Sea Furies in the pits at Reno 2003.

TELEMETRY At Its Best

BY PAUL NOVACEK

Air racing is an exciting sport. It all started when one pilot said to the other, "I'll bet my Wright Flyer is faster than yours" …and the race was on. In the aviation world, nothing compares to the growl of a huge piston engine. The Rolls Royce engines in the Mustangs have a throaty cadence as they taxi by the grandstand and the big Pratt & Whitney and Wright radials vibrate the ground under you. But these sounds pale in comparison to the outright earthshaking roar of 4000 horsepower churning up the air at 500 mph—50 feet over the deck. Stick that in your ear NASCAR fans!

Pylon air racing is the fastest, most exciting and most demanding motor sport in the world. Many air races are held around the country throughout the year, but they all culminate with the National Championship Air Races in Reno, Nev. every September. The 2003 Reno races saw an attendance of 222,000 people over a four-day event.

The culminating event is the Unlimited race on Sunday. These WWII fighters are highly modified and must follow two overlying rules; they must have piston engines and propellers. Everything else is up to the creativity and ingenuity of the teams. At the 2003 meet in Reno, Dago Red, a highly modified Mustang, turned laps at 511 mph. That's faster than most business jets, wow! And you thought jets were fast.

In the years between the first and second World Wars, air racing provided much of the stimulation necessary to the continued development of aviation. Prizes were offered by many individuals and organizations for the first flight across the ocean, the fastest time between two points on the globe, or the fastest time around a pylon course. Sponsors provided financial support for the air racers in the interest of promoting aviation and in improving and marketing their products. The driving force behind the sponsors, pilots and designers was the challenge to constantly improve the performance of their aircraft.

After World War II, pylon air racing returned to the American scene. But in 1946, the famous names of individual race plane builders such as Laird, Keith-Rider, Wedell Williams, Benny Howard and the Granville Brothers were missing. They were replaced with names like Bell, North American, Vought, Grumman and Lockheed. War surplus fighter planes, purchased for a few hundred dollars each, became the Unlimited race plane class.

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The same is true today. World War II fighters, stock or modified, still totally constitute the Unlimited race plane class. In 1947, Cook Cleland won the Thompson Trophy Race at Cleveland in a modified WW II Vought Corsair, at a speed of 396 mph. Using today's technology, these same World War II aircraft are being highly modified, at an enormous expense, to reach speeds just over 500 mph. Pylon air racing involves six separate classes of racers:

1) The originally designed and homebuilt IFM/Formula One Class. These little race planes are designed to a specific set of rules and attain race speeds over 250 mph. They race, from a standing start, on a three-mile course around six pylons.

2) The biplanes are also regulated by a specific set of rules and specifications. They, like the IFM/Formula One Class, race on a three-mile course around six pylons, from a standing start.

3) The T-6/SNJ class is composed of the venerable North American built World War II advanced trainers. These races provide some of the most exciting racing of all, because they are essentially stock and are all close to the same speed, although some modifications are permitted. These airplanes use an air start with a pace airplane and achieve speeds of over 200 mph on a five-mile course around six pylons.

4) The sport class consists of small kit built aircraft, regulated by horsepower and size. This new category of racing aircraft was spurred by the increase in kit built speedsters such as the Questair Venture and Lancair. These little pocket rockets can race at speeds well over 300 mph.

5) Over the past few years the race organizers have attempted to include jets in the line up. With the proliferation of L-39 jet trainers in recent years the Reno race committee has added these jets in a stock class, which limits any modifications from the original aircraft. The Jet class is becoming quite popular and speeds are reaching 430 mph.

6) The Unlimited Class is essentially what the name implies—unlimited. This racing class represents the fastest motor sport in the world! As long as these aircraft are powered by a piston engine with a propeller, almost anything goes! These air racers also use an air start with a pace plane, and attain speeds of well over 500 mph around an eight-mile circular course.

First wanting to do an article about the avionics in the air racers, I discovered to not much of a surprise that an article on the avionics would be very short. If the racers have radios at all, they just have two comms, one tuned to the race committee frequency and the other to their ground crew. What is novel though is that the radios are totally independent, with the stick push-to-talk switch connected to one radio and a throttle push-to-talk switch connected to another. Oh, there's some GPSs and transponders, but that's about it avionics wise for most of the racers. There is another interesting trend though, telemetry systems.

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There are two different types of telemetry systems, those that downlink data from the air to the ground and those that provide both downlink and uplink capability. The amount of information is only limited to the amount of data channels. Many aircraft manufacturers use telemetry to verify flight test data and monitor for failures, greatly easing the certification process. Another important benefit of telemetry is the data logging capability. Thousands of data points are monitored in large or complex aircraft development programs and all

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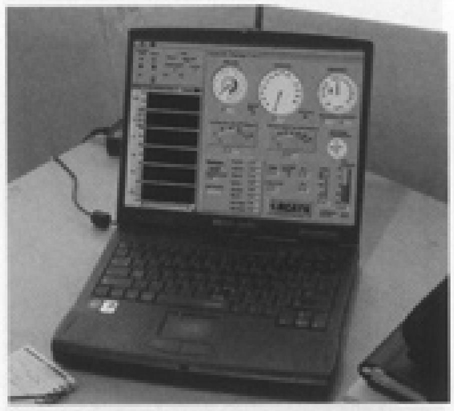

Engine and flight information is displayed and logged with RCATS software on a laptop computer in the pits. Receiver is attached to back of laptop.

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this data is logged for analysis.

Telemetry systems have saved the day many times. The space program simply could not function without telemetry systems transferring data to and from space vehicles. Every vehicle out there, manned or unmanned, have a two-way telemetry system. There may be just three guys headed toward the moon, but there are dozens monitoring the health of the spacecraft from Mission Control.

These data transmission systems are becoming more widespread throughout the racing community. On-board data acquisition units collect mostly engine parameters and transmit the data to the awaiting ground crew to monitor. Many sophisticated aircraft have caution and warning systems created to warn the pilot of impending problems. Some have voice warnings, some just a series of lights, but they all alert the pilot of engine or airframe failures with hopefully enough time to deal with the problem before someone gets hurt. Air racing is another story though.

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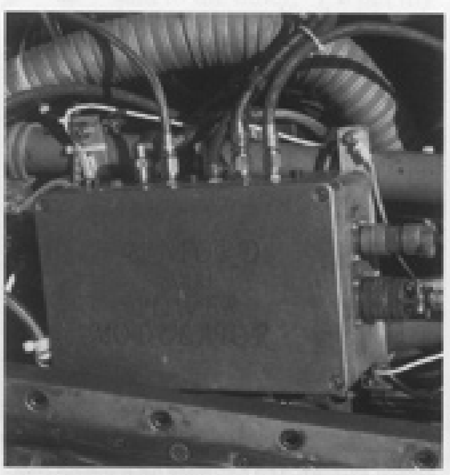
The piston engines used in these racers cost upwards of $100,000 and a race ready Merlin could fetch a quarter million. An engine going south can destroy itself in a matter of milliseconds when it's being pushed way, way past its designed output. Can you say POOF!! And the crews really don't want to spend all night replacing them for the next day's race, if they have a spare engine at all. Flying around the race course at breakneck speeds, at 50 feet off the deck, trying not to cut a pylon, or hit another airplane doing the same requires all the concentration our little human bodies are capable of dishing out. So, instead of dividing attention between the engine instruments and the race course, the ground crew monitors the engine with the help of a telemetry system. The ground crew becomes the monitoring and warning system for the pilot.

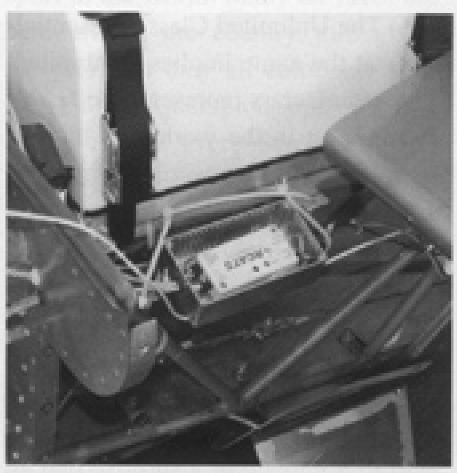
At the moment, racing telemetry systems just provide downlink capability. The uplink being voice communication between the ground crew and the pilot. Current systems consist of four major components: data acquisition, transmitter, ground receiver and display. Various sensors located on the engine and throughout the airframe sense engine parameters such as rpm, manifold pressure and temperature, oil pressure and temperature and a few other parameters that provide telltale signs of impending problems. Critical airframe parameters are also sensed. For instance, the oil and water coolers have a water/alcohol mixture (ADI) injected into the airstream ahead of the radiators to aid in cooling, otherwise known as Spray Bars. If the water/alcohol pump fails, the engine would overheat very quickly. So the ground crew monitors the spray bar pressure through the telemetry system and alerts the pilot over the radio if this critical system fails.

Rare Bear, a highly modified Grumman Bearcat, uses a 16-channel telemetry system built by OSI Soft. The downlink system monitors both the engine oil temperature going into and out of the engine. The perfect job for a telemetry system because of the difficulty in monitoring this differential temperature by the race pilot. A high differential temperature indicates a problem inside the engine; most likely a bearing that may be starting to seize. The OSI system also transmits spray bar pressure and temperature data to the ground crew using packet technology through a 450 MHz radio link in the amateur radio band. The ground receiver directs the data to a laptop computer in the crew support trailer for monitoring and data logging. During a race, the ground crew can monitor the engine, ever diligent to any problems. The crew keeps quiet and lets the pilot deal with the race, only interrupting if something looks bad from the telemetry.

Dago Red, a modified P-51 Mustang, employs a custom made telemetry system designed by the crew. Like the Rare Bear system, it monitors the engine temperatures and spray bar pressure. Because the



The data acquisition unit in the Grumman Bearcat Rare Bear.



The RCATS data acquisition unit in the Formula One racer Plane Mantis.

Mustang uses a water cooled Rolls Royce engine, cooling water temperature is also monitored. The downlink uses a 1-second sample rate modem with a 900 MHz transmitter.

The Dago Red crew also revealed an unexpected benefit of a telemetry system. As a race plane circles the eight-mile course at 500 mph, the G-loading approaches almost a constant 4Gs. This places quite a strain on the instruments in the cockpit and affects the needles in the analog gauges. During flight tests, the pilot reported different readings than the data from the telemetry systems. The G-loading was actually causing the gauge mechanisms to deflect and read incorrectly, but the telemetry sensors do not feel the effects of G-loading and transmit the true engine readings.

Formula One racers must follow strict design rules to compete. A race class born from the 1930s, the airplanes are limited in engine displacement, aircraft weight, wing area and quite a few other areas. The goal is to keep the airplanes relatively inexpensive to foster competition and not limit air racing to the rich. A flyable stock WWII Mustang fetches at least a half million dollars and many of these racers are worth easily a million.

The Formula One rules require the use of the Continental O-200 engine, the same that powers the Cessna 150. Originally designed for 100 HP, these little rockets race around the pylons at speeds up to 250 mph. Let's see your Cessna 150 do that!

Most of these Formula One racers don't have electrical systems, much less telemetry systems with ground crews monitoring the engine. Race rules prohibit help from the ground anyway. But, the Formula One racer Plane Mantis, a modified Cassutt, uses a simple telemetry system that transmits rpm, manifold pressure, EGT, G-loading, GPS position and airspeed down to a ground receiver. The system is small and contains an internal battery, sensors, computer and a modem/transmitter. The airplane is not equipped with a communication radio, so this type of telemetry is strictly used to analyze the engine and flight performance after a flight—valuable information when fine tuning an engine or airframe for maximum speed.

An innovative designer of RC model telemetry systems, Michael Luvara of RCAT Systems, is leading an effort to bring affordable telemetry systems to air racing. Using a 900 MHz frequency hopping RF data link, the system transmits down to an awaiting receiver attached to a laptop computer. Special software decodes and logs all of the information. A prototype system was installed in Plane Mantis at this year's Reno event. In the Formula One racing class, weight is always a concern and the onboard data acquisition unit, sensors and transmitter weigh less than two pounds.

The Sport class of racers consist of kit planes of the Lancair, Glasair and Venture variety with limits on the engine size to 650 cubic inches. Racing around the course at 350 mph, these racer engines employ water injection systems and electronic engine controls. Good candidates for telemetry systems monitored by ground crews. Some telemetry systems have already been installed and are used quite effectively in the Sport class.

Other racers either on the drawing boards or in the prototype stage are implementing telemetry systems as part of the design. The Wildfire Unlimited air racer—now entering the flight test development stage—will use a comprehensive telemetry system built into the design. Sensors throughout the aircraft relay data down to the ground crew for monitoring and archiving. Any abnormalities will be easily detected by the crew and if the condition warrants, the crew will tell the pilot about the problem. Either a back-up system can then be engaged or the power brought back to save the engine for another race. After a race or high-speed test flight, the downloaded data is reviewed for any problems. Small adjustments can then be made to get the best performance out of the engine.

Engines are getting increasingly more expensive to purchase and overhaul. The monstrous engines used in the Unlimited class racers are not being built any more, so every engine on the circuit is an overhaul. With parts getting more scarce and overhaul costs soaring, keeping these engines from destroying themselves is paramount. Telemetry systems allow the ground crew to monitor the engine health and notify the pilot if anything is amiss, letting the pilot concentrate more on the course and other airplanes.

Commanding ignition or mixture changes to an engine from the ground is also possible through a telemetry uplink. Although considered by many crews, only a computer controlled engine is capable of acting on requests from the ground. So far, electronic engine controls have not been applied to the big piston engines, but some of the Sport class racers have cockpit control over electronic ignition systems. With the engines running at full tilt though, there is the fear that a misplaced keystroke from the ground could destroy an engine. And the pilots aren't real hip about somebody on the ground controlling their engine.

Telemetry will gain further use in future racer installations. The auto racing community has been using telemetry systems for years with excellent results. With the escalating cost of race engines and airframes, telemetry systems will grace the pits with more and more data monitoring from the ground. ❑