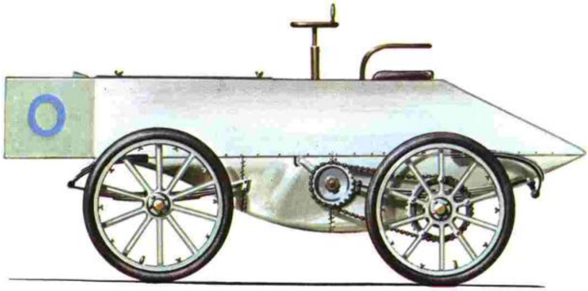
ThrustSSC Supersonic
Land Speed Record Car

Historic Mechanical Engineering Landmark

Designation Ceremony, 15 March 2014

Coventry Transport Museum, Coventry CV1 1JD , UK

History of Land Speed Record for Cars



1898 Jeantaud Land Speed Record Car

The Land Speed Record (LSR) for cars is a competition for 4-wheeled vehicles that aim to achieve the highest possible speed over either a measured mile or kilometre. Regulations of the Fédération Internationale du Sport l'Automobile (FIA) require that the speed is the average of two officially timed runs – one in each direction – and that the second run be completed within one hour of the first.

The first World Land Speed Record was set in 1898 by Count Gaston de Chasseloup-Laubat driving a battery-electric powered, 36 hp, 1400 kg Jeantaud on the road in Acheres Park near Paris, France. On 18 December 1898 he achieved a one-way record speed of 63.1 km/h (39.2 mph) for the flying kilometre. The record then went to Camille Jenatzy driving his own torpedo shaped Jenatzy at 49.2 mph on 17 January 1899. During 1899 the record went back and forth between these two battery-electric, chain-driven vehicles until on 29 April 1899 Jenatzy set the record speed of 105 km/h (65.8 mph) at Acheres – a record that would stand for three years. These early records were all set in France because it had long, straight roads that encouraged high speed racing. This road system was built by Napoleon in order to march his armies from one city to another.

The first non-electric powered land speed record car was built and driven by Leon Serpollet of Paris. On 13 April 1902 he set a record of 120.4 km/h (75.1 mph) at Nice, France in a steam powered Serpollet. This record was short lived; on 5 August 1902 William K. Vanderbilt from the U.S. drove a Mors to a record speed of 122 km/h (76.1 mph) near Chartes in France. The Mors was the first petrol powered record holder. Its 9,232 cc internal combustion engine produced 60 bhp and Vanderbilt ran it with full gear for road racing; i.e. brakes, coachwork, horn, etc. Subsequently, Henry Fournier and Georges Auger (racing under the name Augieres) stripped down the Mors and increased the speed to 123.6 km/h (77.1 mph) for the kilometre. Later, Arthur Duray and then Louis Rigolly took the record driving an internal combustion engined Gobron-Brillie. This pushed the record to 103.6 mph on 21 July 1904. From this early era other important record holders were Mercedes, Darracq, Napier, Stanley and Benz.

1905 6-cylinder Napier
Driver - Arthur McDonald

1933 Blue Bird
Driver - Malcolm Campbell

In 1925 Sir Malcolm Campbell pushed the record to 242.8 km/h (150.7 mph) in a four litre, 350 bhp, 12 cylinder Sunbeam Tiger on the beach at Pendine Sands in the U.K. Then in 1927, Henry Seagrave in another Sunbeam raised the record to 203.8 mph at Daytona Beach, Florida in the U.S.

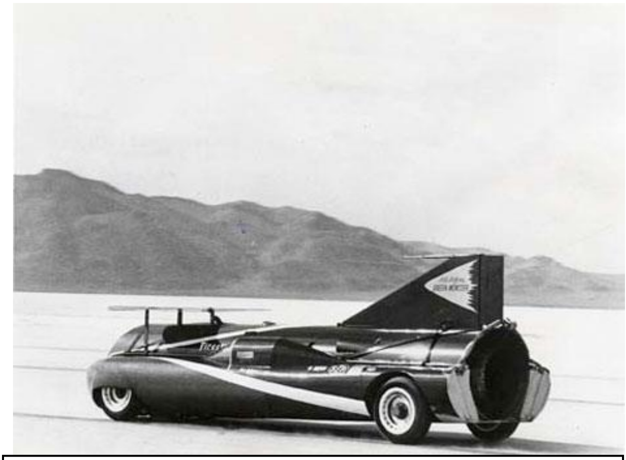
In 1928, Campbell returned with a new car, the Napier-Campbell Blue Bird, which initially set a record of 207.0 mph. A later version of this car pushed the record to 301.1 mph in 1935 at Bonneville Salt Flats, in the U.S. It was powered by a monster 36 litre Rolls Royce V12 aircraft engine producing 2,000 bhp.

In 1947, John Cobb upgraded his Railton Mobil Special to achieve a record of 394.6 mph. Cobb had a maximum one-way speed of 402 mph. It took until 1960 for a southern California hot-rodder, Mickey Thompson, to build the wide-bodied Challenger I powered by four supercharged Pontiac engines mounted in a square 2 x 2 formation. At the Bonneville Salt Flats in 1947, this car had a one-way timed speed for the mile of 406.6 mph. A mechanical mal-function prevented Thompson from making the return run that is required for a Land Speed Record.

1960 Challenger I
Driver - Mickey Thompson

About this time, surplus military jet engines began to become available in scrap metal yards and this completely transformed the Land Speed Record game. These high performance aircraft engines had much more power than internal combustion engines and they were quickly adopted by the innovative designers of Land Speed Record cars. First out of the box was Craig Breedlove, an indefatigable campaigner, who built the jet powered Spirit of America. In 1963 this vehicle went 407 mph propelled by the thrust of the jet engine. However, it did not qualify for the land speed record because it only had three wheels. Subsequently, in 1964, Donald Campbell, the son of Malcolm Campbell, brought to Lake Ayre, a dry lake in Australia, the powerful streamliner Bluebird CN7. This car was powered by a Proteus jet engine with the power transmitted through the wheels. It set a speed record of 407 mph. Later, in October 1964, at the Bonneville Salt Flats, Tom Green's Wingfoot Express increased the record to 413 mph. This car was designed by Green, a chief engineer at a small tool manufacturer, and Walt Arfons, who had experience building racing cars. On the back of Green's insightful aerodynamic design, they obtained funding from Goodyear Tires – hence the name "Wingfoot Express". While Arfons had been scheduled to drive the high-speed runs at Bonneville, he was incapacitated by a heart attack caused by watching Green crash the car through a chain link fence after losing the braking parachutes at 200 mph. Green took over as driver for the record runs although previously he had never exceeded 130 mph while driving.

1964 Wingfoot Express
Driver - Tom Green



1964 Green Monster
Driver - Art Arfons

Three days after Tom Green set his record, Art Arfons increased the record to 434 mph in the Green Monster turbojet car. Then Breedlove returned with a thrust-powered four-wheel car, bumping up the record to 468 mph and then to 536.7 mph. This car also was jet propelled. The following year, Craig Breedlove was back at Bonneville, and at the conclusion of a duel with Arfons, he set a record speed of 600.6 mph with his Spirit of America Sonic I powered by a J79 Turbojet engine from an F-4 Phantom fighter aircraft.

There still were internal combustion cars running at Bonneville. The Summers brothers' streamliner Goldenrod was a notable example – it was powered by four Chrysler hemi engines, mounted in-line and producing a total of roughly 3,000 bhp. In late 1964 it ran at a two-way average of 409 mph, setting a record for wheel driven cars. The wheel driven cars now run in a special class rather than the Unlimited class; the Unlimited class has been dominated by thrust propulsion since 1964.

It took another five years before the liquid fuelled rocket powered Blue Flame, driven by Gary Gabelich, moved the record up to 622.4 mph (1970). This car had very small frontal profile and a liquid natural gas-hydrogen peroxide rocket engine built by Reaction Dynamics. The engine produced only 13,000 lbf thrust during the record runs. This is the only rocket powered vehicle to have held the Land Speed Record.

After a 30 year run of American record holders, the British returned to the fray in 1982 when Richard Noble brought his Thrust2 jet-powered car to Bonneville. This car was powered by a Rolls-Royce Avon 302 jet engine from a Lightning jet fighter. It produced 17,000 lbf thrust. However, that year it rained on the salt flats so the

1982 Thrust2
Driver - Richard Noble

surface was in no condition for record-breaking runs. Consequently, attempts on the record moved to the playa of Black Rock Dry Lake in Nevada – a larger area with a dry-caked mud rather than a dried salt surface. That year Thrust2 achieved over 550 mph but the following year, in 1983, Richard Noble returned with his team to set a new record of 633.5 mph.

The next goal of LSR car constructors was a vehicle to exceed the speed of sound, which is approximately 760 mph. Thrust2 was near its limit when it set the record so it was clear that new ideas were required to achieve such a substantial increase in speed. With the ambition of setting a supersonic record, Noble was able to assemble a team and raise sponsorship to build a new car, ThrustSSC. On 15 October 1997 ThrustSSC, driven by Andy Green, set a LSR of 763.035 mph (Mach 1.02) for the flying mile at Black Rock Dry Lake in Nevada. Their kilometre record is 760.303 mph. This is the only supersonic speed record to be officially recognised.

1970 Blue Flame
Driver - Gary Gabelich

Post-WWII Land Speed Records

Date	Driver	Car	Speed
1947	John Cobb	Railton	394.2 mph
1963	Craig Breedlove	Spirit of America	407.5 mph*
1964	Donald Campbell	Bluebird CN7	403.1 mph
1964	Tom Green	Wingfoot Express	413.2 mph
1964	Art Arfons	Green Monster	434.0 mph
1964	Craig Breedlove	Spirit of America	526.3 mph
1964	Art Arfons	Green Monster	536.7 mph
1965	Craig Breedlove	Spirit of America – Sonic I	600.6 mph
1970	Gary Gabelich	Blue Flame	622.4 mph
1983	Richard Noble	Thrust2	633.5 mph
1997	Andy Green	ThrustSSC	763.0 mph

* 3-wheeled so not recognised by FIA.

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Supersonic Dreams

As surplus jet engines from military aircraft began to be used in LSR cars, the car designers asked themselves, "If these engines can push an aircraft to supersonic speeds, why not a car?" However, they soon recognised that there are some special problems related to operating a car at transonic speeds. One problem is additional drag caused by the wheels ploughing the surface of the dry lake bed. A second problem is a shock wave generated from the nose of the car which is reflected from the ground surface, creating lift, that suddenly increases as the speed approaches Mach 1.

1966 Mockup of Bluebird Mach 1.1

Following his successful record attempt with Bluebird CN7 in 1964, Donald Campbell imagined that the next step would be a supersonic car. His goal was to build a supersonic rocket car with a potential maximum speed of 840 mph. His design engineer, Ken Norris, began preliminary design of a car named Bluebird Mach 1.1. Norris's view was that rocket propulsion would result in a car with low frontal area, high density and low weight in comparison with jet propelled cars. Norris based his design on two Bristol Siddeley BS605 rocket engines – these were reliable, off-the-shelf takeoff-assist rockets for aircraft. Each engine had a rated thrust of 36 kN (8,000 lbf); at 840 mph the pair had thrust equivalent to 36,000 bhp. This project was abandoned, however, when Donald Campbell was killed during an attempt to set a world speed record for hydroplanes.

After he had taken the world LSR, during 1968 Craig Breedlove and his associates searched for funding for a supersonic car. This effort got as far as the governor of Utah providing a hangar facility for construction of the car near the salt flats. The project obtained financial support from Bill Lear and his friend, Art Linkletter. This however was not sufficient and eventually the project was scuppered by a lack of public interest.

It was 1992 before Breedlove obtained funding to build a new vehicle named the Spirit of America – Formula Shell LSRV. This car was again based on an upgraded J79 jet engine producing a thrust of 103 kN (22,650 lbf). The vehicle was constructed around a steel tube frame with an aluminium skin. In 1996 on the Black Rock desert, this car swerved off the track and crashed at around 675 mph. The car slid on its side but hit nothing and the driver emerged unhurt. Breedlove returned to Black Rock with the car in 1997, but after the engine was damaged and then rebuilt the car could do no better than 676 mph. That same year ThrustSSC was running and set the world record of 763 mph.

2007 Sonic Wind & 1997 Spirit of America-Formula Shell
Driver - Craig Breedlove

The idea of a supersonic car came to Richard Noble following his successful bid for the world LSR at Black Rock Dry Lake in 1983. In that year Noble drove Thrust2 to a two-way average for the mile of 633.5 mph – an achievement that took the LSR from the rocket powered Blue Flame. This effort was at the limit for Thrust2. Noble recognised that to go faster he needed substantially more thrust; i.e. a new car. To obtain funding for a new car, however, it was not sufficient to aim for an incremental increase in the record speed – he needed a design aim which would command attention. The goal of a supersonic LSR was a bold step that just might be achievable. At the elevation and day-time temperatures of Black Rock, the speed of sound is about 760 mph. To achieve his goal, Noble pulled together a new team to design and construct ThrustSSC – a supersonic car. This car was ready for initial test runs in 1996 and it finally set the LSR record of 763 mph in 1997.

What is the next step? Currently there are several projects in the works aiming to build a contender capable of 800 or even 1,000 mph. Following his lack of success in 1997, Breedlove sold the Spirit of America to Steve Fossett, a holder of ballooning, aviation and sailing records. This car, renamed as Sonic Wind, was being prepared to run in 2007 but Steve Fossett was killed in a small plane accident in the Sierra Nevada Mountains of California and the effort fizzled out.

Another contender tested during 2013 is named the North American Eagle – a jet powered car based on the fuselage and engine of a F-104A Starfighter fighter jet. This is a relatively low-cost operation by a group of U.S. and Canadian enthusiasts. They removed the wings and beefed up the Starfighter fuselage to support the wheels.

North American Eagle

From New Zealand a new contender is named Jetblack. It will have two throttleable hybrid rocket motors. The builders planned to begin low-speed tests in 2014.

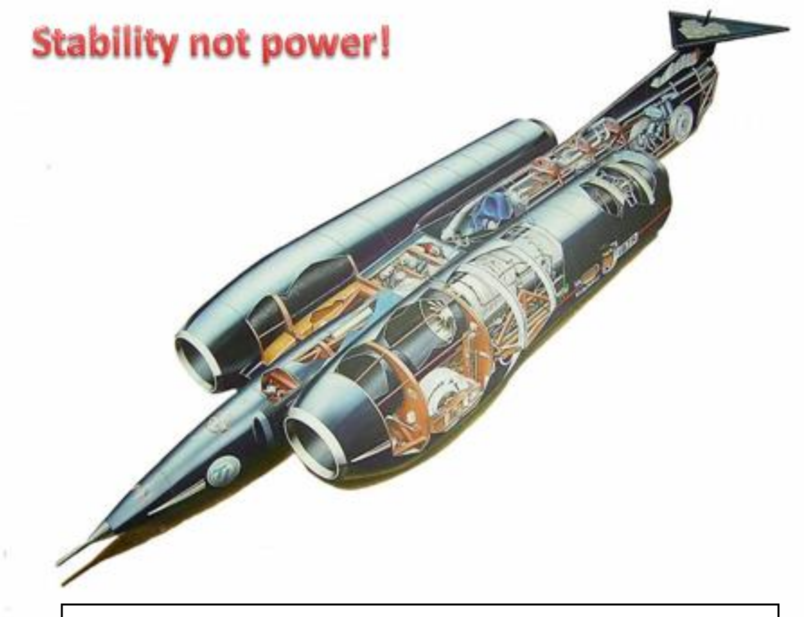
Finally, in Britain, Richard Noble is leading a team building a new vehicle, Bloodhound, with the aim of exceeding 1,000 mph. The team plans to combine a turbojet engine with a rocket. The jet engine will produce 82 kN (18,000 lbf) of thrust while the rocket will add another 109 kN (24,000 lbf). In 2015, the Bloodhound team plans to conduct test runs on a large dry lake in South Africa – a lakebed large enough for a straight 12 mile track.

2013 Bloodhound Mockup

ThrustSSC Design Innovations

At speeds approaching the speed of sound any increase in the record requires a larger ratio of thrust to drag. There are other challenging barriers; some of these were faced by airplanes seeking to cross the supersonic threshold. Pilots of high speed planes became aware of sudden changes in control functions as they accelerated through the speed of sound. Their planes also required a large increase in thrust to continue their acceleration through the sound barrier.

When Richard Noble set out to build a supersonic car, ThrustSSC, he needed a design engineer – someone familiar with the problems of travelling in the range of transonic speeds. He found Ron Ayers, recently retired, who had been Chief Aerodynamicist at British Aerospace on the Bloodhound supersonic missile project. These two



Cut-away layout drawing of ThrustSSC

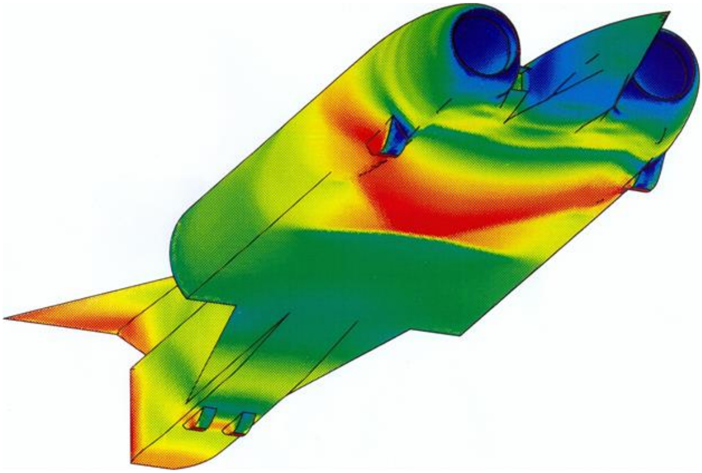
set out the basic layout of a car with two jet engines. The car would have the engines mounted forward to promote stability during acceleration. Noble and Ayers purchased two surplus Rolls-Royce Spey 202 engines as used in the Phantom F4 jet fighter; these produced 100 kN (22,000 lbf) thrust per engine. The design of a chassis and wheels to support this package was turned over to Glynne Bowsher, a mechanical engineer. He hung the engines on either side of a central space-frame fuselage which contained the driver's cockpit, the rear wheels and a tailfin with an adjustable horizontal stabilizer. The rear fuselage needed to contain the rear wheels but be narrow enough to avoid overheating by the jet exhausts on either side. A smaller fuselage cross-section was achieved by staggering the rear wheels – placing one ahead of the other. This satisfied FIA regulations requiring a car to have four wheels. To avoid problems

Work on rear suspension of ThrustSSC

with keeping the tyres on wheels at high rates of rotation, solid wheels without tyres were forged from alum-inium, Al-7075T6. This idea had been used successfully on a previous car, Thrust2. Under normal loading on the playa of Black Rock Dry Lake, these wheels slightly indent the surface, giving grip for steering. At top speed they rotate at 8,500 rpm. ThrustSSC employed rear wheel steering to minimise the width of body that enclosed the front wheels and reduce the size of the wheel openings through a belly pan. This minimised aerodynamic drag.

The principal design concern, however, was transonic aerodynamics. At speeds approaching the speed of sound, aerodynamic drag increases rapidly. Also, shock waves coming off the nose of the car will reflect from the playa surface causing a large lift force near the front of the car. Ayers was aware that the front wheels of one of Craig Breedlove's cars had lifted at speeds above 600 mph. At these speeds, lift-off of the car needs to be avoided at all cost.

Rear View – offset rear wheels and parachutes



Computational fluid dynamic calculation of pressure distribution on belly of car at transonic speed

To investigate the aerodynamic forces acting on the car at the planned operating speeds, a model was tested in a transonic wind tunnel. The resulting estimates of pressures acting on the car were further evaluated through computational fluid dynamic calculations – a technique which clearly illustrated the region of high pressure lifting the front of the car.

Control of the lift force was important not only for stability but also to limit the rolling friction that acts on the wheels. Too much down-force causes the wheels to plough into the playa, increasing wheel drag and retarding acceleration of the vehicle. Some slip between each wheel and the lake bed results in sliding friction which accelerates rotation of the wheel; this friction, however, is another force resisting vehicle acceleration. To balance these forces which change rapidly with increasing speed, the car was built with an active suspension system that increased the nose-down pitch of the car as the load decreased on the front wheels. This system was controlled by force sensors on the front suspension. As the tail rose and the pitch increased, there was increasing downward aerodynamic force distributed across the body panels of the car.

ThrustSSC was designed from the outset with safety as a principal consideration. The engine performance was continually monitored and if there was any unbalance, the engines were automatically shut down. There were more than 120 sensors built into the vehicle to monitor the state of engines, suspension and surface pressures, as well as wheel and ground speed and components of acceleration. This vehicle used both main and reserve parachutes for braking from 600 mph in addition to disk brakes for braking below 200 mph. The car had separate fire extinguisher systems for the driver's compartment and each engine; these were activated by both obscuration (smoke fires) and ionisation (visible flame) detection. The driver used an oxygen mask and an enclosed helmet which provided both impact and fire protection. In the event of a crash, the cockpit fire extinguisher was operated automatically while the driver breathed oxygen.

Contribution to Development of Engineering

ThrustSSC is an example of how world class performance in a technically demanding arena can be achieved by a small dedicated team. This self-funded team raised sponsorship and overcame a myriad of technical and management problems through innovation, imagination, thoughtful design and careful craftsmanship. Its World Land Speed Record, set in 1997, still stood in 2014. Furthermore, the team provided insight into its design process through a website (www.thrustssc.com) which explains the team philosophy and the reasoning behind the unique layout of this vehicle. This website is one of the world's most popular – it has been accessed over 59 million times.

1997, ThrustSSC at 750 mph on Black Rock Dry Lake

Design Specifications

Length	22 m
Weight	10.5 kN
Engines	RR Spey 202 from Phantom jet fighter
Thrust per engine	100 kN (22,000 lbf)
Weight per engine	2 kN
Wheels	0.9 m diam. Forged aluminium
Max. acceleration measured	1.08 g
Max. deceleration measured	1.22 g

Shock waves above ThrustSSC at 763 mph

Some Members of the ThrustSSC Team

Richard Noble	Concept Design, Entrepreneur
Ron Ayers	Concept Design, Aerodynamicist
Glynne Bowsher	Mechanical Engineer, Structure Design, Wheel & Steering Design
Jeremy Bliss	Vehicle Systems Engineer, Active Suspension System
Andy Green	Driver
Adam Northcote-Wright	Communications
Robert Atkinson	Instrumentation Engineer
Martyn Davidson	Operations Manager
Chris Cowell	Engine Maintenance & Repair
Robin Richardson	
Rod Barker	
Jayne Millington	

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In 1971 ASME formed a History and Heritage Committee composed of mechanical engineers and historians of technology. This Committee is charged with examining, recording and acknowledging mechanical engineering achievements of particular significance. For further information, please visit http://www.asme.org

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