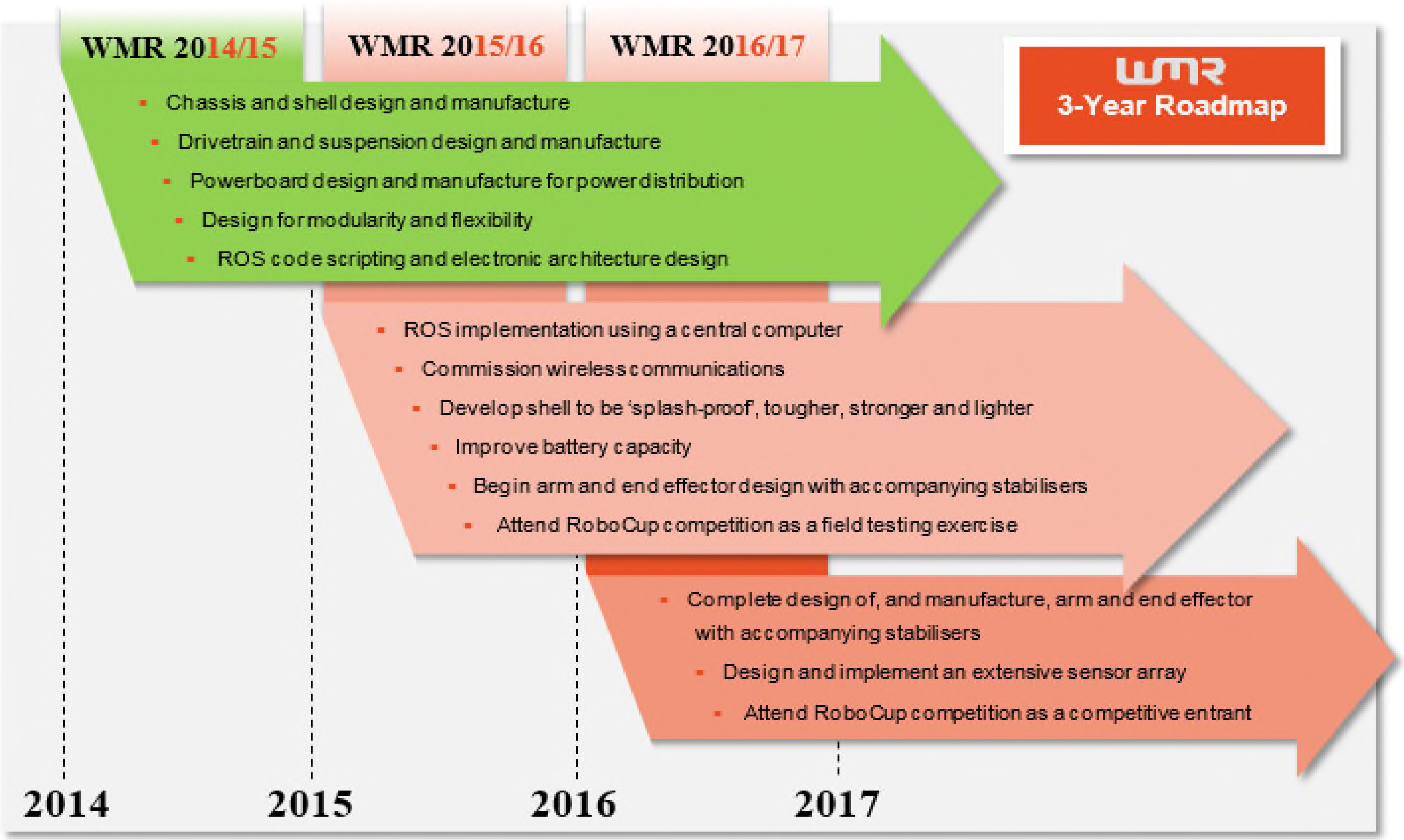
Aim 2:

Provision for design development by future WMR teams ✓

Aim 3:

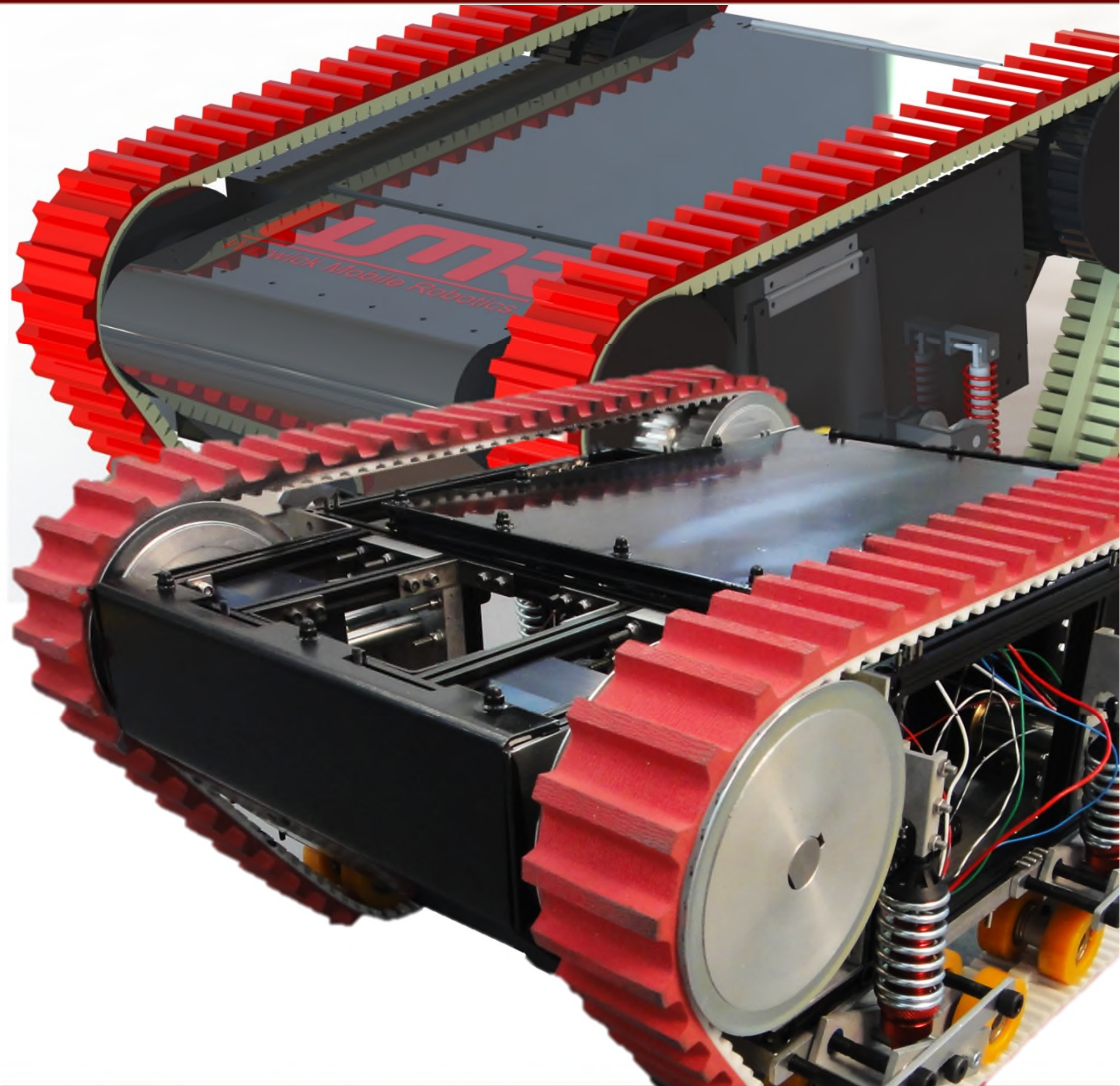
Exhibit the robot as an educational platform to inspire younger generations ✓

Recommendations



Summary

- Innovative Design & Analysis
- Manufacture & Testing
- Programming & Architecture
- Under Budget
- Outreach, Media & Publicity
- Achievement of Aims & Objectives
- Long Term Three-Year Plan



Thank You for Listening,
Any Questions?