Aussie Invader Report

Canard Wing System

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Willetton SHS year 12 engineering Project

Aim:

Our task was to design a canard wing system that applies the optimal down force on the front wheels of the Aussie Invader at high speed. This system must exhibit a quick and simple means to alter the canard wing's angle of attack and, in so doing, maintain vehicle stability and peak performance.

Design solution:

<u>Designing:</u>

Many different design solutions were initially investigated. Although some of these initially sounded like good ideas, after further analysis, these designs displayed several short comings. For instance, key systems specifications included the need to keep both left and right canard at the same angle of attack (AoA) at all time. Further, it was imperative that any system must be fail safe and that any mechanism must fit within a relatively small volume immediately in front of the front bulk head. These last two design criteria eliminated a lot of competing designs. We believe that our design is workable, rigid, reliable and can fit into available space on the AI 5R.

<u>Design Criteria:</u>

- Controls down force over any rolling terrain to stop any unexpected and dangerous lifting of the nose.
- Uses a single shaft ensuring strength and equal AoA on both canards to stop any dangerous unequal down force.
- Single shaft neatly assembles on furthermost bulkhead without interfering with steering or other inner systems.
- Supersonic missile profile canards - 350mm wide by 250mm long, with the wing spar located through the maximum diameter of the main chassis tube.
- Due to the small thickness of the canards, the canard axle can only be a 20mm diameter leading to strength issues.
- The angle of attack range is from 0.00° to -3.00° with adjustments created according to lift generated at speed in front of the LSR vehicle.

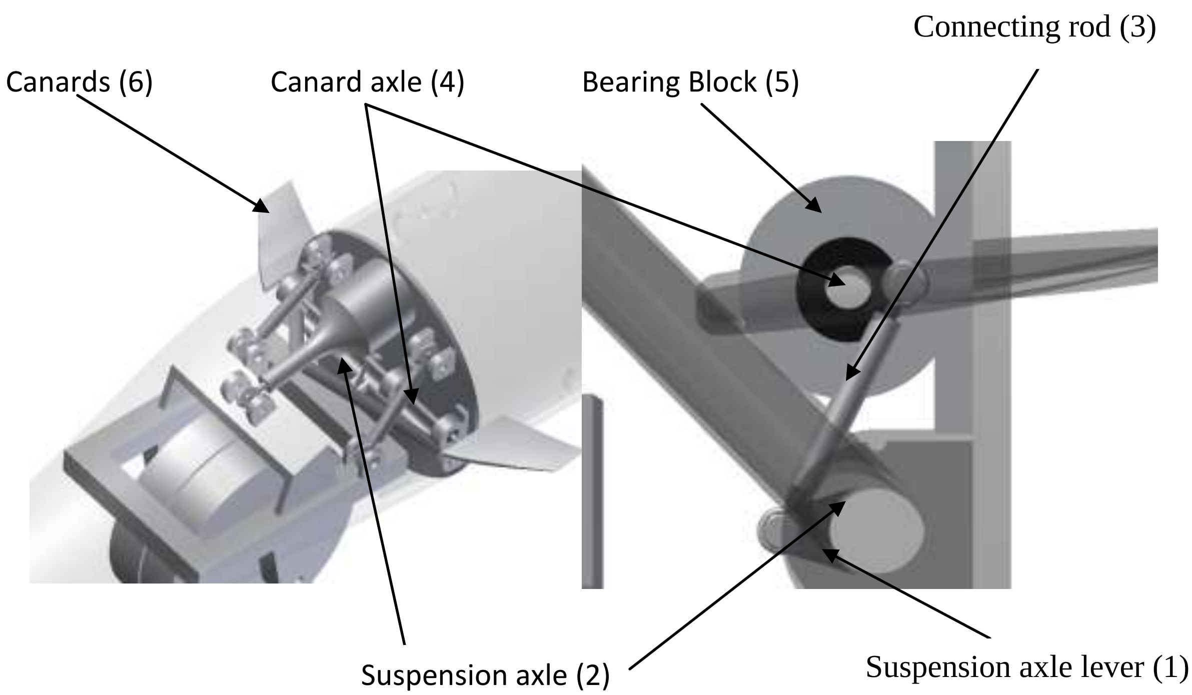
- The angle of attack adjusting mechanism is robust and simple using sturdy leavers to automate all wing rotation without the possibility of failure. Any further adjustments in the mean position of the canards can be made with simple workshop hand tools which can be done quickly in a fail-safe manner.
- The angle of attack adjusting mechanism can be accessed through a small access panel in the nose or main chassis tube skin.
- Flexible fairings are used to seal the canard against the curved surface of the nose.

<u>Appraisal of the Design:</u>

Plus	Minus	Interesting
➢ Controls down force over any rolling terrain. ➢ Stops any unexpected and dangerous lifting of the nose. ➢ Maximum safety of driver. ➢ Uses a single shaft ensuring strength and equal AoA to stop any dangerous unequal down force. ➢ Single shaft neatly assembles on furthermost bulkhead without interfering with steering or other inner systems. ➢ No chains motors or gears only a simple lever system ensuring no design failures (eg broken teeth or chains).	➢ No driver control. Cannot change down force during run if digging into the ground. ➢ Max AoA must not be reached (hard to ensure fail-safe eg. Stops at 3º). ➢ Any unexpectedly rough terrain could cause a nose ploughing effect. ➢ Wheel will excessively vibrate due to shockwaves and uneven surface. This will cause canard flutter and strong cyclic loads (unless a damper is used).	➢ Canard compensating front wheel Suspension. ➢ If the wheel is lifted due to any terrain abnormalities a leaver will produce the required AoA for canard down force. ➢ Shaft is threaded through pillow blocks an then bolted onto furthermost bulkhead. ➢ Factor of safety of at least 6-8 (depending on material) will have to be used due to large cyclic loads. ➢ May be able to modify mean AoA between runs depending on the required down force.

How it works:

Excessive air pressure generated at speed under the vehicle's nose could cause the car to flip. Further, a canard system in theory should be able to optimise front and rear axle loads as the vehicle moves along its LSR track. To eliminate the chance of flipping and to optimise axle loads, we hope to incorporate our canard wing system. This design solution incorporates variable supersonic missile wings driven by the Invader's front wheel vertical movement. As the car begins to lift due as a function of increased speed and or increased terrain undulation, the lever (1) attached to the suspension axle (2) is pulled downwards causing the connecting rod (3) to pull on a lever connected to the canard axle (4). This causes the canard axle to rotate within the bearing blocks (5) and in turn rotates the canards (6) anticlockwise. By rotating the canard wing, it causes an increase in the angle of attack (AoA) hence increasing the down force exerted on the front of the rocket car. If tuned correctly, the increase in down force on the vehicle's nose should counteract the lift acting on the car thus ensuring safe and fast horizontal travel.



At high speeds, the system may experience excessive vibrations of the canards due to fast moving terrain. This could cause a fluttering effect producing unwanted lift. To solve this problem, our team proposes that we use a damper in series or parallel with the connecting rod to control or minimise canard vibrations. The damper should also reduce cyclic induced force and allow the canards to only respond to generalised terrain undulations.

Supporting calculations:

Approximation of max down force on Aussie Invader Canards

Assumptions

Max angle of attack (AoA) of canards is 3^{o}

Air Density: $1.225 Kg/m^3$

Max velocity of vehicle: Mach 1.31 = $447 m\ s^{-1}$

Area of wing approx 0.25m X 0.371m = $0.093\ m^2$

Co-Efficient of lift at M 1.31:

AoA = Angle of attack in radians

M= Max Mach No

Cl= Coefficient of lift

$$Cl = \frac{4 \times (AoA)}{\sqrt{M^2 - 1}}$$

$$= \frac{4 \times (\pi / 36)}{\sqrt{(1.312)} - 1}$$

$$= 0.2475$$

Max Down force at M 1.31:

C_l = Coefficient of lift

P = Air density(kg/m^3)

V = Velocity (ms^{-1})

A = Area (m^2)

Fd = Down force (N)

$$F_d = 0.5\ C_l \times p \times v^2 \times A$$

$$= 0.5 \times (0.4125) \times (1.225) \times (447)2 \times (0.093)$$

$$= 2827\ N$$

% increase of front of axle load:

Axle Load = 3000 kg

$$\text{Down force (Kg)} = \frac{2816.93}{9.8} = 287.442\ kg$$

$$\%\ \text{increase} = \frac{\text{down force (kg)} \times 100}{\text{Axle load (kg)}}$$

$$= \frac{287.442 \times 100}{3000}$$

$$= 9.58\%$$

The 9.58% increase in axle load should suffice to counter the change created by excessive terrain undulation and or increased under nose pressure.

Supporting calculations continued:

Max deflection of canard Axle with 3° AoA and varying materials

Assumptions:

Max down force at 3° AoA = 2816.93 N
Assume force acts at centre of canards
Axle is a solid rod, Diameter = 20 mm
Factor of safety = 8 (*due to cyclic load)*

Moment of area of solid rod:

$$\text{Moment of area (I)} = \frac{\pi D^4}{64}$$

$$=7854$$

Beam deflection Calculation:

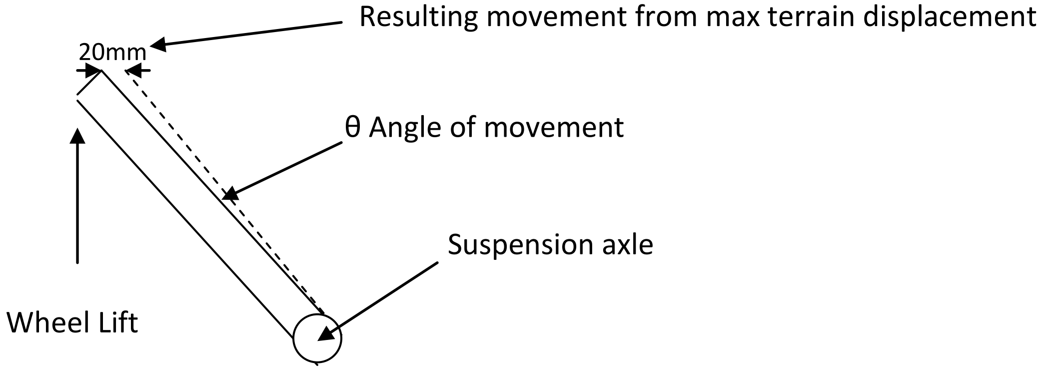
$F_{\text{at } 3° \text{ AoA}}$ = 2816.93 N
L ≈ 235.5 mm

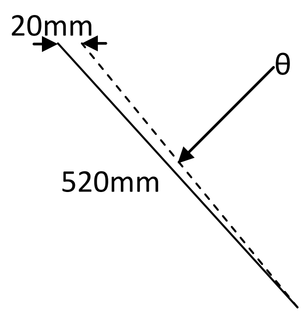
$$\text{Max deflection (mm)} = \frac{FL^3}{3EI}$$

Material	Elastic Modulus (GPa)	Max Deflection (mm)	<10mm Deflection
Alumec – 100	69.6	22.44	No
Alu – 2014	72.4	21.57	No
Carbon Fibre – M55 UD	300	5.21	Yes
Axle Steel – 4130	207	7.54	Yes

These calculations prove that for the small diameter canard axle to support the large cyclic loads only solid M55-UD carbon fibre or 4130 – axle steel materials can reduce deflection to an acceptably safe level.

<u>Lever Ratio</u>

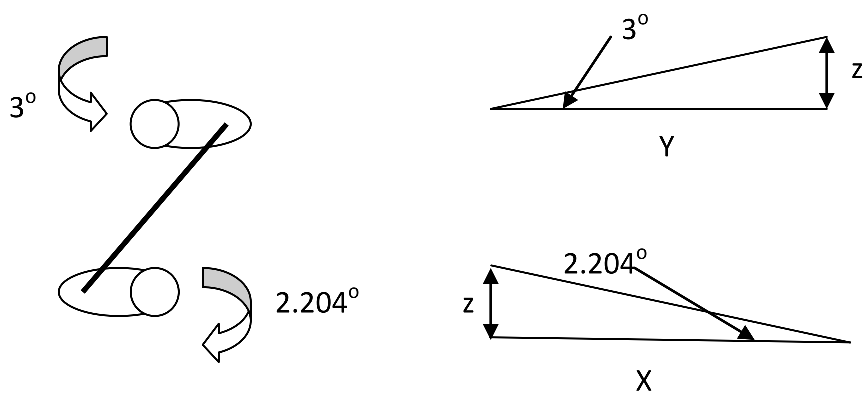




$$\theta = \cos^{-1} \frac{(520^2 + 520^2 - 20^2)}{2x(520^2)}$$

$$= 2.204^o$$

This angle resulting from maximum wheel displacement must result in the max angle of attack safely possible by the canards. This means that the two levers that link the suspension to the canards must be in a certain ratio.

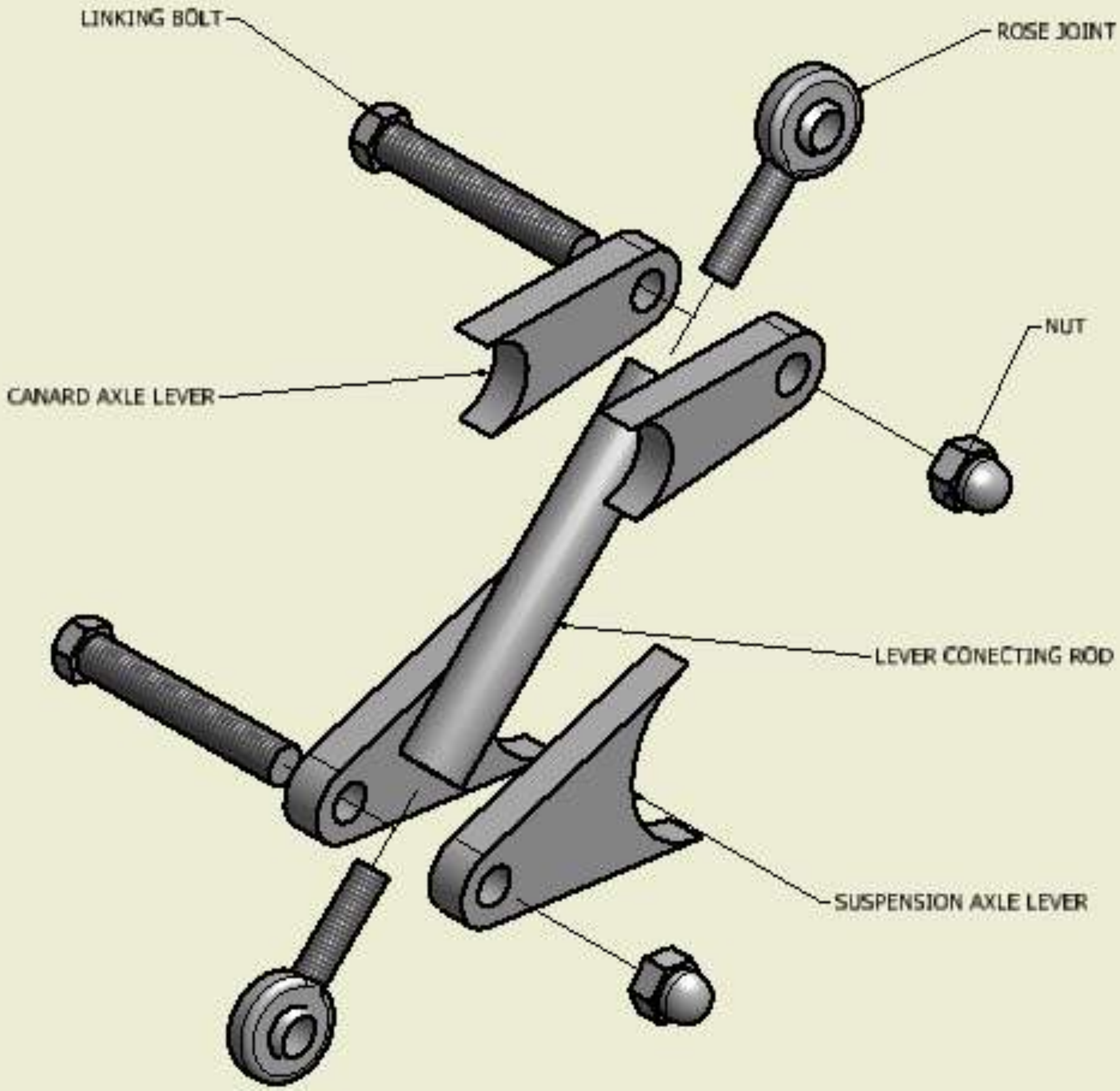


Z= Y tan 3

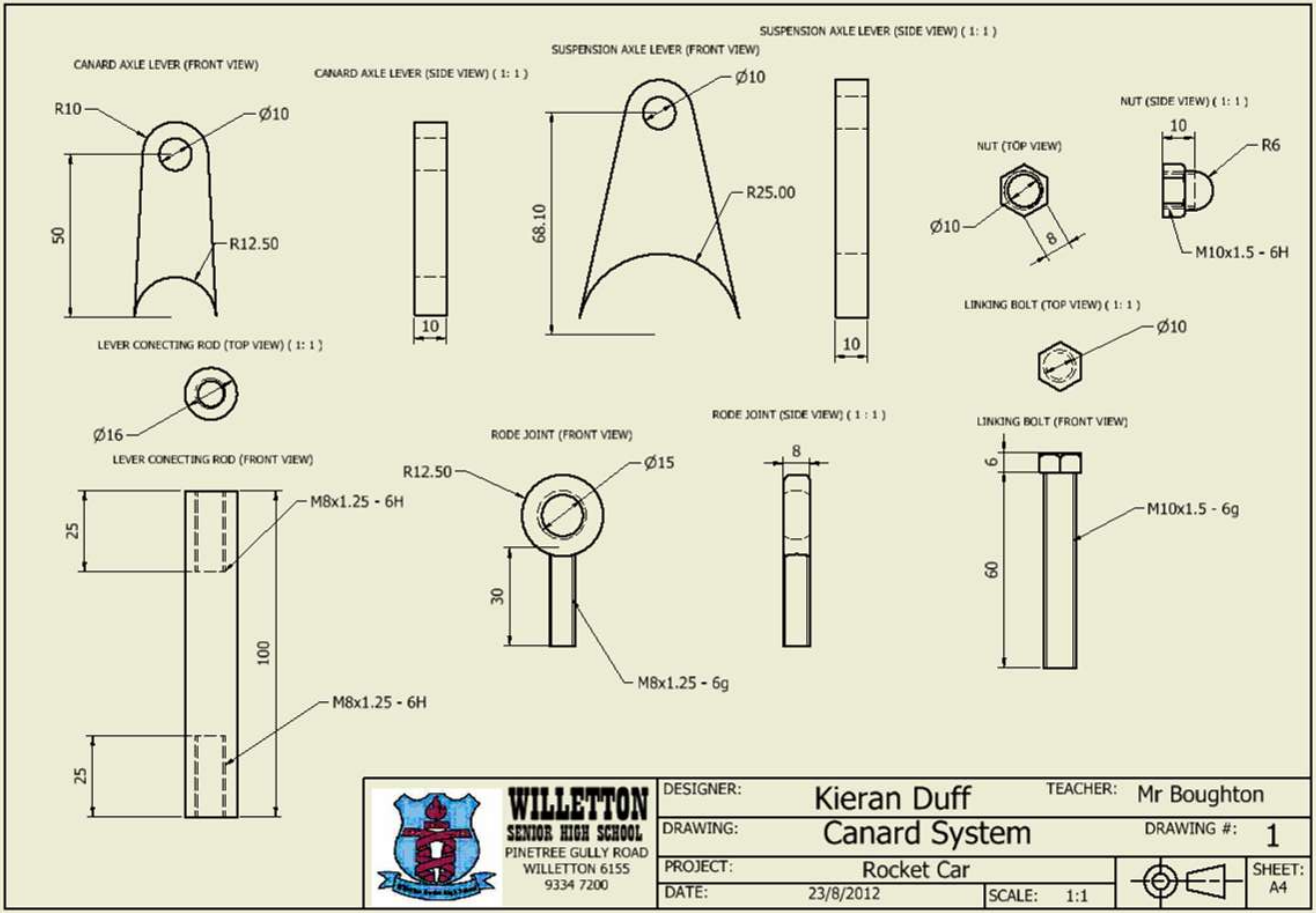
Z = X tan 2.204

Hence: Y tan 3=X tan 2.204

This means that any length X/Y of the levers corresponds to the other by the equation Y tan 3=X tan 2.204. The canard lever (Y) would best fit the design at a length of 50mm hence by using the equation above we can work out the suspension lever (X) to be 68.1mm



WILLETTON SENIOR HIGH SCHOOL PINETREE GULLY ROAD WILLETTON 6155 9334 7200	DESIGNER: Kieran Duff		TEACHER: Mr Boughton		
	DRAWING: Canard System Assembly		DRAWING #: 2		
	PROJECT: Rocket Car				SHEET A4
	DATE: 23/8/2012	SCALE: 1:1			


CANARD AXLE LEVER (FRONT VIEW)
R10
Ø10
50
R12.50
CANARD AXLE LEVER (SIDE VIEW) (1: 1)
10
SUSPENSION AXLE LEVER (FRONT VIEW)
Ø10
68.10
R25.00
SUSPENSION AXLE LEVER (SIDE VIEW) (1: 1)
10
NUT (TOP VIEW)
Ø10
8
NUT (SIDE VIEW) (1: 1)
10
R6
M10x1.5 - 6H
LINKING BOLT (TOP VIEW) (1: 1)
Ø10
LEVER CONECTING ROD (TOP VIEW) (1: 1)
Ø16
LEVER CONECTING ROD (FRONT VIEW)
25
M8x1.25 - 6H
100
M8x1.25 - 6H
25
RODE JOINT (FRONT VIEW)
R12.50
Ø15
30
M8x1.25 - 6g
RODE JOINT (SIDE VIEW) (1 : 1)
8
LINKING BOLT (FRONT VIEW)
6
M10x1.5 - 6g
60
WILLETTON
SENIOR HIGH SCHOOL
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DESIGNER: Kieran Duff
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Conclusion:

We believe that the design solution satisfies all the requirements and thus is an effective system suitable for use on the Aussie Invader. In the ideal situation, the integration of the canard system with the suspension should negate or minimize nose lift at speed and theoretically allow the least possible rolling resistance and maximum performance to be achieved. The design, subject to fabrication and further testing, should provide the safest and optimal down force for Rosco's world record run.

As the canard wings are fully automated, the design will greatly reduce the chance of excessive nose lift and catastrophe since the canards will be able to react instantly to any down force demand. If this system was put under manual control, the terrain undulations could only theoretically be responded to within 0.2 of a second. The ability of a human to respond to such small response times is almost minimal.
Further, the outlined suspension driven canard system does not require additional energy sources and motors. Thus, the proposed canard system has a reduced chance of failure and there is more available room around the internal components of the canards.

Our team hopes to incorporate this system into the finished version of the Invader 5R and trusts that our insight has helped the development of this great project into a word record vehicle.

Further Requirements:

Future development includes the design of a fail safe Angle of Attack (AoA) locking system so that if something goes wrong the canards are locked in a position that provides maximum safety for the remainder of the run. Secondly, more testing must be done to calculate the forces on the wing and how that affects the front axle load during each run. This would require significant CFD testing. However, such testing would give us useful data in determining the required dimensions of the wing and what mean AoA the canards must be set with respect to instantaneous velocity. The perceived canard oscillation problem specified earlier has not been investigated. However, it is anticipated that a damper system could be incorporated into the canard connecting rod. A performance appraisal of such a canard damping system needs to be undertaken.