



Midnight Sun Solar Car Team
University of Waterloo

Preliminary Vehicle Design Report

MSXII

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Contents

1	History	1
2	Mechanical	2
2.1	Overview	2
2.2	Chassis	2
2.2.1	Design	2
2.2.2	Manufacturing	2
2.2.3	Roll cage	2
2.3	Seat Belts	2
2.4	Braking System	3
2.4.1	Primary Brakes	3
2.4.2	Parking Brake	3
2.5	Steering System	3
2.6	Suspension	3
2.6.1	Front Suspension	3
2.6.2	Rear Suspension	3
2.7	Structural Analysis	4
2.7.1	1G Turn	4
2.7.2	2G Bump	4
2.7.3	1G Braking	4
3	Electrical	6

List of Figures

1	Top view showing major dimensions and system positions	2
2	Side view showing major dimensions and system positions	2
3	Chassis, front view	3
4	Chassis, top view	3
5	Chassis, side view	3
6	Welding jig under construction	4
7	Chassis with roll cage elements highlighted	4
8	Chassis mounting points for seat belts	4
9	Single seat belt tab	5
10	Side view of seat belt geometry	5
11	Top view of seat belt geometry	5
12	Schematic of primary braking system	5
13	View of dual-primary and parking calipers on front suspension upright	5
14	View of linkage from steering column to rack and pinion	5
15	View of front suspension assembly	5
16	View of rear suspension assembly	5

List of Tables

1	Table of major vehicle dimensions	2
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1 History

Midnight Sun was founded in 1988 at the University of Waterloo. The team has produced 11 solar-powered vehicles since its inception, numbered MSI through MSXI. MSX and its predecessors have been traditional Challenger class cars. MSXI was the team's first attempt at a Cruiser class vehicle, which ultimately suffered from

Figure 1: Top view showing major dimensions and system positions

Figure 2: Side view showing major dimensions and system positions

design issues relating to its monocoque design. With MSXII, the team has regrouped and designed a new Cruiser vehicle from the ground up, focussing strongly on reliability, safety, and manufacturability.

2 Mechanical

2.1 Overview

MSXII is a dual-occupant Cruiser class vehicle. Its structural design uses a steel alloy tube chassis with non-structural fibreglass body panels. The majority of the vehicle's powertrain systems are located behind the occupant cell, including the battery pack, power junction box, motor controllers, and EV charger. The vehicle is rear-wheel driven by two hub-mounted DC motors. The locations of these components are marked in Figure 1 and Figure 2. Major vehicle dimensions are summarized in Table 1.

2.2 Chassis

2.2.1 Design

The chassis is a tube structure enclosing the occupant cell with small front and rear subframes to support suspension hardpoints. Smaller non-structural tube members will extend from the main frame to provide support to body panels as necessary. The majority of tubes are round, with square tubes being used only for elements intended to mount suspension and powertrain components (battery pack, motor controllers). Chassis elements use SAE 4130N chromoly tubes with diameters or side lengths ranging from 0.750" to 1.250", and wall thicknesses ranging from 0.035" to 0.065". Isometric drawings of the chassis are shown in Figures 3, 4, and 5.

2.2.2 Manufacturing

Bending, cutting, and profiling of tubes was done by an external supplier. Welding of the chassis was done by a professional welder using GTAW, with support from team members for jiggging and assembly. A complete welding jig was designed in CAD and manufactured using 80/20 aluminum extrusion tubing, shown in Figure 6. Custom tube clamps were machined by the team to slot into jig members and fully support all chassis elements through multiple stages of assembly and welding.

2.2.3 Roll cage

The roll cage is integrated into the design of the chassis members enclosing the occupant cell. For the purposes of ASC regulations, the roll cage can be considered to include the A and B pillar hoops and elements connecting these two hoops lengthwise through the car. For clarity, these elements have been highlighted in Figure 7.

2.3 Seat Belts

MSXII is equipped with 5-point seat belts for both occupants. Seat belt hardpoints are mounted to metal tabs welded to chassis members, shown in Figure 8. Figure 9 shows one of these tabs. Figures 10 and 11 demonstrate compliance with ASC regulations 10.3.E.

Parameter	Value
Wheelbase	2.60 m
Track	1.60 m

Table 1: Table of major vehicle dimensions

Figure 3: Chassis, front view

Figure 4: Chassis, top view

2.4 Braking System

2.4.1 Primary Brakes

The primary braking system is designed with dual redundant front braking, consisting of two identical systems with separate master cylinders, hydraulic lines, and calipers to each of the left and right wheels. The master cylinders are operated in unison via a single mechanical brake pedal. A schematic of the primary system is shown in Figure 12.

Front brake calipers are Willwood parts 120-8374 (left) and 120-8373 (right). Willwood's website indicates the caliper pads have 2 in² (12.9 cm²) contact area and 0.30" (7.6 mm) depth including the backing plate.

The master cylinders are Willwood part 206-3374. They have a 3/8"-24 outlet size which will need to be connected via an adapter to the M10 x 1.25 inlets of the calipers. Brake lines will be DOT-approved hose assemblies sized for 3/8"-24. The brake pedal is Willwood part 340-15079 and is mounted in the standard configuration to the left of the accelerator pedal.

Brake rotors will be custom-machined within the supported disk thickness and diameter supported by the Willwood calipers. All mounting geometry on the suspension upright for primary calipers are designed to position the primary calipers in the optimal positions to meet braking specifications.

2.4.2 Parking Brake

The parking brake will be implemented by a cable-actuated caliper mounted at one of the front wheels. The caliper is the Tolomatic ME10LA, part number 0732-0003. It will share the same brake disk as the primary braking system but is otherwise mechanically independent. Due to unresolvable dimensioning differences between the Tolomatic and Willwood calipers, the parking brake caliper cannot be mounted perfectly as per the manufacturer's recommendations and will have only 80% overlap with the brake disk. However, this is expected to provide more than sufficient countertorque to keep the vehicle stationary as per ASC regulations 10.6.

Figure 13 shows a front suspension upright with all three calipers mounted (two primary and one parking).

2.5 Steering System

The steering system uses a rear-steering, left-hand-drive rack and pinion from Helix (part number 188754).

The system uses a collapsible steering column from Sweet Mfg., part number 405-10310. The steering system linkage uses multiple U-joints and is shown in Figure 14.

2.6 Suspension

2.6.1 Front Suspension

The front suspension uses dual A-arms with an outboard dampener and coilover spring. The upper and lower control arms are custom-built from 4130 chromoly tubes. The dampener and coilover are a single integrated assembly supplied by Öhlins, sold as the TTX25, which is marketed for Formula SAE vehicles. Figure 15 shows the front suspension assembly.

TODO: rod-end sizing justification based on shear loads

2.6.2 Rear Suspension

The rear suspension uses independent trailing arms mounted outwards from the rear of the chassis. The trailing arm itself is custom-machined and mounts the same Öhlins TTX25 shock absorber as the front suspension. Figure

Figure 5: Chassis, side view

Figure 6: Welding jig under construction

Figure 7: Chassis with roll cage elements highlighted

16 shows the rear suspension assembly.

TODO: rod-end sizing justification based on shear loads

2.7 Structural Analysis

FEA of suspension and steering components was done using ANSYS software. The specific loading conditions prescribed by ASC regulations are analyzed in this section.

2.7.1 1G Turn

2.7.2 2G Bump

2.7.3 1G Braking

Figure 8: Chassis mounting points for seat belts

Figure 9: Single seat belt tab

Figure 10: Side view of seat belt geometry

Figure 11: Top view of seat belt geometry

Figure 12: Schematic of primary braking system

Figure 13: View of dual-primary and parking calipers on front suspension upright

Figure 14: View of linkage from steering column to rack and pinion

Figure 15: View of front suspension assembly

Figure 16: View of rear suspension assembly

3 Electrical