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AUTOMATIC PILOT, 1913 VERSION

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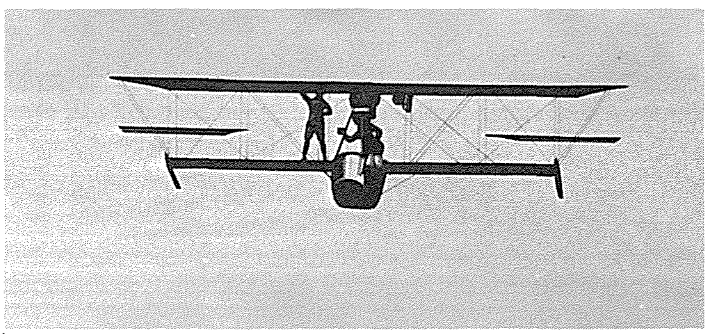
Summary — The 1913 Sperry Aeroplane Stabilizer became famous as the first successfully demonstrated automatic pilot. Its design features, in an era of crude and unstable aircraft, were perhaps even more remarkable.



This is the famous photograph of Lawrence Sperry's flight at Bezons on June 18, 1914. Pilot Sperry is standing in the cockpit as mechanic Emile Cachin stands on the wing.

Introduction

The first public demonstration of a successful automatic pilot took place in France in June 1914, when the powered airplane was only 10 years old. Although the airplane had improved at a rapid pace during those first 10 years, it was still an unruly and untamed beast, ready to turn on its pilot at the least sign of his inattention. But in the midst of this aeronautical instability, the world was treated to a most spectacular show.

The scene was Bezons, in the northwestern suburbs of Paris. Lawrence B. Sperry second son of Elmer A. Sperry and one of the 21 contestants in the *Concours par L'Union pour la Securite en Aeroplane,* began his aerial demonstration by flying his Curtiss flying boat off the surface of the river Seine. In the cockpit with him and his mechanic was the Sperry Aeroplane Stabilizer, a gyroscopic device which Lawrence had been explaining to the skeptical contest jury for the preceding hour and a half. Now that all questions had been answered, the flight had begun. The flying boat swooped low over the surface of the river, heading toward the judges. The mechanic, Emile Cachin, climbed out on the lower wing and clung to a strut several feet out from the hull. Although a program of the flight demonstration had been distributed to the jury, they were still amazed when the young pilot stood up in the cockpit and held his hands over his head. Never before were such antics possible in the air without inviting disaster, but the flying boat continued on its course guided by the steady hand of the "automatic pilot," as the French press dubbed the device.

There were other phases of the flight demonstration, but this scene was captured by a camera and remained through the years a symbol of the domination of the Paris contest by the Sperry Aeroplane Stabilizer. Two additional aerial demonstrations and one additional ground lecture were necessary before the jury awarded the 50,000-franc first prize to this entry.

The Equipment

The Aeroplane Stabilizer making its public debut was actually the third model to be built by the elder Sperry. The first attempted to stabilize the airplane by applying gyroscopic forces directly to the airframe. It was built in 1910, but after brief trials was abandoned. The second Aeroplane Stabilizer, built and flown in 1912, was the first true automatic pilot. It used the principles followed in all the later models, but lacked the refinements. Although it was flown for a full year, it had many shortcomings; probably the most serious was the fact that it was installed in the stick-and-wire airplanes typical of the 1912 era. The pilot's seat was out in the open air: there was no floor below it, nothing beside it, and not even a windscreen in front of it. Only one of the two gyro units of the 1912 stabilizer was easily visible to the pilot, the other being mounted behind his seat. And even the visible unit was for all practical purposes inaccessible in flight.

When the 1913 model was sent to the Curtiss factory and flying school at Hammondsport, N.Y., scene of most of the early flight tests, Lawrence installed it in a flying boat sporting a cockpit inside the hull. With the gyro unit installed inside with the pilot, it was easily accessible at all times. As the stories go, numerous flights were made in this type of aircraft with Navy Lieutenant P.N.L. Bellinger at the controls while Lawrence sprawled on his stomach on the cockpit floor observing the gyro unit and making necessary adjustments.

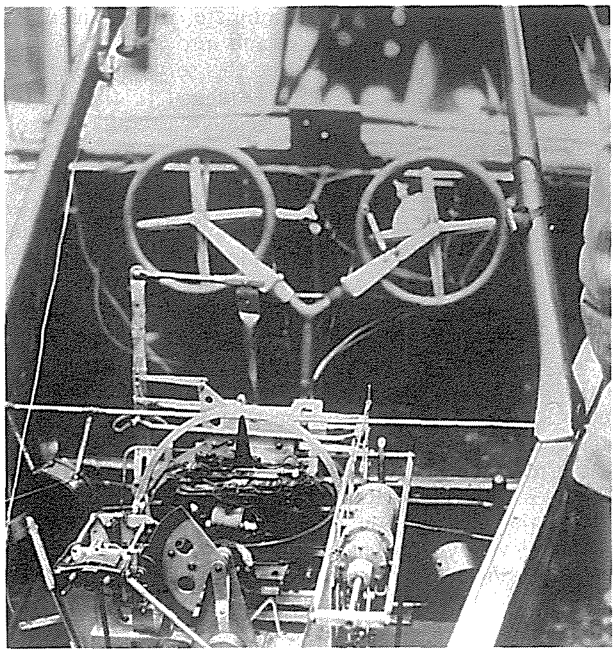
When the flying boat was dismantled and shipped to France for the contest, the 1913 stabilizer was rapidly becoming obsolete; a much improved model was taking shape in the Sperry Laboratories. The new model, in turn, was superseded by others, but it is the 1913 model which is of interest here.

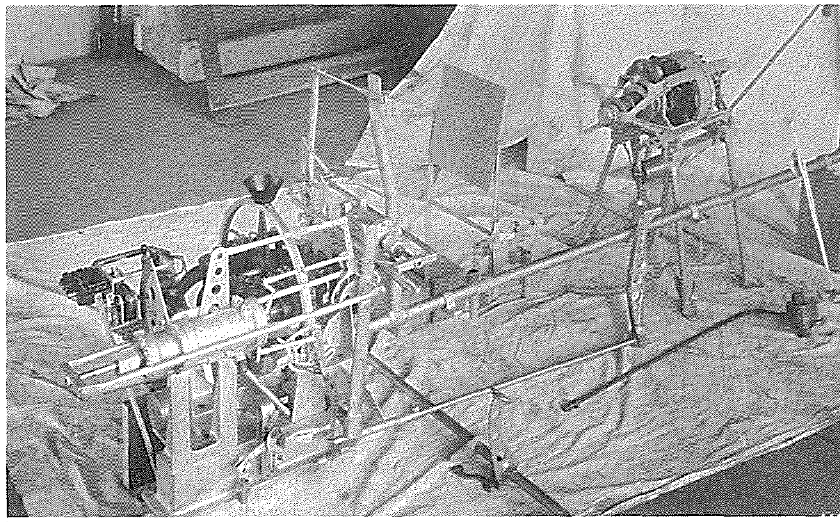
Stabilizer Units

The 1913 model of the Aeroplane Stabilizer consisted of seven basic components: the gyroscopic unit with its mechanical pickoffs and pneumatic servo cylinders, the anemometer plate, an air pressure tank, a check valve to take compressed air from one engine cylinder during the power stroke, an engine-driven generator, a foot pedal to disengage the unit, and a hand control for the pilot. The complete installation weighed about 46 pounds.

The heart of the entire Aeroplane Stabilizer was the gyroscopic unit. It was mounted on the cockpit floor forward of the pilot's control column where it could easily be seen and monitored. In describing the gyroscopic unit it is best to start with the stabilized reference, the device incorporating the gyroscopes. Starting from the outside, a Cardan ring, carried by vertical brackets, acted as a roll gimbal. Inside its circumference is carried the inner frame which, in turn, carried the gyroscope precessional housings and acted as a pitch gimbal. As can be seen in the illustrations, the inner frame filled the Cardan ring, for it carried not one, but four gyroscopes. And here is one of the primary features of the Aeroplane Stabilizer, necessitated by the limited state of gyro development at that time. Four gyroscopes were used in two pairs, each pair stabilizing the inner frame about one axis.

The gyros at the right and left sides of the inner frame had their spin axes oriented for-and-aft while the other two spun about a transverse axis. The two gyro wheels of each pair spun in opposite directions and thus would precess in opposite directions under the influence of an external torque. To insure their precessing together and to avoid cross-coupling effects, the two housings were interconnected by small steel bands running from one side of one housing to the opposite side of the opposing





The photograph above left shows the 1913 Sperry Aeroplane Stabilizer installed in a Curtiss flying boat. Over-all view of the stabilizer is shown above right. Gyro unit is at left with pitch servo in foreground. Push rod from bottom of pitch crank arm leads to crank for attachment to control column in aircraft. Aileron servo behind gyro twists torque tube leading to vertical lever at extreme right (aileron control was through a shoulder yoke, thus extreme length of torque tube). Square plate behind the aileron servo is a vane anenometer. Engine-driven generator is on mount at right. Below is a view of the gyro arrangement, with each pair of gyros interconnected by steel tapes visible at center of unit. Elevator servo cylinder is at right, aileron servo at upper left. The force-impressor motor with its clutches is in foreground. Force-impressor switch is fitted to top of gyro, upper left.

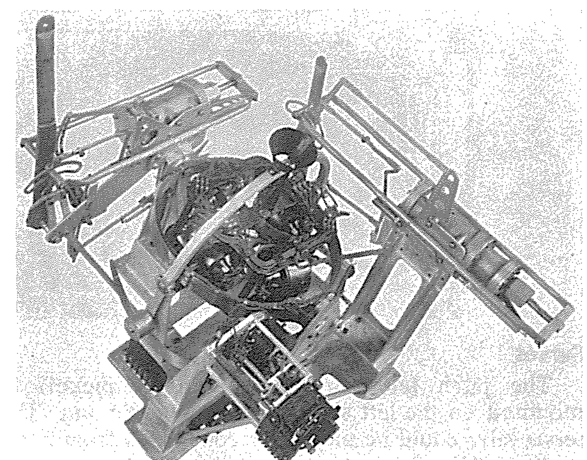
housing, forming an X across the center of the gyro unit when viewed from above.

The use of steel bands was unique to the 1913 model, the 1912 and all later models using sector gears for the same purpose. Indeed, before the 1913 unit was discarded, it too was fitted with sector gears to replace the steel bands, one gyro pair carrying its gears at the top of its housings, the other pair at the bottom. It is not known whether this modification was made before or after the Paris contest demonstration flights.

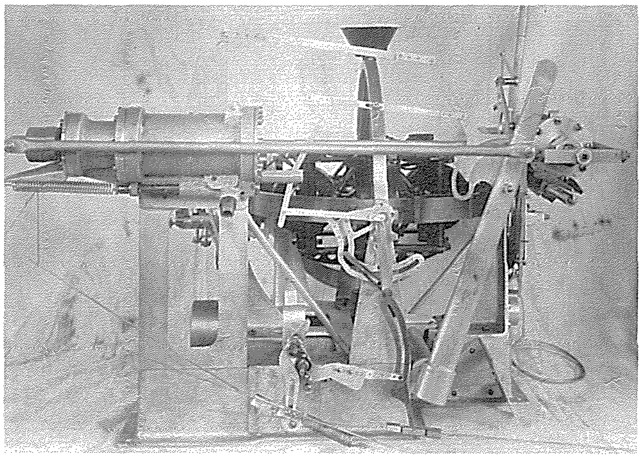
Force Impressor

Except for the weight under the center of the inner frame to render the gyro unit pendulous, the description of the basic stabilized reference is complete. What remains are the pickoffs and servos, and the force impressor. In modern day language the latter would be known as a torquer. Since the background of the force impressor is as interesting as its application, it behooves us to go back to the 1912 Aeroplane Stabilizer and look at one of its more important shortcomings.

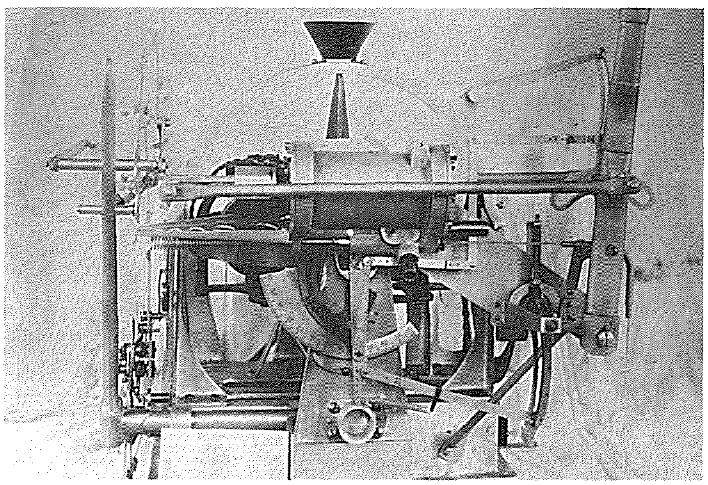
As already mentioned, the stabilizer built late in 1912 had two gyro units. Each unit used one interconnected gyro pair with counter-rotating wheels, and was pendulously mounted. To center the gyros, the two precessional housings were connected by a spring which exerted a torque on the housings only when they were displaced. In flight, it was assumed, the external torques applied over a period of time would integrate to zero: thus both gyros would precess about their centered positions. This was a valid assumption for the pitch plane under most conditions, but in a steady turn the roll stabilizer, by virtue of its pendulosity, suffered a constant torque in one direction. As the gyro pair precessed, the centering spring, normally compensating for only minor unbalances, misalignments, and gyro drift, attempted to pull the housings back to their neutral positions. The torque thus applied internally caused the gimbal—the roll gimbal in this case—to precess rapidly in the direction of the original external torque. The end result was, of course, a violent rolling maneuver of the airplane which was guaranteed to give the pilot some anxious moments.



To avoid this unfortunate characteristic in the 1913 model, the centering springs were removed and a force impressor was fitted. One of the roll precessional housings was fitted with a roller contact which rode on a commutator on the inner frame. The commutator had a fiber contact in the center, on which the roller normally rested, flanked by two copper contacts. When the roll gyros precessed too far, the roller made contact with one of the copper strips, sending a signal to the force impressor. The latter consisted of a d-c- motor driving two large gears serving as latter consisted of a d-c motor driving two large gears serving as clutch plates. The two gears rotated in opposite directions; between them was a clutch disc, which on command from the roller contact was engaged with one or the other of the gears by electro-magnets. The disc was geared to a large sector gear mounted on the Cardan ring, thus applying a torque opposing that due to the turning of the airplane. All torques, therefore, were external. The device proved to be a tremendous success; on the 1914 model Aeroplane Stabilizer it was fitted in both pitch and roll planes.



The left-side of the stabilizer (above) shows clearly the mechanical pickoff for pitch control. The cam with the oddly shaped slot is rigidly attached to the bail extending over the gyro unit. The wire attached to the bottom of the dark link is for the pilot's control. The other two wires, part of the anemometer system, control the gain of the pitch control by changing the fulcrum of the dark link. The rear view (below) shows the mechanical pickoff for roll control, partially obscured by the aileron servo. The dark slotted cam carrying the graduated quadrant is rigidly attached to the Cardan ring. The cable hanging at the extreme right is part of the pilot's override, connected to the foot pedal. The cable leading out from the pulley provides the pilot's control through vertical motion of the right end of the lower horizontal link. The pitch pickoff linkages and the pitch servo may be seen clearly at far left.



Servos

The pitch (elevator) servo with its pickoff linkages was mounted on the left side of the gyroscopic unit. The pneumatic servo valve could be moved by commands from any one of four sources. The first was an angular displacement of the inner frame. To carry the displacements outside, the top of the inner frame was fitted with a bracket whose upper end rode in a channeled bail. The bail, easily seen over the top of the gyroscopic unit in the illustrations, was carried by brackets on both sides of the unit. A cam was fitted to the left bail pivot to provide the first source of pitch command. Through a cam follower and a series of links, the servo valve was moved to direct the pressurized air to one side of the servo piston. The piston moved a large crank arm, which in turn moved the second source of command—the follow-up linkage.

On the pilot's control column were mounted two levers for controlling the Aeroplane Stabilizer, one for pitch and one for roll. By moving his control the pilot could exercise the third source of command and reset the zero position of the pickoff linkage, thereby trimming the airplane to either a climbing or a gliding attitude. The fourth source of command was a vane type anemometer mounted on a strut leading from the cockpit area to the upper wing. The deflection of the anemometer under the force of the air stream was transmitted by cable to the pitch linkage where it effectively changed the servo sensitivity. When the speed dropped too low and the anemometer linkage reached the end of its travel, it forced the airplane into a glide. In the airplane the large crank arm moved by the servo piston was linked to a pushrod which was in turn attached to the pilot's control column. From that point, the regular aircraft control system was used to move the controls.

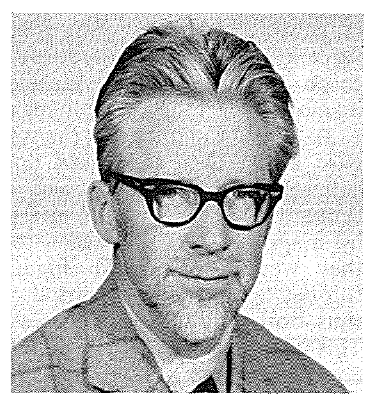
The roll (aileron) servo was mounted behind the gyroscopic unit. Its pickoff linkages were similar to those of the pitch servo, except that they operated on the displacements of the Cardan ring. A cam was fitted to the rear Cardan ring pivot to provide the first source of roll command. A follow-up link and the pilot's command were fitted as in the pitch unit, but there was no anemometer function for the aileron linkages. Again the servo was connected to a large crank arm, but in the airplane this crank arm was attached to a long torque tube which ran back along the side of the cockpit. Behind the pilot's seat another lever tied into the regular aileron control.

The early Curtiss airplanes had a distinctive type of pilot's control system; in those days it was the custom for the airplane designer to use the type of control he personally liked best. It was not until the war years that airplane control was standardized. The Curtiss system had a wheel in front of the pilot with which he controlled the elevators and rudders. Aileron control was through a yoke mounted on the back of the seat, embracing the pilot's shoulders when he was seated. It was for this reason that the aileron servo motion had to be carried so far before reaching the airplane control system.

The only components of the Aeroplane Stabilizer which need further comment are the engine-driven generator and the foot-pedal override. The generator provided three-phase, 23-volt A.C. to spin the gyroscopes, and a 25-volt D.C. for the force impressor clutches. The foot pedal, through cables, opened valves under the two servo cylinders, porting both ends to atmosphere, thus giving the pilot complete control of the airplane. With the Aeroplane Stabilizer engaged, the pilot was reportedly unable to move the controls against the servos.

One-Of-Its-Kind

This was the unit which amazed the aeronautical world in the Spring of 1914. It was a unique device; its predecessor was built in two separate units, while its successor carried its four gyros in a different arrangement, used electrical pickoffs instead of mechanical, and did away with the pneumatic servos. If it appears crude to the reader, it is only necessary to note that in June 1914 the F.A.I. (Federation Aeronautique Internationale) world records for airplanes were 634 miles for distance, 20,073 feet for altitude, and 126.6 miles per hour for speed. In a day when the airplane itself was still very crude, the Sperry Aeroplane Stabilizer was indeed a magnificent device.



ABOUT THE AUTHOR

Charles L. Keller has been an AAHS member since 1958. His one previous article in the Journal appeared in Volume 5, Number 3 under title, "The MacMechan-Kamp Airship". In addition his writings include a monograph on the U.S.S. Shenandoah, 1965, and two historical pieces for the now defunct Sperry Engineering Review, including a similar version of the "Automatic Pilot, 1913 Version".

Mr. Keller served in the Army Air Corps during World War II, and thereafter picked up degrees at Tulsa University and Adelphi College. His home is in Salt Lake City.