The Aircraft Engine: An Historical Perspective of Engine Development through World War I

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As the quest for manned, heavier-than-air flight progressed into the latter half of the 19th century, man still did not possess sufficient scientific understanding of all the principles that would permit the successful accomplishment of what many still considered to be a fanciful pursuit and a waste of time. As a functional directional control system for aircraft had not yet been developed, little more than partially controlled glides or “powered hops”, rather than fully controlled sustained flight, were even realized. Although gliders had been scientifically designed and tested with limited success since the beginning of the century, it became apparent that a sufficient source of motive power would be required for the sustained, powered flight of man. However, engines of the day were still crude and inefficient, and were just being developed and refined into devices that could do useful work. Some of the earliest aircraft designs of the day exhibited a range of potential for successfully accomplishing controlled, powered flight and incorporated sometimes novel and often primitive engine designs to develop propulsion.

As early as 1808, Englishman Sir George Cayley designed and experimented with a calorific engine which burned gunpowder as the fuel (Berliner, pp. 12-15). The gaseous products of combustion drove a piston within a cylinder that converted the reciprocating piston’s motion to mechanical work, possibly rowing Cayley’s “aerial oar”. Had this prototypical engine proved successful, Cayley might have used one in an attempt to propel a variation of his early helicopter designs or his Boy Carrier aircraft. In 1857 Felix du Temple of France successfully flew a clockwork (wound spring) powered model having the very modern characteristics of monowing construction, rear empennage, tricycle gear, and with the propeller located in the nose (Berliner, pp. 20-22). In preparing his full scale monoplane in 1874, du Temple’s search for the ideal powerplant caused him to reject the available steam engines (too heavy) and gasoline engines (too unreliable) of the day. Instead, he used a “hot air engine” which was reported to operate in a manner similar to that of a steam engine; unfortunately, the underpowered engine was not able to propel the aircraft beyond a “powered hop”. Ultimately, success in these early efforts was not to be, resulting in other inventors and experimenters continuing the quest for manned flight utilizing other engine designs to develop the required power.

American James Watt designed and built steam engines that were practical in their use to propel wheeled land vehicles as early as the 1780s (Davies, p. 18). Typical steam engines of the mid 1800s were essentially refined versions of Watt’s simple external combustion steam boilers, including designs such as those developed by Englishmen William Samuel Henson and John Stringfellow (Berliner, pp. 17-22; Jordanoff, p. 8). Energy was converted into useful work by generating steam in a boiler typically fueled by rendered oils. The expansion of the steam inside a cylinder–piston arrangement converted the reciprocating piston to shaft rotation, which, in turn, drove a propeller (or multiple propellers) directly or through a drivetrain. In addition, this type of engine required separate reservoirs for water and fuel, making these types of engines excessively heavy and grossly underpowered for the aircraft designs of the day. Stringfellow’s 1848 model experiments employed a miniature steam engine that weighed 9 lbs., including the two propellers and gearing. In his full scale experiments which began in 1868, Stringfellow used a larger steam engine based on the successful model engines. In 1869, the French Michaux brothers attached a steam engine to a bicycle, creating their first powered motorcycle (Davies, p. 23). In 1879, Russian naval officer and engineer Alexander F. Mozhaiski journeyed
to America and then to England where he eventually found two suitable steam engines of 10 and 20 horsepower (HP) for his flight experiments (Berliner, pp. 23-25). It would not be until July 1884 when Mozhaiskii successfully flew his steam powered full scale aircraft to accomplish a "powered hop" and not truly powered flight as had been claimed by the Russian government. French inventor Clement Ader also conducted flight experiments in October 1890 in his steam powered Eole aircraft, and even claimed to be the first man to have successfully flown a heavier-than-air craft (Angelucci, pp. 14-15). His later efforts, also funded by the French War Ministry, resulted in the October 1897 flight of the Avion III, a bat-winged aircraft powered by two 20 HP steam engines. Although victory was announced once more, various witness accounts of the event tended to discount its actual success, again discrediting Ader. Samuel Pierpoint Langley's model Aerodrome experiments in the 1890s used small steam engines. His highly successful flights of the model Aerodrome No. 5 in May 1896 utilized a 1 HP steam engine (Jordanoff, p. 8; Berliner, p. 53; Angelucci, p. 15). His later efforts in manned flight with his full scale Aerodrome, however, used a gasoline powered engine. It became apparent over time after the many attempts by numerous inventors that steam powered engines were far too heavy and produced insufficient power for aircraft; an alternative source of power would have to be found. Although steam engine development and production for aircraft engine applications would continue into the next century, the development of the far more powerful and lower weight gasoline-powered internal combustion engine in the late 19th century would soon render the steam engine obsolete in aviation.

Two important events of the 19th century helped change the direction of engine technology development used in aviation and other modes of transportation. First, the now famous Pennsylvania oil fields were struck by Edwin Drake in 1859, making available seemingly unending quantities of crude oil from which gasoline and other useful petroleum-based fuels could be made (Northey et al, V. 14, pp. 1673-1678). The science of distilling crude oil into different petroleum products (gasoline, naptha, kerosene, fuel oils, etc.) was becoming a better-understood and controlled industrial process. This process was initially derived from the distillation of oils from coal, a practice necessitated by decimation of the world's whale population, and the resultant decline in supply of whale oil. At this time of the gasoline-powered engine's evolution through the beginning of the 20th century, the demand for gasoline would not outstrip production. Thus, gasoline, a fuel having very high specific energy content, was available in relatively plentiful supply in America.

Secondly, practical versions of two stroke and four stroke engines had finally been invented and were being experimented with by would-be aviators as the turn of the century approached. In two stroke engines, each revolution of the crankshaft produces one complete power cycle. Exhaust is scavenged out of the cylinder during the piston's downward power stroke, shortly followed by intake of fresh fuel-air mixture. As the piston hits and then passes bottom dead center (BDC), it begins its upward travel, creating the compression stroke, where the fuel-air charge is compressed. At or near top dead center (TDC) ignition occurs, causing the expanding gases to push against the piston (and thereby generating power). The cycle then starts over again. A crude version of the two stroke engine was initially designed in 1801 and patented in 1804 by Frenchman Phillipe Lebon d'Humberstein. In his design, fuel and air was to be ignited in the cylinder at atmospheric pressure, a design which most likely would have resulted in relatively low power output; unfortunately, d'Humberstein was assassinated before he could build his engine. It was not until 1854 when Italian inventors Eugenio Barsanti and Felice Matteucci patented a somewhat more useful two stroke engine. In their design, the ignited fuel-air mixture pushed against a free piston within a cylinder which transferred motion to another piston, rotating a shaft (Northey et al, V. 10, pp. 1181-1182; Northey et al, V.14, pp. 1599-1601). Frenchman Etienne Lenoir, fascinated by inventing useful devices, began work in 1850 on a new type of engine that electrically ignited lighting gas (typically used for street lamps) with atmospheric-pressure air, thereby producing the expanding gases that could be harnessed for the generation of power. This engine was completed in 1858, and patented in 1860. One such engine was fitted to a cart, creating the first direct predecessor, albeit a very crude iteration, of the automobile (Northey et al, V. 10, p. 1181). Power output for these early Lenoir two stroke engines were 1 HP from a 6 liter (366 cu. in.) displacement engine, and 2 HP from an 18 liter (1098 cu. in.) displacement engine. Lenoir claimed his engines would work on a variety of fuels including liquid hydrocarbon, pure hydrogen, and sulphurous gas. It was at this time that German inventor Nicolaus August Otto and his brother Wilhelm designed variations of the two
cycle Lenoir non-compressed (atmospheric pressure) gas engine. Although these and other engine design and modification efforts were successful, patent applications were rejected based on the finding that these engines were simply refinements of others’ work. The Otto brothers, with Eugen Langen, then made the critical technical advance of compressing the fuel–air charge before it entered the cylinder. Favorably viewed as an original innovation, it won patent approval on 21 April 1866. Later, Nicolaus Otto reorganized his company with Gottlieb Daimler as president, and Franz Rings as chief engineer. Rings’ most important contribution was to discard the free piston idea and to focus on one of Otto’s engine concepts of 1862, the four cycle engine (Nordheyt et al, V. 14, pp. 1599-1600). In a four cycle engine, two full rotations of the crankshaft comprised of four distinct cyclic stroke events produce one complete power cycle. These are the intake stroke, the compression stroke, the power stroke, and the exhaust stroke. As with the aforementioned two cycle engine design, the critical distinction of the four cycle engine’s operation was compressing the fuel–air mixture within the cylinder prior to ignition, dramatically raising power output and overall efficiency. So ingenious and novel an approach was this that the air standard “Otto Cycle”, ascribed to its inventor, is a fundamental engineering thermodynamic principle (Holman, pp. 424-425). In May 1876, Rings conceptualized such an engine and by 1877, had successfully produced a working prototype. In practical terms, a higher compression ratio produces greater thermal efficiency, which equates to more power and higher performance, other things being equal. By 1885, gasoline fueled motorcycles and automobiles powered by both two and four cycle engines were being manufactured in relatively small quantities; manufacturing in volume would not be long in coming, however.

The engine used by Langley in the attempted flights of his full sized Aerodrome aircraft on October and December 1903 was developed by Charles M. Manly, based on a substantial redesign of a Balzer automobile engine (Angelucci, p. 15; Jordanoff, pp. 8–9; Gunston, p. 100; Angle, pp. 325–327). A static water cooled 5-cylinder radial, it featured a displacement of 540.2 cu. in. (8.85 liter), weighed 125 lbs. dry and 207.5 lbs. wet including coolant water, and produced 52.4 HP for a specific power rating of 2.4 lbs./HP (dry) or 4.0 lbs./HP (wet). Note that the specific power rating is simply a measurement of weight efficiency (the amount of engine weight per unit of generated output power – a lower number being more efficient). Although it does not indicate absolute power, reliability, operating limits, nor any other actual performance information, the specific power rating can be used as a relative measure in comparisons of overall design efficiency of different engine configurations. The early experiments of Orville and Wilbur Wright employed a horizontally arranged inline 4-cylinder, four cycle engine designed by Wright employee and mechanic Charles Taylor (Jordanoff, p. 9; Gunston, pp. 178–186). This engine, which powered the Wright Flyer on 17December 1903 when Orville flew those immortal 12 seconds over Kitty Hawk, NC, produced a consistent 12 HP, peaking to as much as 16 HP. A unique feature of this engine was that it had no carburetor or active fuel injection system; ordinary automobile gasoline dripped into a heated tray, vaporized, mixed with air, and was drafted into the chimney intake. The bare engine weight was 152 lbs.; weight with all accessories (including radiator and piping, but no water) was 174 lbs.; and specific power rating was 12.7 lbs./HP (dry). After some Wright–designed modifications were made in 1904, the engine seemed to improve with use; 15 HP in 1904; 16.6 HP in January 1905; and over 20 HP by the end of 1905. This may have been attributable to “loosening up” following break–in, resulting in reduced internal friction and the apparent power gain. Later Wright designs included a series of V–8 engines. Although they were contemporaries, Manly had designed an engine that was decisively superior to the Taylor engine. Such experimental efforts would pave the way for future successful engine designs.

As the beginning of the 20th century unfolded, several technological advancements surfaced that contributed to the development of effective aircraft engines. A key industrioeconomic phenomenon sweeping both Europe and America was the wildly increasing popularity of automobiles, trucks and motorcycles. Commercial and consumer demand placed production pressures on all manufacturers, giving rise to the development of critically needed mass production techniques. These vehicles, once curious toys of the affluent and adventurous, were now becoming the new workhorses of daily commerce and the new standard of personal transportation. In the unending game of performance one-upmanship, automotive engine designers were driven to develop higher powered, more efficient engines. Moreover, the soon-to-be-discovered process of petroleum cracking would increase the yield of specific refined petroleum fractions such as gasoline from crude oil and would
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avert a shortage of the fuel. All of these factors, in conjunction
with the public's new-found fascination with aviation, spurred
the development of higher performance aircraft engines.

THE QUEST FOR FASTER, BIGGER, AND BETTER

In the first few years immediately following Orville
Wright's flight at Kitty Hawk, several other aircraft had been
successfully designed, built, and flown. As aircraft designers
and builders were understanding and applying all known
scientific theories to flight, they also realized the need for
greater power and more weight-efficient engines. And as
various monetary prizes were being offered for setting new
performance records for speed, altitude, and especially
endurance, the need for increased reliability also became
paramount. Thus, aircraft designers and pilots turned to
specialty aircraft engine builders and to the still fledgling but
quickly advancing automotive industry for those powerplants.

From the very beginning, the Antoinette engine, designed by
French engineer Leon Levavasseur with businessman Jules
Gastambide, was clearly technologically advanced. It
featuring direct fuel injection, gears or belts driving the
accessories (fuel injection pumps, oil pumps, and magnetos),
thin, lightweight copper water jackets, and a lightweight
aluminum condenser (radiator). In comparison to an air
cooled design, water cooling generally provides higher
thermal efficiency due to a reduced loss of work due to
overheating and longer engine life, but at the cost of being
heavier and susceptible to freezing (Pollard, p. 33). The water
cooled, 3.2 liter (185 cu. in.) displacement V-8 Antoinette
engine, reportedly designed as a motorboat engine in 1905,
was quickly adapted to aircraft use by 1906 (Gunston, pp.
14–15; Angle, pp. 36–38; Angelucci, pp. 19–23). It produced
24 HP, weighed approximately 50 kg (110 lbs.), had a
specific power rating of 4.6 lbs./HP, and cost only £328. A
1908 version produced up to 67 HP; at a weight of 209 lbs.,
it provided a specific power rating of 3.1 lbs./HP (Fedden,
pp.7-9). A 1909 version featured headed and cylinder barrels
machined from a single steel forging, a fabrication method
that resulted in improved mechanical strength (leading to
better engine reliability) compared to the castings used in
competing designs. Later variants included a V–16 which
produced between 100 and 134 HP and weighed 264 lbs.
(120 kg), providing a specific power rating of as low as 2.0
lbs./HP. Even a V–32 configuration was produced, although
it is not known to have successfully powered an actual aircraft
in flight. Samuel F. Cody, the American who was the first
person to fly in England on 16 October 1908, designed and
built an aircraft similar to the Wright Flyer, but powered it
with a 50 HP Antoinette engine.

The Aeronautical Experimental Association (also referred
to as the Aerial Experiment Association by the British) was
founded in September 1907 by Alexander Graham Bell and
top motorcycle racer/engine builder Glenn Curtiss. AEA
members built experimental aircraft such as the Red Wing
which first flew in March 1908. It was powered by a Curtiss
air cooled V–8 engine known as the model “B–8”, which
featured a displacement of 265 cu. in. (4.3 liter) and
developed 40 HP for a 6.6 lbs./HP specific power rating
(Gunston, pp. 45–46). Other related engines include the 50
HP “E–4” and the 100 HP “E–8” (the latter having powered
the Curtiss aircraft that won the top prize of the Prix de la
Vitesse at the July 1909 Rheims air meet in France. However,
Curtiss’ most well known and prolific pre–war engine series
started with the “OX–5” V–8, which was introduced in 1910
(Gunston, Ibid.; Curtiss, p. 4). This engine produced a
reportedly unreliable 90 HP from a displacement of 503 cu.
in. (8.3 liters). Weighing approximately 320-390 lbs., it gave
a respectable performance rating of 3.6–4.3 lbs./HP (while it
worked). Its inconsistent reliability arose out of quality control
issues during production, a problem that would not be solved
by the time an impending WW I mandated increased
production rates by several different manufacturers. This
engine is best known for powering the ubiquitous Curtiss JN–
4 Jenny trainers of WW I. Alliott V. Roe is credited with
being the first Englishman to have flown a totally English
airplane, powered by a 9 HP J.A.P. air cooled British
motorcycle engine. Perhaps one of the more notable French
ingines to have been successfully developed in the mid
post–Wright/pre–WW I era of 1909 was a unique 3-cylinder
ingine designed and built by motorcycle builder Alessandro
Anzani (Gunston, pp. 15–16). This engine was built in an
unusual "W" configuration resembling a two cylinder “V”
design with a third cylinder inserted between the other two. A
typical rating of 24 HP was derived from the 3.75 liter (230
cu. in) displacement; the total weight of the air cooled engine
was 66 kg (145 lbs.), resulting in a specific power rating of
6.0 lbs./HP. The most well known flight using this engine was
accomplished in July 1909 when the Bleriot XI airplane,
piloted by Louis Bleriot, was the first to cross the English
Channel, winning the London Mail prize in the process.
Not all engine designers were locked into that most popular paradigm of engine operation, where the engine crankcase remains stationary and internal components move, providing power through a main output shaft. Of all those who may have been aware of its existence, it was the French who first acted upon the possibilities that lay in a unique rotary engine design of an American by the name of Farwell. A rotary engine’s non-moving crankshaft is affixed to the aircraft, and the cylinders and external casing (to which the propeller is firmly attached) rotates. Frenchmen and brothers Laurent and Louis Seguin finished their improved version of Farwell’s rotary engine design around 1907 but waited a year before revealing it. By 1909, they began marketing their improved engine under the Gnome company name. Although an early prototype featured five cylinders that produced 34 HP, the first commercial design incorporated seven cylinders (Gunston, pp. 71–73; Angle, pp. 210–215). This version of the air cooled rotary, the “Omega”, produced 50 HP from a displacement of 488.5 cu. in. (8.0 liters) and weighed 172 lbs. dry, giving a specific power rating of 3.4 lbs./HP. Other features included the use of nickel steel for high temperature operation and corrosion resistance, and internal parts designed with reinforced “H” cross sections for structural rigidity. These engines proved immediately popular and were soon mounted on all varieties of aircraft. L. Paulhan used a Gnome engine to power his Voisin in June 1909. Henry Farman replaced his 4-cylinder, water cooled Vivinius engine with a 7-cylinder, air cooled Gnome rotary engine during the Rheims air meet of August 1909. At that meet, Gnome powered aircraft won the Grand Prix de Distance event on 27 August, and the Grand Prix des Passageurs event on 28 August. Improvements and revisions to the basic design resulted in greater power (70 HP) in the 7-cylinder, 680 cu. in. (11.1 liter) displacement “Gamma” engine by 1910. A double row variation having a total of fourteen cylinders developed between 100 and 120 HP. By 1914, Gnome had developed a wide range of rotary engines that would meet a large variety of customers’ power and weight requirements. Other maker of rotary engines included Le Rhone and Clerget, Blin et Cie of France (Pollard, p. 12). Like Gnome, or perhaps inspired by their financial success, Clerget developed and marketed a line of rotary engines as well as more conventional inline and “V” types by 1911. Although they proclaimed their rotary engine as “improved” in the areas of fuel consumption and lubricant use, the Clerget design often led to severe overheating problems (Gunston, p. 41; Angle, pp. 122–130).

Rotary engines had the reputation of losing their lubricating oil due to poor seals. As three of the primary jobs of lubricating oil are to reduce friction, cool internal parts, and carry away wear particles and contaminants, a loss of lubricant in the high friction environment of the aircraft engine, rotating at up to thousands of revolutions per minute, invited total engine failure and the sudden end to one’s flight. The engine lubricating oil most commonly in use at this time (and the only oil reportedly used in rotary designs) was the vegetable based castor oil derived from the castor bean. This specific oil was preferred for its relative immiscibility in fuel, higher flash point, and higher viscosity (required in the higher operating temperatures of air cooled engines) (Pollard, pp. 29–30). However, one problem associated with castor oil was that as it cooled, its viscosity thickened to the point of being unserviceable and also allowed sediment to fall out of suspension. The oil would have to be heated or thinned with “methylated spirits” before the engine could be restarted to prevent excessive wear or other damage. Moreover, the sediments would have to be removed or stirred back into solution to prevent damage to the engine’s bearings. As castor oil was an expensive commodity and as Benjamin Lipsner was still several years from developing a suitable petroleum based substitute, oil consumption remained a critical issue with rotary engine designs. Another problem inherent with the rotary design was the enormous amount of inertial moment arising from the rotating mass. That inertial moment was so great that the gyroscopic forces it created made it disproportionately easy to turn the aircraft into the direction of engine rotation, and disproportionately difficult to turn the aircraft away from the direction of engine rotation.

NEEDS OF THE WAR MACHINES

Although most automobile manufacturers maintained their focus on the exploding and very profitable automobile industry, many had ventured forth into the aviation engine business well before the outbreak of WW I. However, whether they were located on the European or North American continent, virtually all automobile companies joined their aviation counterparts in assessing their industry’s role in that impending conflict. For European automobile and aircraft manufacturers, war production meant producing only those products that would save one’s homeland. However, with war looming on the horizon overseas and not on American soil, many of the American automobile and aircraft manufacturers recognized a tremendous business opportunity in the offing if America became involved. For some short-sighted
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European companies, this meant producing trucks or other utilitarian goods. For the visionaries, this meant getting involved in aviation. By 1910, several companies had production engines, experimental engines or engine modifications under development that they believed would meet Army and Navy needs.

Charles Lawrence had been a successful race car engine designer since 1910, but the events leading up to WW I mobilized him to focus on aircraft engines, and in so doing, he created the Lawrence Aero-Engine Corporation in 1917. Its first program was to design an engine that would eventually be fitted to the non-flying Army Penguin trainer, an aircraft used to indoctrinate pilots in ground maneuvers. This 28 HP, air cooled 2-cylinder engine, designated the Model “A”, weighed almost 200 lbs., and delivered a specific power rating of 7.1 lbs./HP (Angle, pp. 291–298; Gunston, pp. 92–93). Although it delivered far less power than other available engines, this was satisfactory in the non-flying Penguins. 450 units were eventually built under license by the Excelsior Company, signifying a huge commercial success for Lawrence. Based on the Army’s successful order, the Navy requested Lawrence build a 40 HP engine weighing 80 lbs.; this 2-cylinder engine was designated the Model “N”. This engine was then modified to meet Army requirements and now featured 3 cylinders in a radial arrangement, produced 65 HP, weighed 147 lbs., and provided a specific power rating of 2.3 lbs./HP; it was designated the Model “L” in 1918. With these efforts being both design and commercial successes, Lawrence began a developmental effort based on two 9-cylinder radials. The “J” and “R” variants were specifically developed for the Navy and Army, respectively, becoming the first air cooled radials produced in America. The “J” developed 200 HP, displaced 787 cu. in. (12.9 liters), weighed 476 lbs., and had a specific power rating of 2.4 lbs./HP. The “R” developed 147 HP, displaced 670 cu. in. (11.0 liters), weighed 410 lbs., and had a specific power rating of 2.8 lbs./HP. It is interesting to note that Lawrence, being somewhat of an entrepreneur, sought and successfully negotiated the $100,000 seed money for developing the Navy “J” engine from the Navy’s Bureau of Steam Engineering. The successful Lawrence Aero-Engine Corporation was eventually bought out by Fred Rentschler of the newly formed Wright Aeronautical Corporation.

French patriot Rolland Garros and Dutchman Anthony Fokker both looked into the problem of aerial combat from a tactical viewpoint. Garros, known as the “Father of Aerial Combat”, postulated that aircraft made an ideal platform to mount an attack on another aircraft, if one could use an effective and proper weapon – a machine gun. Garros is generally credited with being the first to analyze the problem of shooting forward directly through one’s own propeller. He is reported to have attached metal blocks on the inside surfaces of the propeller to block and deflect the bullets fired from his own machine gun away from the propeller. It is has also been reported that he may have worked with the manufacturers of his Morane Saulnier aircraft to devised an interrupter gear to prevent the machine gun from firing when the propeller was in the way. However, historical reports clearly indicate that Fokker had evaluated the inner workings of a Parabellum machine gun and had quickly designed, manufactured, and installed a working interrupter gear to work with his aircraft’s engine. Such a gear timed the machine gun’s firing so that it could not shoot when the propeller blade was in the way and in danger of being damaged. Ultimately, it was the German military that first utilized this modification to great effect. Mounted on the Fokker-designed Eindecker E-1, it contributed to great Allied losses that helped give the deadly E-1 the name, “Scourge of the Sky”.

One can observe the development of the famous Liberty engines from an automotive manufacturer’s perspective to gain an understanding of the events leading to its development and learn a little automotive history as well. Up through 1912, the Packard Automobile Company had been developing a series of high performance automobile racing engines of the 6-cylinder in-line configuration producing 38 to 48 HP (Katz, Chpts. 5, 25, 26). As WW I unfolded in Europe, Packard Company president Henry B. Joy grew ever more concerned and realized that the fledgling and largely disorganized American aircraft industry would need a more powerful engine for its aircraft fleet. In December 1914, Jesse Vincent, the Packard Company’s chief engine designer, got the inspiration to combine two sixes into a V-12 configuration. Initial prototypes were limited to 289 cu. in. (4.7 liters) to permit testing in a race car that was restricted by automobile racing regulations to a maximum 300 cu. in. displacement engine. This prototype engine worked well, and soon its displacement was eventually boosted up to 905 cu. in. That effort came to fruition in 1915 when the design of the “Twin Six” engine was complete. This experimental engine weighed 817 lbs and produced 110 HP, and went on to set several automotive race track records. The second iteration of this
engine was known as the “905”, referring to its cubic inch displacement. It weighed 979 lbs. and developed 275 HP at 1600 rpm. The “905” was perfected and marketed as the automotive “Twin Six”, and installed in an unprecedented 10,000 production automobiles in 1916.

America entered the war on 6 April 1917, following the attack and sinking of the civilian transport ship Lusitania. At this time, Packard had the third version of the “905” engine under development and had already invested nearly two years and $400,000 of company resources into the latest automobile engine. Feeling the need to aid the war effort, company president Alvan Macanley (Henry Joy’s successor) offered his company’s resources, knowledge and facilities to the government. Although it makes perfect business sense, perhaps it would be pure speculation to suggest that they might have been thinking, “If the government is about to buy a lot of aircraft engines for the Army planes it surely will build and send across the Atlantic, then those engines may as well be Packards!” Certainly, the competition felt the same. The company representative Macanley had sent to Washington DC was Vincent, their chief engine designer. Vincent met with Aircraft Production Board members Edward Deeds and S. Waldon (a former sales manager of Packard) and proposed that a standardized Army aircraft engine be procured for all Army aircraft, and that it be Packard’s “905” design. Vincent reinforced his proposal with the statistic that, at the time, the British and French had developed 83 different types of aircraft engines and likely warned his audience of the logistics nightmare of trying to maintain an American and Allied aircraft engine fleet of that composition. He also added that the Germans, in comparison, were flying only eight engine types. They, in turn, asked Vincent to confer with E. J. Hall, another engine expert from the San Francisco, California based Hall–Scott Motor Car Company who, coincidentally, also happened to be in Washington DC with a similar proposal. Vincent and Hall conferred for three days and nights, along with Dr. Samuel W. Stratton of the Bureau of Standards. Then on 21 May 1917, it was decided that an engine combining the features of the Packard V–12 “905” engine and the Hall–Scott V–12 “A–8” engine was to be the Army’s new standard aircraft engine (Angle, pp. 229–238). Knowing that several companies would be building it under contract for the government, they felt a more “neutral” name was desirable. Thus, the “Liberty” engine was born. It was formally announced on 4 July 1917. In fact, much had been going on since the final design was agreed upon on 21 May.

Engineering and construction plans were completed by 4 June. Parts for assembly were built and assembled by 3 July, the day before the formal announcement. The first engine was assembled and run on 23 July. After the first engine installation was completed, the aircraft was flown by 29 August, setting a new American altitude record!

The first iteration “Liberty” engine was a V–8 configuration which borrowed the cylinder design from the Hall–Scott engine and many other features from the Packard “905”. However, it was soon discovered through initial tests that in light of increasing aircraft performance requirements, the V–8 would be underpowered. And as one of the more unique design features of the “Liberty” was the provision to build the engine in 4–, 6–, 8–, and 12–cylinder variations, most of the 20,487 engines manufactured prior to the end of WWI on 11 November 1918 were of the V–12 configuration (Gunston, pp. 93–94; Angle, pp. 305–315; Sherbondy and Wardrop, pp.159–169). The original V–8 engine produced 250 HP. The mass produced V–12 engine had a displacement of 1649 cu. in. (27.0 liters), produced a nominal 421 HP and a maximum 449 HP, and weighed approximately 844 lbs. dry. Its specific power rating was 2.0 lbs./HP, one of the most weight efficient engines of the era. Different compression ratios were offered to the Army (5.42:1.00) and Navy (5.00:1.00), who had requirements for optimum operation at different altitudes. The 45° included angle between cylinder banks was purposely made narrow to reduce engine width, and therefore, able to fit into a narrower engine cowl. Ignition was provided by a generator / battery system similar to that used in automobiles rather than the usual induction magneto system commonly used in aircraft ignition systems. The “Liberty” engines were installed in the American produced deHavilland DH–4s and Curtiss JN–4 Jennys, and shipped overseas as spares.

POST WWI DEVELOPMENTS

The end of WWI brought an end to military hostilities on the European continent, and with it a sudden end to the need and demand for aircraft pilots, aircraft mechanics, aircraft, and aircraft engines. The world had invested so much recent effort into the development of effective and efficient aircraft and aircraft engines. Adventure and exploration were the principal motivators of aviation development through 1910, and aerial domination and national survival through the war years. The war had elevated aviation to a new level of public awareness in this country. Everyone had heard of the extraordinary skills of the daring Army pilots as they intently listened to the war stories of those heroes, with much of their individual
successes attributable to the development of high powered, reliable aircraft engines.

Although aircraft had played only a marginal role in deciding the outcome of WW I, they left a tremendous influence on America because of that involvement. Aviation technology had advanced from the pre–Wright aviation stone age of gliders and low powered steam engines to the high performance age of flight with speeds well over 100 MPH and V–12 “Liberty” engines of almost 450 HP within just fifteen years. Pre-war designs and manufacturing technologies were usually considered proprietary information that were tightly held as company secrets and as the business edge against competitors. The joint government / multi-company efforts surrounding the development and manufacture of the “Liberty” engine promoted the sharing of information between the country’s best engine designers, engineers, and industrial manufacturing talents. This was accomplished through the creation of the National Advisory Committee on Aeronautics (NACA, the predecessor to today’s National Aeronautics and Space Administration) which facilitated the crossflow of scientific and other technical information in areas as diverse as wing and propeller design, propulsion, materials, and overall aircraft performance. Although the war was over, other events and perceptions would continue to push the development of engines and aircraft to even higher levels of performance. And as aircraft continued to develop, a few government officials began to realize the possibilities that lay dormant in aircraft and envisioned them as a means to transport goods, people, and the mail in a manner much more expedient than the current railroad system.

It goes without saying that great insight and genius lay in the minds of the designers and builders of aircraft engines throughout their development. In the very beginning, tenacity drove those who dared to pursue their folly, despite criticism and, in many instances, persecution by the non–believers. But once flight had been accomplished, creativity merged with that persistence to develop powerplants that would help aviators set even greater records for speed, distance, and endurance, all of which depended upon powerful, lightweight, and reliable powerplants. All of these successes depended on the technical contributions by the many individuals and companies, of which only a few are identified here, who participated in aviation history through the development of effective aircraft engines. □
<table>
<thead>
<tr>
<th>Mfg / Designer</th>
<th>Date</th>
<th>Eng Model</th>
<th>Eng Type</th>
<th>Displ (cl / l)</th>
<th>Fuel</th>
<th>Power (H)</th>
<th>Spc Pwr Rtg (lbs/HP)</th>
<th>Comments</th>
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<td>Pre-Wright</td>
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<td></td>
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<td></td>
<td></td>
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<td>1857</td>
<td>Clockwork</td>
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<td></td>
<td>Wound Spring</td>
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<tr>
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<td>Electrically ignited street lamp gas</td>
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<tr>
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<td>2 Cycle</td>
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<td></td>
<td></td>
<td></td>
<td>10, 20</td>
<td></td>
<td>Steam powered models flown</td>
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<td>Full scale / powered hop</td>
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<td>540 / 8.9</td>
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<td>12</td>
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<td>540 / 8.9</td>
<td>Gasoline</td>
<td>52.4</td>
<td>2.4 (dry) / 4.0 (wet)</td>
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<td>100-134</td>
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<td>V-8</td>
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<td>Air cooled</td>
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<td>V-8</td>
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<td>Gasoline</td>
<td>50</td>
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<td>100</td>
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<td>Anzani</td>
<td>W-3</td>
<td>230 / 3.8</td>
<td>Gasoline</td>
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<td>6.0</td>
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<td>Seguin / Gnome</td>
<td>1909</td>
<td>Omega</td>
<td>7-cyl rotary</td>
<td>488 / 8.0</td>
<td>Gasoline</td>
<td>50</td>
<td>3.4</td>
<td>1st mass marketed rotary, successful</td>
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<tr>
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<td>1910</td>
<td>OX-5</td>
<td>V-8</td>
<td>503 / 8.3</td>
<td>Gasoline</td>
<td>60</td>
<td>3.6-4.3</td>
<td>JN-4 engine, unreliable - poor QC</td>
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<td>1910</td>
<td>Gamma</td>
<td>7-cyl rotary</td>
<td>880 / 11.1</td>
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<td>70</td>
<td>3.4</td>
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<td>Clerget</td>
<td>1911</td>
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<tr>
<td>Packard</td>
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<td>6-cyl In-line</td>
<td></td>
<td>Gasoline</td>
<td>38-48</td>
<td></td>
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<td>High-performance auto engines</td>
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<tr>
<td>Gnome</td>
<td>1914</td>
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<td>Gasoline</td>
<td>100-120</td>
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*APPENDIX*
### WW I and Beyond

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<tr>
<th>Manufacturer</th>
<th>Model Year</th>
<th>Type</th>
<th>Cylinders</th>
<th>Displacement</th>
<th>Horsepower</th>
<th>Design Notes</th>
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<td>Gasoline</td>
<td>38-48</td>
<td></td>
<td>Auto racing engines</td>
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<td>1915</td>
<td>Twin Six V-12</td>
<td>305/14.8</td>
<td>Gasoline</td>
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<td>7.4</td>
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<tr>
<td>Packard</td>
<td>1916</td>
<td>V-12</td>
<td>305/14.8</td>
<td>Gasoline</td>
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<td>3.56</td>
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<tr>
<td>APB Alliance</td>
<td>1917</td>
<td>Liberty V-8</td>
<td>Gasoline</td>
<td>250</td>
<td></td>
<td>Initial design - underpowered</td>
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<td>APB Alliance</td>
<td>1917</td>
<td>Liberty V-12</td>
<td>1649/27.0</td>
<td>Gasoline</td>
<td>449 max</td>
<td>2.0</td>
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<td>Lawrence</td>
<td>1917</td>
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<td>28</td>
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<td>Penguin engine / air cooled</td>
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<td>1918</td>
<td>Model N 2-cyl</td>
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<td>40</td>
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<td>Designed for Navy</td>
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<td>65</td>
<td>2.3</td>
<td>Designed for Army</td>
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<td>1918</td>
<td>Model J 3-cyl radial</td>
<td>Gasoline</td>
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<td>2.4</td>
<td>1st American prod air cooled radial / Navy</td>
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<td>147</td>
<td>2.8</td>
<td>Variation of the &quot;J&quot; / Army</td>
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</tbody>
</table>
Bryan Sanbongi holds a B. S. in Mechanical Engineering/Materials Science from the University of California at Davis and is currently pursuing a M.S. in Aviation Safety from Central Missouri State University. He is a Senior Materials Engineer in the Nondestructive Evaluation Branch of the Air Force Research Laboratory, located at Wright-Patterson Air Force Base in Dayton, Ohio.

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Berliner, Don, "Before the Wright Brothers", Lerner Publications Company, Minneapolis, Minnesota, USA, 1990.


