LOCKHEED MARTIN

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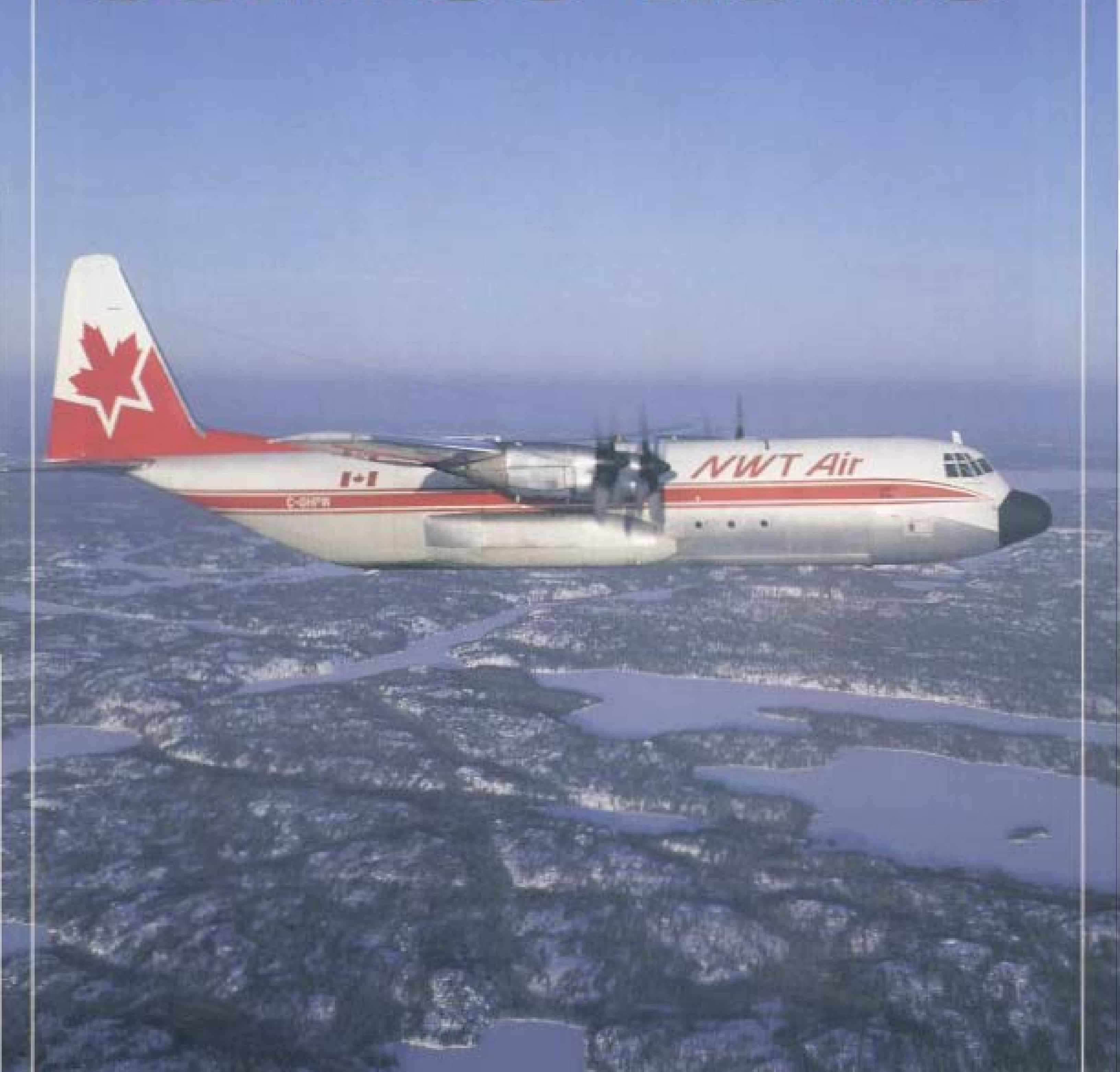

A Publication of Lockheed Martin Aeronautical Systems

LOCKHEED MARTIN

service news

A SERVICE PUBLICATION OF
LOCKHEED MARTIN
AERONAUTICAL SYSTEMS

Editor
Charles I. Gale

Art Direction
Ann G. Anderson

Vol. 22, No. 3, July - September 1995

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Front Cover: An L-100-30 operated by NTW Air cruises over the Arctic tundra in the vicinity of Yellowknife, NWT, in northwestern Canada. Photograph courtesy of Henry Tenby (see Cover Notes, page 10)

Back Cover: The Potomac River at historic Harper's Ferry provides a spectacular background for this C-l 30H training flight. The aircraft is operated by the 167Airlift Group, based at Martinsburg, West Virginia. Photograph by John Rossino.

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Address all communications to Editor, *Service News*, Lockheed Martin Aeronautical Systems Support Company, 2251 Lake Park Drive, Smyrna, GA 30080-7605. Telephone 770-431-6544; Facsimile 770-431-6556. Internet e-mail may be sent to cigale@mar.lmco.com.

Focal Point

The Avionics Revolution: A Personal View

Don Dawson

The feature article of this issue discusses inertial navigation systems in general, and ring laser gyro systems in particular. While sneaking an advance look at the article, I could not help reflecting on the astonishing progress that has taken place in navigational systems between World War II-vintage LORAN sets and today's GPS-aided inertial systems. My first exposure to "serious" electronic navigation equipment was with the AN/APN-9 LORAN used in World War II. Today's navigator would marvel at how his B-29 counterpart could possibly find a destination in the wide Pacific Ocean while searching for distinctive time markers on a cluttered CRT display. But he got the job done, and without digital displays or a pocket calculator.

We saw integrated avionics weapon systems come into their own in the fighters and bombers in the early 1960s, but they did not immediately wi n a place in cargo aircraft. It was only in the late 1960s, with the emergence of the C-5A Galaxy, that a progressive step was made toward integrated avionics systems for cargo aircraft. The C-5A had its own on-board monitoring system, a concept that severely taxed the capability of the available hardware: imagine a state-of-the-art airborne computer with a 1-kilohertz clock and 4 kilobytes of RAM! Sophisticated status monitoring and data downlink were groundbreaking concepts then, but they are everyday realities now, made possible by a proliferation of highly capable data processors and display devices.

Radar is another area that has seen dramatic improvements.The C-5A multimode radar systems of 1968 required X and Ku band radars with two large antennae mounted on the forward pressure bulkhead. The radar that equips today's C-130 has vastly superior capabilities, with a greater number of operational modes–and it comes in a much smaller package. With the integration of GPS-aided inertial navigation systems, flight instruments, and a multimode radar, recent Hercules aircraft offer a sophisticated and reliable positron-fixing and situational awareness capability that was simply not available five years ago.

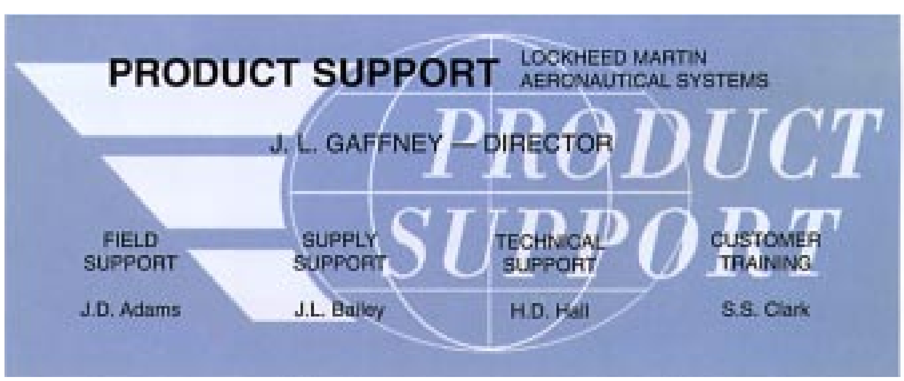
These are just a few reminders of the fundamental changes that have occurred in so many technologies within our working lifetime. In the generation to which I belong, we passed from vacuum tubes to transistors to logic devices and on to microchips and lasers. Virtually every item of electronic equipment in new airplanes now includes data processing components. With the rapid growth of data processing and the introduction of multifunction graphics displays, unlimited opportunities exist for expanding and improving airborne equipment and ground support capabilities. In the modern military environment, the availability of accurate data has become a weapon unto itself, and contributes dramatically to the scope of future mission capabilities.

There's an old saying that the more things change, the more they stay the same. I believe that today's generation of designers and operators will, in their own time, and with a knowing smile, recall the excitement of new 20-megahertz computers, liquid crystal color displays, and inertial navigation systems with error rates of less than 3 miles per hour. Technology, when applied with common sense and good judgement, has no boundaries.The only limitations on the designer of tomorrow are self-imposed. I hope the designers, operators, and maintainers of our future aircraft derive as much satisfaction from the development of the systems to come as so many of us have from the experiences, associations, and simply being part of getting to where we are today. The journey is worth the effort.

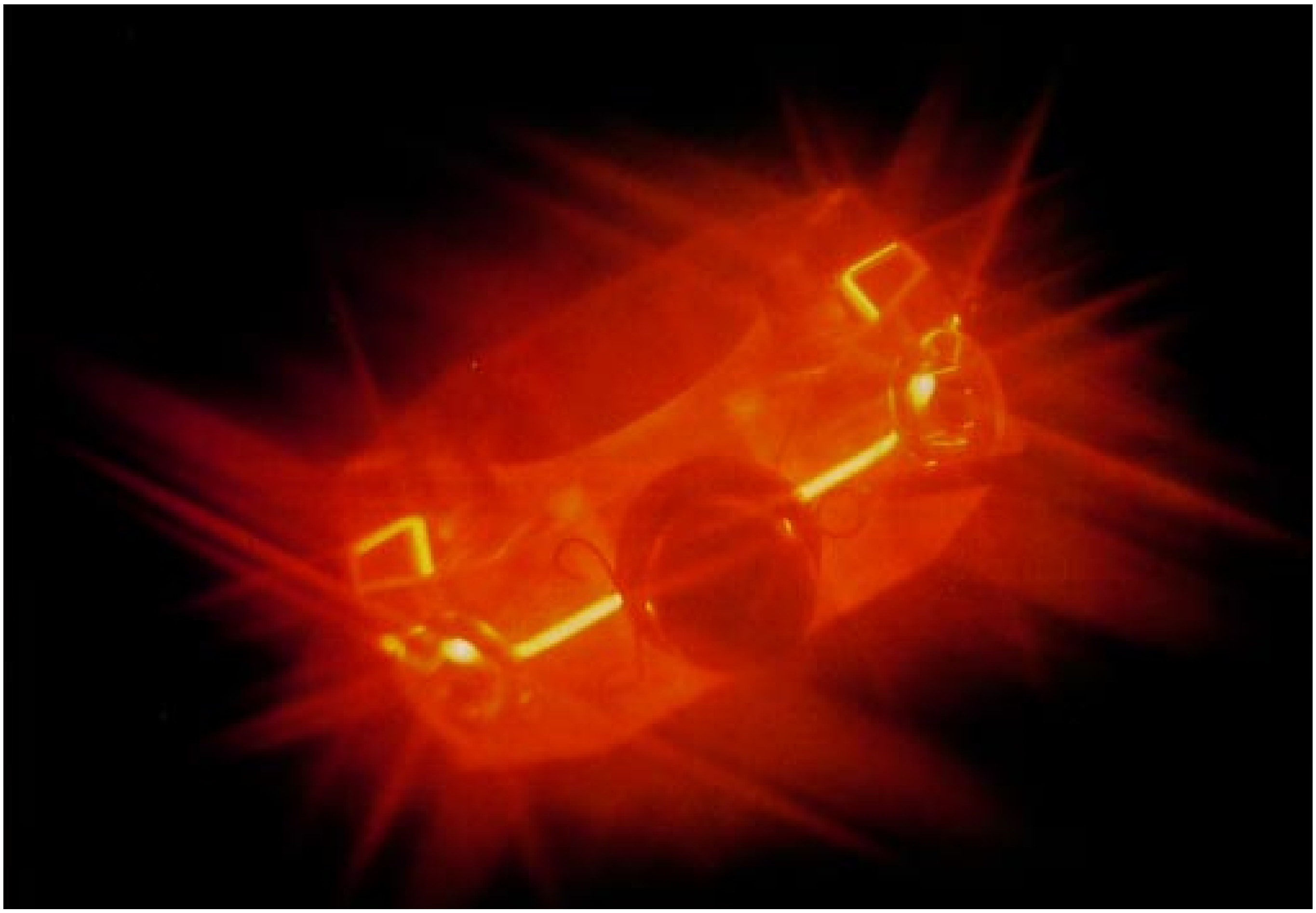
Sincerely,

Don Dawson

Don Dawson, Deputy Manager
C-130 Avionic Systems



RING LASER GYROS FOR THE HERCULES



by **Wayne Shiver**
Electrical/Instruments/Guidance Instructor
Customer Training Systems Development

The self-contained, all-weather navigation system has been with us for a long time now, ever since the introduction of inertial navigation systems into aircraft. Typically, this has been accomplished through the use of mechanical gyroscopes and a highly mechanized gyro platform that needs a lot of electronics to keep it level. A large number of systems of this type are currently in use on aircraft, including the Hercules, but there are changes ahead. Over the past decade or so, the application of an array of innovative, advanced technologies has been revolutionizing the field of inertial navigation. Today, these changes are being reflected in the Hercules aircraft as well.

Gyroscopes

At the heart of a conventional inertial navigation system (INS) are rotating-mass gyroscopes that are essentially high-tech versions of the familiar gyroscopic tops that have intrigued generations of budding young physicists. The characteristic behavior of these devices is due to the angular momentum of the spinning

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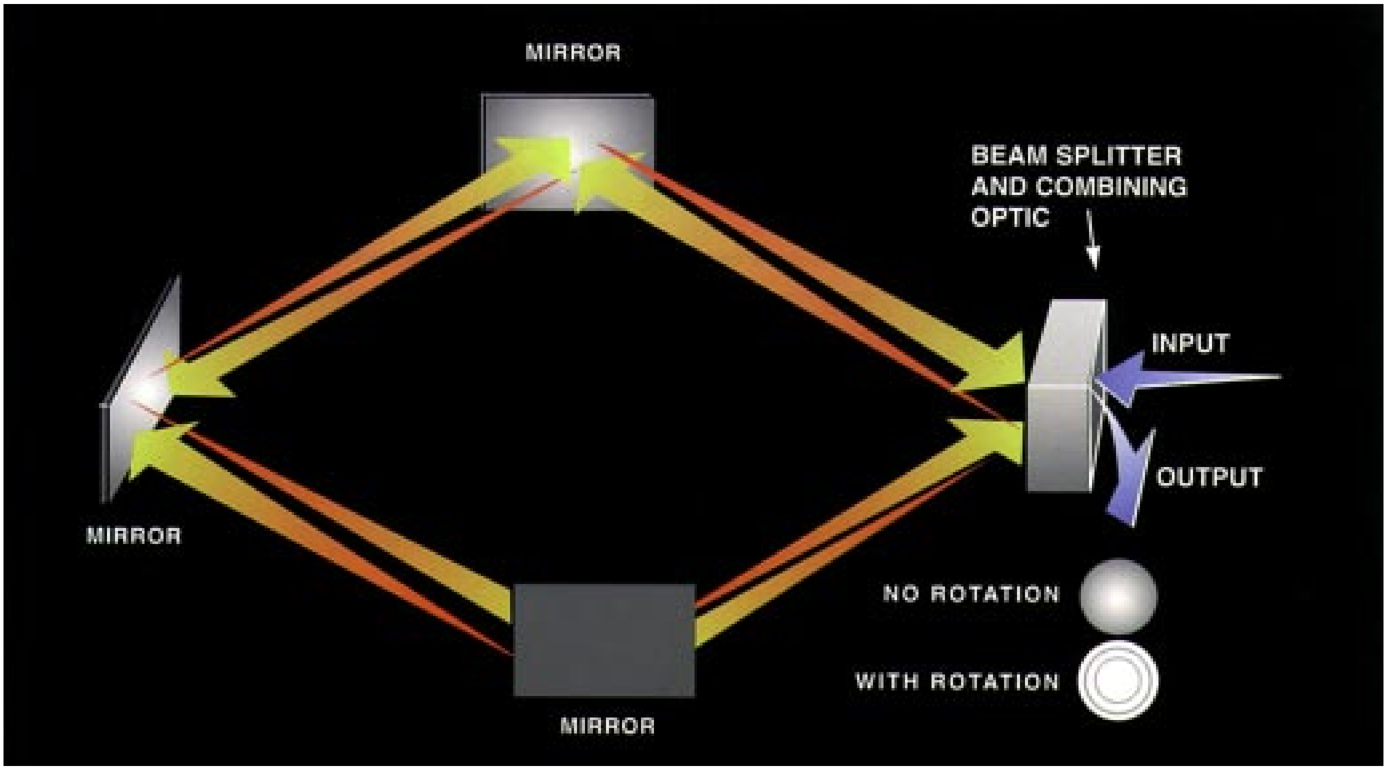


In the Sagnac interferometer, two beams of light from the same source are reflected in opposite directions around a ring of mirrors and then recombined. If the device is rotated, interference fringes will be displayed in the recombined beam.

rotor, which causes the top to resist changes in its orientation even when the frame in which the rotor is mounted is deliberately disturbed.

It is these same properties that also make the mechanical gyroscope useful in INS units. When combined with accelerometers and other supporting equipment in a properly designed system, spinning mechanical gyroscopes can provide high-quality directional and rate change information for use in navigational computations.

The problem with conventional mechanical gyroscopes is that they are subject to the same troubles that beset other complex mechanical systems. Conventional gyroscopes are expensive, sensitive to physical shock, and subject to wear. By the 1980s, when conventional INS equipment had already reached a high level of development, the mechanical gyroscopes on which these systems depended failed, on average, after only a thousand or so hours in service. It was obvious that an entirely different type of gyroscope would be needed before a significant increase in reliability could be expected.

As it turned out, the breakthrough came from what would seem a totally unexpected quarter: the field of optics. Laser gyroscopes, or more precisely, the *ring* laser gyroscopes that comprise the core of some of today's most advanced INS units, belong to a family of simple but elegant devices known collectively as optical gyroscopes. Although they differ in the particulars of their operation, all optical gyroscopes have in common the fact that they make use of a light beam to measure motion. Let us take a closer look at the background of the optical gyroscope and see how this remarkable feat is accomplished.

The Sagnac Effect

The key that unlocked the door to the development of this revolutionary new gyroscope had already been discovered long before the first mechanical gyroscope was installed in an aircraft navigational system. In 1913, a French investigator by the name of Georges Sagnac devised an experiment in which two beams of light from the same source were reflected in opposite directions around a fixed ring of mirrors and then recombined.

All of the components of this device–including a light source, mirrors, and a photographic plate–were mounted on a disk that could be turned at various speeds. The photographic plate was placed at the point where the beams were recombined to record any changes that occurred in the course of the experiment. Sagnac found that when the disk was rotated, interference fringes appeared at the point where the beams came back together.

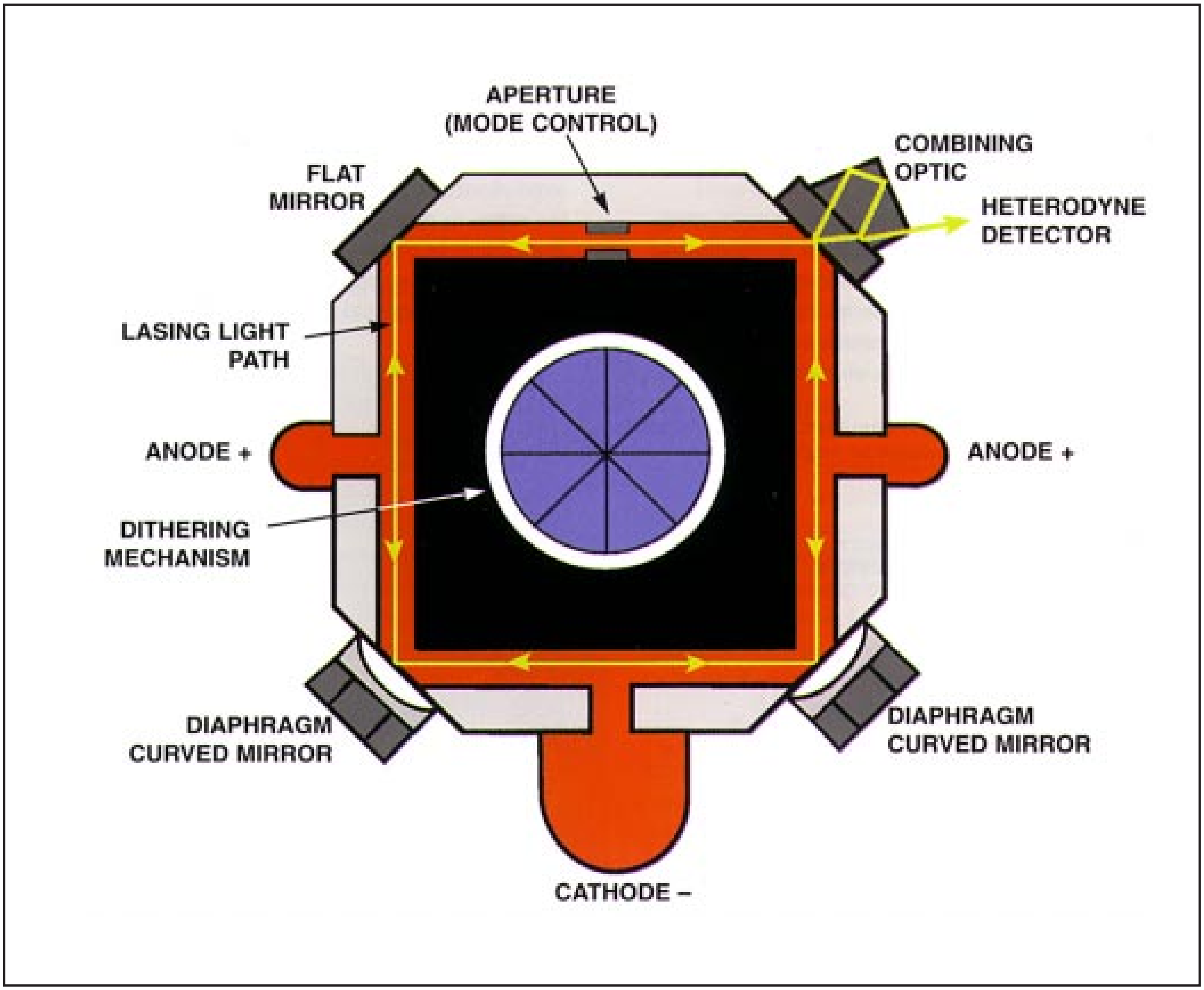
The explanation of this phenomenon is that the rotation has the effect of shortening the light path in the case of one light beam and lengthening it in the case of the other. This causes a detectable change in the wavelengths of the two beams as received at the focal point. Furthermore, the displacement of the fringe pattern under these conditions is proportional to the rate of rotation. At one stroke, Sagnac's experiment had demonstrated the fundamental concepts that would lead to the development of a gyroscope based on *optical*, rather than mechanical, principles.

An Academic Question

Of course, much of this was only partially understood at the time. The Sagnac interferometer, as it is called, had not been designed with any specific practical application in mind. Its purpose was to test one of the predictions of Einstein's theory of relativity. Sagnac was a classical physicist who was uncomfortable with many of Einstein's ideas, and in the end he misinterpreted the results of his experiment as evidence against relativity, rather than a proof of its validity.

The relativistic explanation for the phenomenon that Sagnac had observed has proved to be the correct one, but this does not diminish the significance of his discovery. Recognition for his contribution to the science of navigation would have to wait, however. In the

High-tech Sagnac: In the ring laser gyro, electrical energy applied to electrodes generates two laser beams that travel in opposite directions inside a glass cavity. No outside light source is required since the cavity itself contains the lasing element.



second decade of the 20th century, the entire matter was regarded as little more than an academic debate. The technology of the age was incapable of making practical use of Sagnac's findings. For nearly 50 years, Sagnac's interferometer and the Sagnac Effect languished on the laboratory shelf, just another arcane and probably useless scientific curiosity.

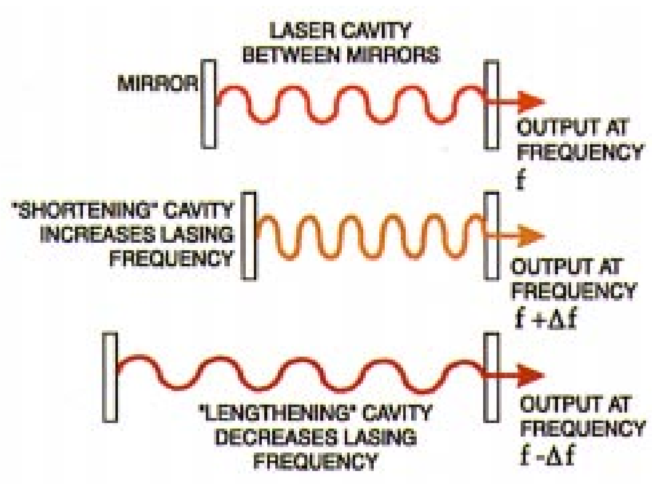
Laser Magic

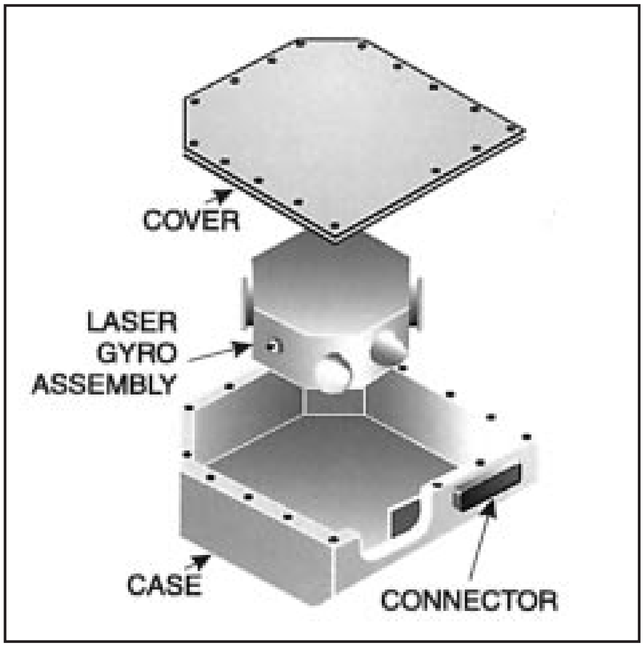
It was the discovery of the laser–plus the availability of high-speed microprocessors and inexpensive, compact memory–that first made the optical gyroscope a practical reality. Lasers have been around as scientific novelties since the 1950s, but only recently have they come into their own in everyday applications as diverse as grocery store bar code scanners and compact disc players.

The word laser is by now a familiar term that almost everyone has heard and used, although not everyone knows what it means. Actually, the word is an acronym derived from the term *light amplification by stimulated emission of radiation.* Let us look at what a laser is and how its unique characteristics are used in ring laser gyros.

An ordinary light bulb illuminates when its tungsten filament is heated to incandescence by an electric current. The atoms that make up the filament emit photons in large quantities, but they do so independently of one another. A variety of frequencies are represented, and there are no specific phase relationships among the light waves in the beam. This random and chaotic mix of light energy is called noncoherent light.

Emitted at a precise frequency, laser light is very sensitive to changes in its path length caused by motion.





Compact, light in weight, and containing virtually no mov-ing parts, laser gyros are ideal for airborne applications.

By contrast, a laser emits what is known as coherent light. The atoms of a suitable substance are stimulated electrically to emit light that is in phase and has the same, or nearly the same, frequency. When emitted from the right material under the proper conditions, the result is a narrow and concentrated beam of light that has both temporal and spatial coherence.

The radiating substance must be one that will lase; that is, it must be a medium that will support the stimulated emission of photons. Many substances will lase in the right circumstances, but practical considerations usually dictate the selection of the lasing medium. For example, a ruby crystal is often used in applications requiring a solid-state laser; a helium-neon mixture may be preferred where a gas laser is needed; and gallium arsenide is commonly employed when a semiconductor laser is considered appropriate.

Inside the Ring

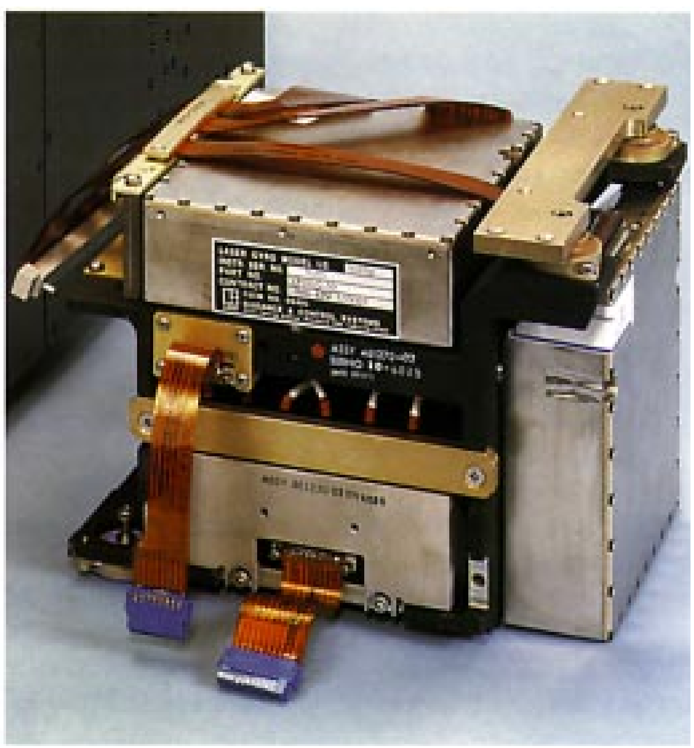
In the case of the ring laser gyros used in the Litton LTN-92, one of the INS units that can be used in the Hercules, the lasing medium is a proprietary mixture of helium and neon. The special blend is contained in a partially evacuated four-sided cavity–the "ring" of the laser–that is cut out of a single piece of solid glass. The dimensions of the cavity (in this case, 28 cm) are selected to ensure that it is resonant to the wavelength of light emitted by the helium-neon mix. This permits the most efficient amplification of the generated signal.

The medium is excited, or stimulated to lase, by the application of high-voltage electrical energy from a single-cathode, two-anode arrangement within the four-sided laser gyro. The placement of the two anodes is such that the two laser beams will travel in opposite directions around the cavity whenever the power is applied. No outside light source is required since the gyro cavity contains the lasing element.

Mirrors on the corners of the cavity sustain the laser oscillations, and a combining optic is located at one corner where the two laser beams are brought back together. Each of the beams is reflected around the inside of the cavity many times, increasing in amplitude all the while, before being recombined at the focal point.

Now that the two beams of light are moving in opposite directions around the closed, polygonal cavity, the next step is to establish a method of determining relative movement of the gyro from its rest condition. Fortunately, the purity, or coherence, of the laser's emitted signal makes the detection of any apparent changes in its wavelength a straightforward matter.

The LTN-92 combines three ring laser gyros in a single assembly, allowing direct measurement of motion in all three axes: pitch, roll, and yaw.



In a typical installation, the ring laser gyro is hard-mounted to the aircraft in the axis to be measured. The effect of rotating the gyro about its axis–moving the airplane–will make the path length traveled by one beam appear shorter, and the path length of the other beam seem longer.

When these two laser beams, traveling in opposite directions, converge at the combining optic while the aircraft is in motion, interference fringes are observed: the Sagnac Effect. These fringes will move according to the rate and direction of the rotation of the gyro itself, which allows the displacement to be quantified.

Frequency Lock

If this is all beginning to sound almost too good to be true, skeptics will be reassured to learn that also in the case of the ring laser gyro, not everything has been arranged to suit human convenience. There are still a few problematic details that must be dealt with, despite all the technological wizardry. The most significant of these arises as a byproduct of the very physical principles that the ring laser gyro exploits. It is a phenomenon called frequency lock.

Frequency lock seems first to have been noted by Galileo, who observed that the pendulum motions of two clocks mounted on the same wall tend to become synchronized over time. It turns out that frequency lock or lock-in, as it is often called, can also affect the operation of devices that utilize far higher frequencies than would ever be seen in a mechanical clock. This includes the ring laser gyro.

When the frequencies of the two beams are very close together and have a low applied rotation rate, a coupling or interaction between the two beams can occur. In the ring laser gyro, this interaction can be traced to backscatter of the laser beams off the mirrors inside the laser cavity. The performance of a ring laser gyro is therefore very dependent on the quality of the mirrors used in its construction.

By using mirrors with high reflectivity and accurate surfaces, the backscatter problem can be reduced to a manageable level that can be dealt with by the addition of a "dither" mechanism. The dither device is mounted in the center bore of the laser cavity and provides a means of purposely introducing oscillations to ensure that the ring laser gyro will always see an input rate sufficient to prevent the two beams from locking in and

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Components of the LTN-92 include the main INU assembly containing laser gyros, power supply, and system electronics; the mode selector (foreground); and the CDU. The CDU features a five-line, 16-character display and expandable function keys.

synchronizing. This added signal is removed or demodulated later in the processing of the gyro output signal.

Strapdown Navigation

The potential offered by the laser gyro for inertial measurements of high precision and stability would have to remain just potential without a practical way of interfacing the gyros to the aircraft itself. This is where the concept of *strapdown* navigation comes in.

INS units that are based on mechanical gyroscopes are typically *platform stabilized*. That is, they utilize a sensor that is mounted to a system of gimbals. This allows the vehicle body–the airplane–to rotate around the sensor. The sensor typically consists of the gyros, accelerometers, and their associated electronics. In these gimbaled systems, the vehicle motion is usually measured as a gimbal position relative to the gyro vertical position.

The mounting arrangements in laser gyro systems are altogether different. In these systems the sensor package that measures angular data (i.e. positional changes) is securely mounted to the vehicle in which it is transported. One gyro is hard-mounted to the aircraft structure (through the strapped-down inertial navigation unit) for each axis that is to be measured directly.

When the aircraft pitches up, for example, the vertical (pitch) gyro pitches up at the same rate and amount. The same principle applies to movements in the horizontal axis, which is measured by a directional (yaw) gyro. In the case of the LTN-92, three ring laser gyros are provided. This permits direct measurement of motions not only in pitch and yaw, but also in the roll axis as well. Movement that involves combinations of these components is derived by analysis of the combined signals from all three gyros. Clearly, this is a very different kind of gyroscope than the type used in the older-style systems.

It is indeed. One welcome difference is that there are almost no moving parts in most inertial navigation units (INUs) based on ring laser gyros. None of the elaborate mechanization that was previously required in the older INUs is needed. Everything that was done mechanically is now being done optically, electronically, or in software. The same high level of technological sophistication that permits light beams to be used to detect positional changes also allows an impressive array of advanced capabilities to be built into these units. In addition, improvements in the user interface now offer unprecedented versatility and ease of use from the standpoint of the operator.

Summing It Up

The process of detecting motion through the use of a ring laser gyro can be summed up by saying if the laser gyro cavity rotates, the path length changes for the two beams. This causes changes in the interference fringe pattern at the point where the two beams are combined. The changes are then detected by a photodiode, and the results read out as an incremental angle. For example, rotating a ring laser gyro with a path length of 28 cm through approximately 1.9 seconds of arc will result in a one fringe-cycle change.

The application of the advanced technology represented by the ring laser gyro offers many important advantages for the modern INS. The new systems are accurate and reliable well beyond the capabilities of any system based on mechanical gyros. With virtually no moving parts, there is nothing mechanical to wear out, and no periodic maintenance or replacement of compo-nents is required.

Laser gyros can also claim other advantages in that they are compact in size and relatively light. The glass blocks containing the laser cavities are only a few inches across and practically negligible in weight when compared with their mechanical counterparts in a conventional INS.

Ring Laser Gyros and the Hercules

For a number of years now, Hercules aircraft built for the U.S. Air Force have been equipped with INS components designed to meet USAF specifications for Standard Form, Fit, and Function Medium-Accuracy Inertial Navigation Units, sometimes also known as "FΔ" INUs. In the case of the Hercules, either a Honeywell model H-423 or Litton model LN-93 may be used in these installations.

Both of these units utilize ring laser gyros as their stable elements and are functionally similar. Physically, they differ mainly in that the Honeywell system uses three-sided gyros and the Litton employs a four-sided design. Both systems interface with the Self-Contained Navigational System (SCNS) of the Hercules airlifter to provide inertial positions and other guidance functions. In the latest C-l30H models, the inertial platforms provide all attitude and heading references, which permits the deletion of separate compass systems and vertical gyros on these airplanes.

Since the FΔ INUs operate in conjunction with a flight management system, there is no separate control display unit, such as is often used in other installations. The INUs are controlled by an integrated display computer unit (IDCU), which takes the place of a control display unit.

The LTN-92

The Litton LTN-92 is now the baseline INS provided on new Hercules aircraft for customers other than the U.S. military. The LTN-92 and its ring laser gyro stable element replaces the electromechanically stabilized Litton LTN-72, which had been the baseline equipment on the Hercules aircraft for many years. Many operators are now also retrofitting the LTN-92 to existing Hercules aircraft.

One of the LTN-92's most useful features is the bulk storage of flight plan and navigation information in a customer database. This database is capable of holding navigational data for up to 2005 waypoints, airports, and stations. As many as 99 custom routes, with up to 98 waypoints in each route, can be accommodated in the available memory. In addition, the crew has the option of assembling a temporary catalog containing 120 data items not found in the customer database. This can also be added to the permanent database storage in certain installations.

In addition, a local-station catalog is available which contains the 20 closest TACAN or VOR/DME stations within a 200-mile radius of the present position for use in updating the INS, either in a manual or automatic mode. Global Positioning System (GPS) updating is also provided for in some installations. If a Litton GPS is installed, the update priority automatically selects the GPS without any special initiative on the part of the operator.

With so much information available, an advanced control display unit (CDU) is required. The CDU is a multiline LED display using a five-line by 16-character matrix. The keypad on the CDU is highly versatile, with expandable keys available to enhance the user's ability to access data stored within the system.

For maintenance personnel, a built-in test (BIT) capability allows access to diagnostic action prompts and malfunction messages which identify a suspected problem and recommended corrective action. The system also goes through a series of tests at power-up, and conducts continuous BITs during operation. These checks alert the operator of problems that have been detected by displaying appropriate messages on the master warning indicator on the control display unit.

Using the System

All inertial navigation systems must be aligned with earth axes so that pitch, roll, and heading can be resolved. The operator does this by placing the system in the alignment mode and entering the aircraft's present position. Normal alignment time is approximately 7 to 10 minutes. This time is not lost, since the crew is generally occupied in setting up the flight plan, checking the status of the alignment, performing the self-tests, and performing the autopilot/flight director tests, if available.

After the alignment process has been completed, the INS is ready to do its job, including aircraft guidance, providing attitude outputs for other aircraft systems (depending on the particulars of the installation) and, of course, navigation. The INS is also capable of providing time and distance estimates to selected waypoints, landing zones, drop zones, and calculating a computed air release point in some installations.

Future Developments

We noted above that the accuracy of the INS can be improved by updating it with input from certain other navigational aids, including GPS, depending on the specifics of the individual installation. In this connection, there has been much discussion of the capabilities and potential of GPS in recent years, and it is only natural that questions should arise about the prospects of INS, and what role it can be expected to play in the future.

In spite of the impressive progress being made with GPS-based navigational systems, it seems unlikely that INS will become obsolete anytime soon. INS has a number of intrinsic capabilities that combine to ensure its continuing importance over the long term.

The most obvious one is the ability of an INS to operate without any external references. It cannot be interfered with by any outside source, and provides accurate present-position and along-track guidance for many hours of flight. Another factor to consider is that in some aircraft installations, INS provides the only attitude reference for the aircraft; in others it provides at least a secondary or alternate attitude reference system.

Perhaps the future truly belongs to those systems which combine the special advantages of both of these advanced approaches. The GPS-aided inertial navigation systems now in use in some Hercules installations combine the stability of ring laser-based INS with the precision of GPS. These accurate and dependable aircraft navigation systems offer levels of performance that meet or exceed all presently identified requirements for long-range air travel. In so doing, they come enticingly close to providing perfect solutions to classical problems that have been faced by navigators since the dawn of human history. ❏

The author and Service News wish to thank Don Dawson of Lockheed Martin Engineering for his advice and encouragement during the preparation of this article. We wish also to acknowledge the invaluable help of Richard Cunningham and J. D. Skaggs of Litton Aero Products. The photographs on pages 3, 7, and 8, appear courtesy of Litton's Aero Products Division.

Wayne Shiver may be reached at 770-494-6856 or 770-494-7083.

Cover Notes

The photograph on the front cover of this issue comes to us courtesy of Henry Tenby of NWT Air, who also provides the following background information about NWT Air's operations:

NWT Air operates Canada's only civil-registered Hercules from its Yellowknife base. Since the late 1970s, NWT Air's Hercules has served a variety of customers worldwide. However, most of the work involves bulk fuel hauls, mining and drilling equipment delivery, and construction materials hauling for resource-based companies operating in Canada's vast Arctic regions. NWT Air's Herc gets many opportunities to demonstrate its toughness, since it operates mostly from packed gravel and frozen lake airstrips.

Introducing a new–

Propeller and Nacelle Cover Set

by **Dennis Dewberry**, *Product Support Engineer*
Reliability and Maintainability Engineering Department

The PN 404100-31 Propeller and Engine Nacelle Cover is a protective covering system designed for use in all lands and latitudes, but it is especially valuable in areas where harsh or extremely harsh environmental conditions prevail during a substantial part of the year.

This new cover set can protect engine components from sand, ice, salt water, and heavy rain. It will also protect engines that have been cannibalized, shielding exposed electrical connections and hydraulic fittings until the missing parts can be replaced. Nesting birds and insect swarms out on a hunt for new living space will find it very difficult to set up housekeeping in your aircraft's engines when these covers are installed. The covers can, in addition, be used in conjunction with the engine inlet cover while the aircraft is parked.

An Updated Design

The improved cover system is an updated configuration based upon an older design that incorporated a special weather- and sunlight-resistant vinyl fabric and used zippers and straps to make the necessary attachments. The tough vinyl covering material has been retained in the new design, but Velcro is now used instead of zippers to make the closures. This results in better adhesion and longer service life. Experience has shown that the Velcro also works better than zippers under extreme climatic conditions. Arctic ice and desert sand particles have a tendency to clog zippers and prevent them from closing properly.

Propeller Protection

The new covers should be especially helpful in protecting propeller blades from corrosion damage, such as pitting, cracking, and splitting. In the old design, the propeller blades were only covered to just past the deicing boot, with most of the blade left exposed to the weather. The new design incorporates a complete cover for each propeller blade, using straps in two locations to secure the cover and close it tightly around the propeller shaft.

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The large spinner cover fully protects the entire spinner.

The nacelle cover encloses the nacelle; overlaps the spinner.

In addition, the new spinner cover actually covers the entire spinner. It fits snugly around the propeller shaft, and overlaps the seam between the spinner and the nacelle. In most cases, this should prevent foreign debris from slipping past the spinner cover and entering into the mechanical workings of the propeller. The design also incorporates a red-tip blade cover to help designate the No. 1 propeller blade so that it can be clocked to the 12 o'clock position to help prevent excess hydraulic fluid from draining into the hub.

Cover Installation and Removal

Ease of use was a major consideration in the design of this new cover system. The complete set can be installed in approximately 15 minutes per engine and

The complete propeller and nacelle cover set can be installed in about 15 minutes, and can be removed even more quickly.

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removed even more quickly. The main cover encloses the nacelle, overlaps the spinner cover, and closes tightly around the spinner cover using a belt. In addition, there is a belt at the aft end of this cover that can be drawn tightly around the nacelle structure.

Careful attention has also been paid to the small touches that contribute so much to the useability and practicality of a product of this type. For example, the nacelle cover incorporates three drain holes to allow condensate moisture and other fluids to drain to the outside rather than collect inside the cover.

The nacelle cover, spinner cover, and three propeller blade covers will all fit into a single blade cover.

Protecting the engine, each propeller blade, the spinner, and the nacelle to the leading edge of the wing, this new engine cover design provides optimum protection of the engine and the propellers. Regular use of this system, particularly in cases where aircraft must be stored outdoors under harsh weather conditions, can pay big dividends in lower maintenance costs and extended service life.

The PN 404100-31 Propeller and Engine Nacelle Cover System is available through the Lockheed Aeronautical Systems Support Company, P. 0. Box 121, Marietta, GA 30061-0121. Telephone 770-43l-6664; fax 770-404-43 l-6666. ❑

Dennis Dewberry can be reached at 770-431-6730.

The PN 404100-31 Propeller and Nacelle Cover system protects the engine, propeller blades, spinner, and nacelle all the way to the leading edge of the wing.

Auxiliary Fuel Tanks:

Leak Detection Coating Update

by **Wayne Thompson,** *Field Service Representative*
Airlift Field Service Department
Lockheed Aeronautical Systems Support Company

Most Hercules aircraft carry two auxiliary fuel tanks in the center wing section, one on each side. These tanks are installed in the large bays that are defined laterally by the fuselage structure and the inboard engines, and front to rear by the front and rear wing beams. Each tank consists of three flexible, interconnected bladder cells made of a strong, hydrocarbon-resistant synthetic rubber.

In aircraft Lockheed serial number LAC 4461 and up, the surfaces of the bladder cells are coated, except at the top, with colored, fuel-soluble dye compounds. The purpose of these coatings is to assist in the detection and location of fuel leaks. Fuel leaking from any of the cells will be tinted a distinctive color by the dye coating that was applied to the cell from which it came, and this will aid in tracing the leak's origin.

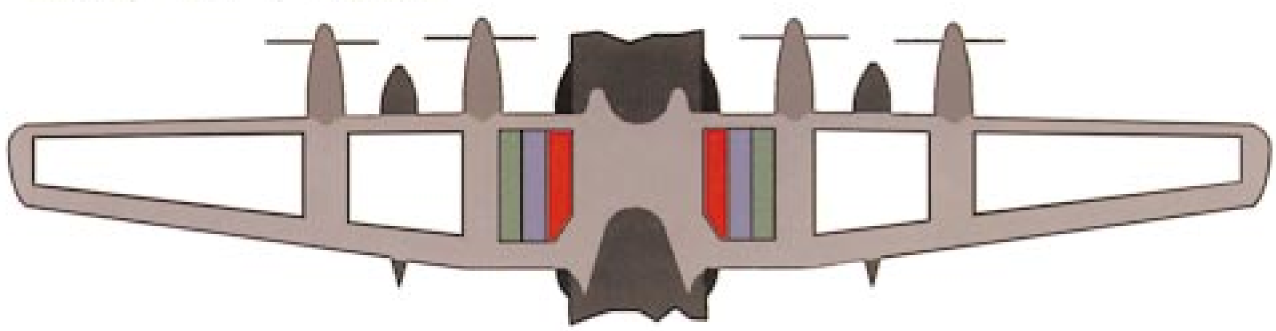
Service News Vo1.2, No. 2 (April-June 1975), contains an article "Locating Leaks in Auxiliary Fuel Tanks by Color." This writeup (which is still available) deals in some detail with the subject of auxiliary fuel tank leak location using the color markers provided by the special tank coatings. Most of the material in this article remains applicable to the majority of Hercules aircraft now operated worldwide. Operators should, however, note the following updates:

The article listed three part numbers for leak detection coatings used on the auxiliary tanks. The current information is shown in the table at the bottom of the page.

The address of the manufacturer of these materials has also changed, and is now as follows: Rockland React-Rite, Inc., 327 Industrial Drive, Rockmart, GA 30153, USA. Telephone (toll free) 800-221-4799, or 770-684-6626; fax 770-684-0011. ❑

Wayne Thompson can be reached at 770-431-6550.

CELL LOCATIONS	COATING COLOR	APPROVED PART NUMBERS
Inboard	Red	FCC - Red
Center	Blue	FCC - Blue
Outboard	Green	FCC - Green



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The P-38 Lightning

by **Terry Linehan,** *Service Analyst*
Lockheed Aeronautical Systems Support Company

Wing Span - 52'
Length - 37'10"
Height - 12'10"
Gross Weight - 15,416 lbs.
Empty Weight - 11,507 lbs.

Power Plants - 2 Allison V1710-C9 reciprocating engines, 1150 BHP each
Max. Speed - 413 MPH at 20,000'
Cruising Speed - 320 MPH
Service Ceiling - 38,000'

The XP-38, pictured at March Field in California in 1939, was a development of the prototype Model 22, a radical 1937 Kelly Johnson design. The aircraft that evolved from these early models became a truly great Second World War fighter, the famous P-38 Lightning, over 10,000 of which were built by war's end. The P-38 performed with distinction in both the European and Pacific theaters of the war. In addition to being the first UK-based aircraft able to provide round-trip bomber escort to Berlin, it was also used exclusively against the Japanese by the two top-scoring American aces. This versatile design later became an outstanding performer in the role of fighter bomber and photoreconnaissance aircraft.

Photo courtesy of Robert E. Herndon
Terry Linehan can be reached at 770-431-6594.

LOCKHEED MARTIN

Aeronautical Systems

Customer Training Systems Department
Lockheed Martin - LMAS
Marietta, GA 30063-0601