ELEMENTS OF PERFORMANCE

Studying the Factors that Influence What Aircraft Can Achieve

Honeywell

How well your aircraft performs is how well your organization can accomplish its goals. If you want faster flights, more efficient air transportation, more military air capabilities or better rescue capabilities, you need higher-performing aircraft.

Performance isn't a single measure but a combination of capabilities in categories such as propulsion, lift, drag, weight, maneuverability or control and how each of these influences an aircraft's ability to accomplish its purpose. Atmospheric variations and degradation also impact performance.

For the military, performance may also include measures such as the speed of target acquisition and the accuracy of weapons systems.

The aviation industry is in the midst of a transformation in how it approaches performance. Organizations are applying new technologies and techniques in aircraft structure and components, but the biggest change is in data. Big data analytics offers entirely new ways to optimize performance. Insights about how weather, aerodynamics, weight and other factors influence each other can now be delivered in real time. As the industry continues to explore these advances, aircraft will be able to achieve missions faster or more efficiently - or take on new tasks entirely.

THE FUNDAMENTALS OF IMPROVING PERFORMANCE

In today's world, technological improvements are often a combination of physical and digital. New materials are put to use in novel designs, or old systems are given new life with advanced software. Through advances in hardware, data and software, individual aircraft and the industry as a whole are advancing in four major categories:

- Pilot visibility and control of performance
- Thrust and propulsion
- Precision, navigation and maneuverability
- Lift and payload

Let's look at the current status and the future of each of these elements of performance.

VISIBILITY AND CONTROL OF PERFORMANCE WITH THE CONNECTED AIRCRAFT

An Airbus A350 can generate 2.5 terabytes of data every day. Future models are expected to generate three times that amount. [2]

Despite the age of this quote, the insight that performance relies on the integration of aircraft components is just as important today as it was 60 years ago. Thinking about the system as a whole is fundamental to improving performance.

Today, the application of this insight has reached new heights with the Connected Aircraft. Connected Aircraft solutions gather data from nose to tail and aircraft to ground. Plus they provide ways to share, analyze and act on that data.

Connected Aircraft solutions can help track aircraft performance in real time through a broader data pipe with advanced data analytics that can optimize performance elements. They offer one of the most robust ways of grappling with aircraft degradation. By monitoring system and engine performance, the solutions deliver alerts when actual maintenance is needed and predictions of degradation to account for when scheduling maintenance.

The Connected Aircraft can also provide a more holistic view of variables that affect performance, such as weather, air density, air traffic and hazardous terrain. You can create predictive models of these variables by applying statistical analysis techniques, analytical queries and machine-learning algorithms. The models can place a numerical value - or score - on the likelihood of a particular event happening. By combining more data sets, it's possible to have a more comprehensive understanding of equipment health, weather, terrain hazards and more.

"Another thing that kept us from going ahead faster was the belief that engines and air frames are separate entities. A review of aircraft design clearly shows how much time and cost were consumed in trying to fit existing engines into air frames that were never designed for each other. The two are, after all, a unit, and - with the advent now of vertical flying - air-flow requirements around a wing from the jet engine gas generator source make the wing construction an intimate part of the power plant." - Grover Loenig, 1959 [1]

1. https://www.theatlantic.com/magazine/archive/1959/06/american-planes-the-lessons-of-history/303362/
2. https://www.datasciencecentral.com/profiles/blogs/that-s-data-science-airbus-puts-10-000-sensors-in-every-single

PILOT SUPPORT AND CONTROL

Giving pilots better controls can improve the performance of the equipment those pilots command.

Situational awareness capabilities with enhanced graphical features and weather tools help pilots find the most efficient path for highest performance. Efficient flight paths also avoid harsh conditions, thus reducing unnecessary wear on equipment and boosting ongoing performance.

Advanced avionics can give pilots easier access to these situational awareness tools as well as upgrade cockpits with brighter displays and visual-aid systems for more precise maneuvering in both clear skies and poor weather.

Health monitoring solutions, such as health and usage monitoring systems (HUMS) available for helicopters, can also give both pilots and other crew greater control over aircraft performance. The systems provide details on equipment operation so pilots and ground crews can understand any ongoing performance issues, adjust to them in flight and prepare for their repair when back on the ground.

ADVANCES IN THRUST AND PROPULSION

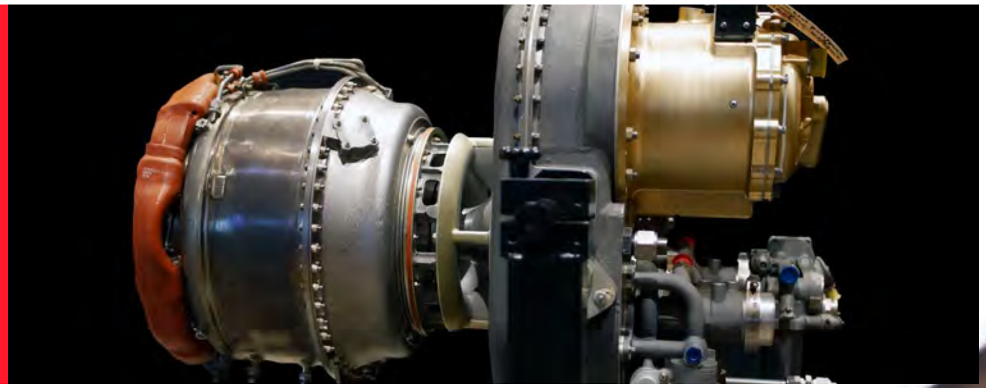
Without the power of modern aircraft engines, the speed and range of modern flights would be impossible. Gas turbine engines - whether in the form of turboshaft engines for helicopters or turbofans and turbojets for fixed-wing aircraft - have been the most powerful available option in propulsion for many years.

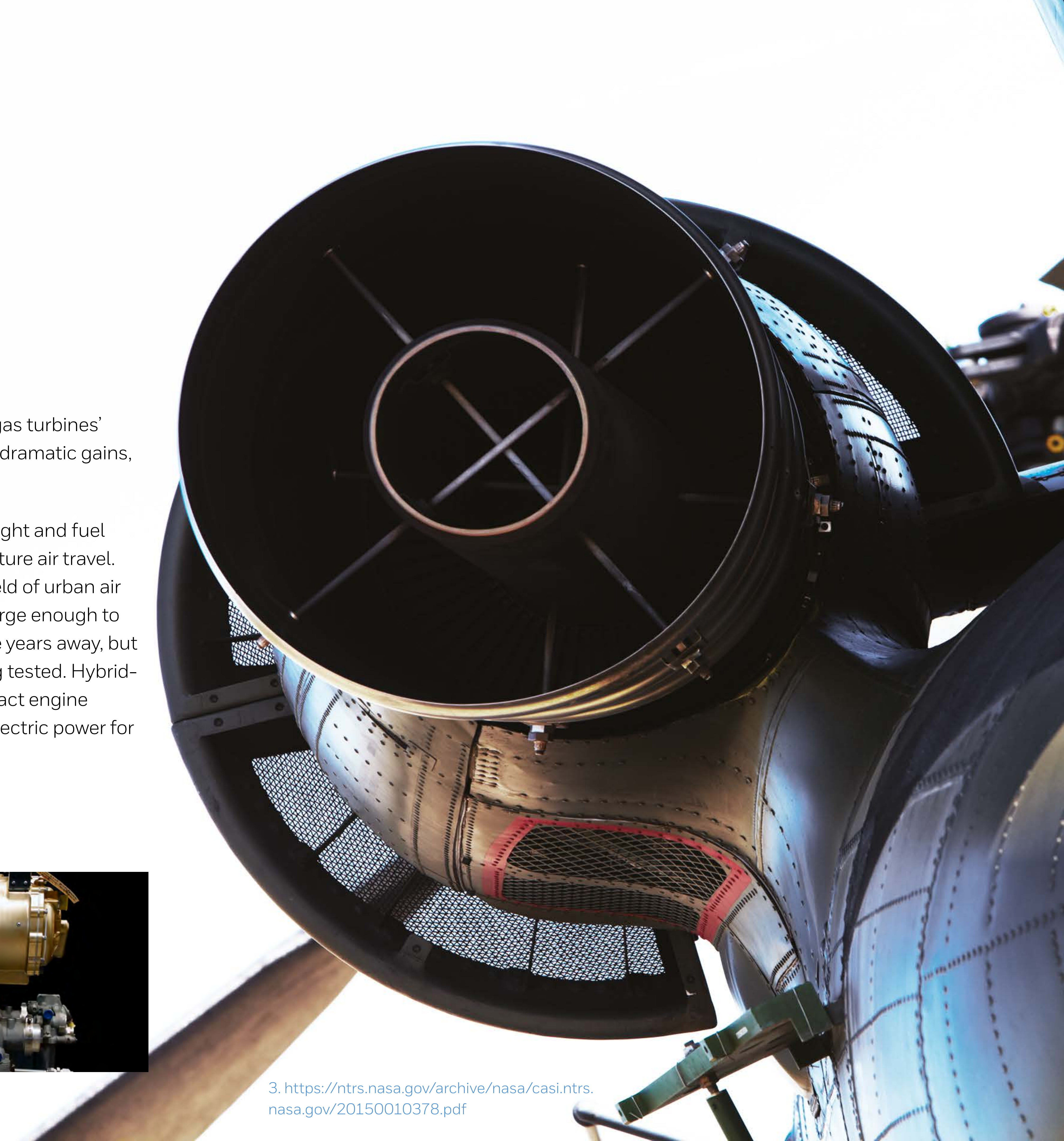
Over the past three generations, gas turbine engines have increased turbine inlet temperatures, compressor pressure ratios, bypass ratios, fan and nacelle performance, and more to dramatically improve performance. Thrust-to-weight ratios of gas turbine engines have seen a 350% improvement. [3]

At the same time, engines are also now quieter and more fuel efficient. While further advances in engines and engine optimization will increase gas turbines' capabilities to some degree, for future dramatic gains, the industry is turning elsewhere.

Electric engines promise to reduce weight and fuel use and potentially reduce noise for future air travel. They are of particular interest to the field of urban air mobility. Completely electric aircraft large enough to carry human passengers are still some years away, but components of them are already being tested. Hybrid-electric systems exist that use a compact engine combined with a generator to create electric power for future electric propulsion systems.

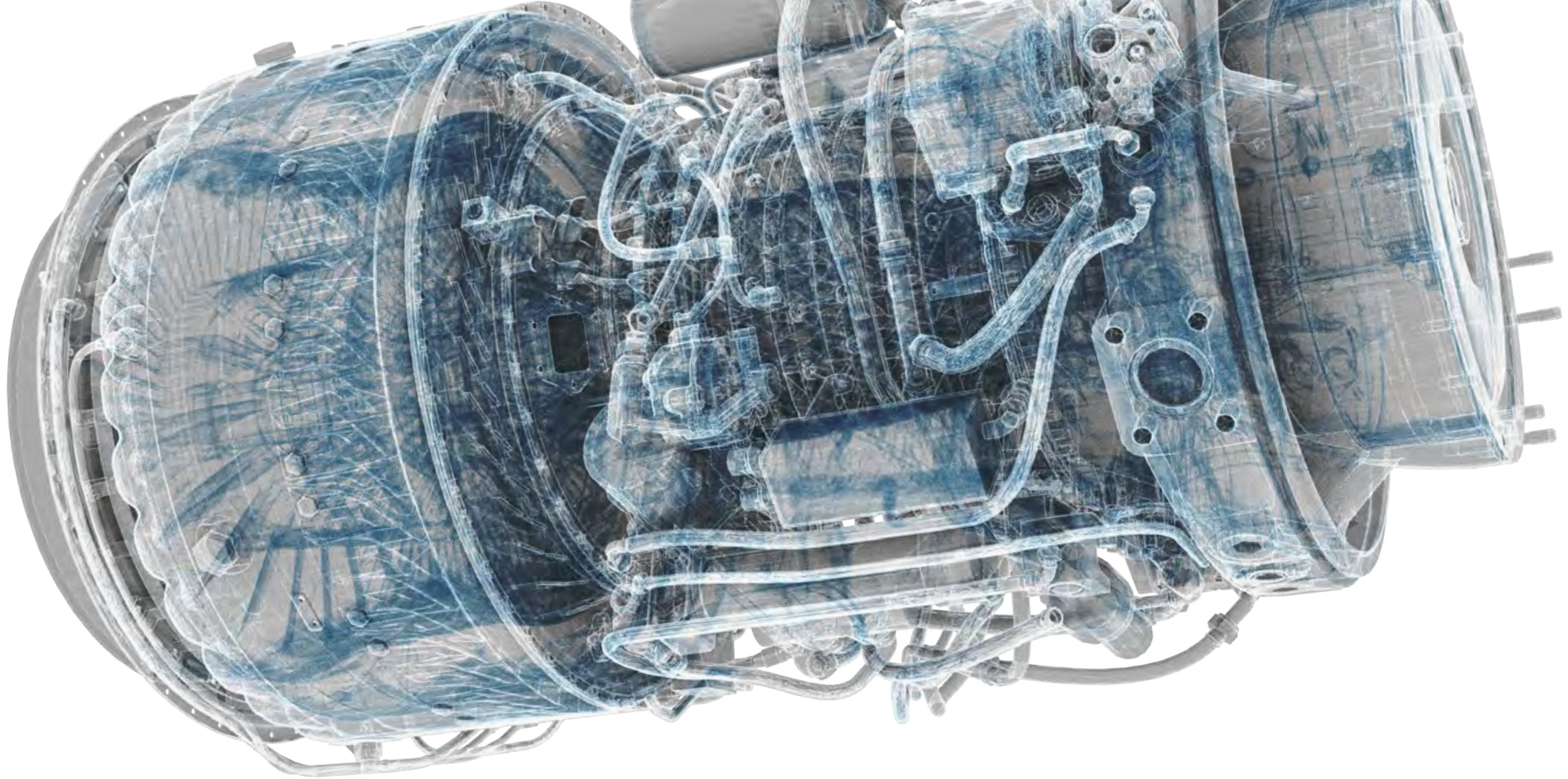
"All of us at Honeywell believe the electric propulsion market is a matter of when, not if." - Bryan Wood, Senior Director of Hybrid-Electric and Electric Propulsion Programs, Honeywell





3. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20150010378.pdf

SPECIFIC ENGINE NEEDS



Across platforms, engines are critical for their power and reliability in producing needed thrust while providing safety. Each area of the aerospace industry has slightly different requirements for engines. Here are a few of the considerations each faces when attempting to maximize engine performance.

AIRLINES

Fuel costs are the single largest cost for airlines. That makes the fuel efficiency of an engine of extreme importance to airlines. As engines have continued to evolve, improvements have been made, with more power and lower fuel consumption. Superior performance in engines can also deliver faster speeds to accomplish routes in less time, adding to passenger satisfaction and loyalty.

BUSINESS AVIATION

In the last 50 years, business aircraft speeds have only increased slightly. This is partially because new jet designs have focused on roomier and more comfortable cabins, rather than maximizing speed. Speed is now receiving new attention. Multiple companies are currently working on commercial supersonic jets, which will use many of the advances learned in large airliner engines to bring exceptional speed to business travel.

HELICOPTERS

Without aerodynamic properties to keep them aloft, helicopters are particularly reliant on engines for their flight capabilities. Helicopter designers and operators are constantly searching for more power and fuel efficiency in smaller or lighter-weight packages. Helicopters need engines that can deliver power for improved climb rates and faster speeds especially if used for air ambulance or other missions.

Because helicopters often operate in harsh environments, such as during search and rescue or aerial firefighting, helicopter engines must also be particularly robust to account for high heat, poor weather, or flying dust and debris.

DEFENSE

Engines for defense need to meet rigorous requirements and provide maximum performance. For modern fighter jets, high-thrust engines with thrust vectoring are becoming necessary to obtain air combat superiority.

Outside of this cutting-edge use case, however, many of the needs for defense are similar to those elsewhere in aviation. Engines must be highly reliable. There is also high demand for lighter and more fuel-efficient engines, which can increase aircraft range.

GENERAL AVIATION

Safety and reliability are primary concerns in general aviation engines, but must be achieved economically. Pilots and operators rarely have access to dedicated maintenance crews. Because some general aviation aircraft have only a single engine, pilots must be able to trust that engine completely.

ADVANCES IN NAVIGATION, PRECISION AND MANEUVERABILITY

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In the short history of flight, navigation has gone from being reliant on paper maps to providing pilots with extremely precise and constantly updated location data based on GPS. Aircraft maneuverability has made similar remarkable advances.

Inertial Measurement Units (IMUs) are a part of the next step forward. IMUs are devices that sense rotation and acceleration. By measuring these forces, IMUs can tell a machine where in space it is, how fast it is moving, and in what direction. IMUs are crucial when GPS signals are unreliable. In aviation, IMUs have long held important roles in military missions for precise and accurate missile deployment and are being used frequently in drones. They will be a fundamental component of unmanned flight.

In fact, the market for IMUs is not just in aviation, but includes automobiles and other devices, including robots. That is one reason it is so large. The IMU market was valued at $3.18 billion in 2017, and is expected to reach $4.33 billion by 2023, at a compound annual growth rate of 5.31%.[4]

There are other navigational technologies that promise to change the way aircraft operate, as well. For instance, advanced, satellite-enabled air navigation using an ecosystem of information and 3D imaging will be able to provide aircraft with more precise flight paths.

4. https://www.mordorintelligence.com/industry-reports/high-end-imu-market

HIGHLIGHT ON ACTUATORS

Actuators move flight control surfaces, guide satellites, extend aircraft landing gear, open weapons-bay doors on military planes and flush airliner toilets. Without lightweight, precise actuators, modern flight is impossible.

As you'd expect from a class of products that performs so many jobs, actuators come in many versions. They can be operated by electric current, hydraulic fluid pressure or pneumatic pressure.

Actuation systems provide aircraft engine and thrust management control, noise and vibration control, flight surface control and aircraft utility functions, such as fuel inverting.

In space, actuators are key to launch and satellite propulsion controls, solar array drives, antennae pointing and docking control. The reliable steering control provided by actuators is critical to all aircraft, including space platforms, unmanned aircraft, tactical missiles and guided munitions.

Improvements in actuators can make aircraft handle more precisely, or can help leverage thrust (such as through thrust reverser actuation). Today's actuation systems are built on modern variable geometry control needs and strive for low weight, high energy efficiency and maximum reliability.

ADVANCES IN LIFT AND PAYLOAD

While propulsion plays a part in creating lift, it is only one factor in getting aircraft off the ground. Aerodynamics and payload play equally important roles.

AERODYNAMICS

Current work to make planes lighter and performance higher includes the exploration of various new aircraft designs and wing types, including lifting body, flying wing, tilt-rotor, and flexible or morphing wing surfaces. Even the winglets many airlines have added to their aircraft can have significant effects on lift. By breaking up or reducing the vortex produced at the end of an airliners' wing, the winglets can reduce drag and thus boost aircraft performance.

PAYLOAD

Payload is the carrying capacity of an aircraft. Usually measured in terms of weight, an aircraft's payload limit determines what it can do. Payloads can be made up of cargo, passengers, flight crew, munitions, scientific instruments or experiments, or other equipment.

Lift and payload are oppositional, yet you obviously want to achieve the most of each at the same time. One way to increase the payload of a given aircraft design is to reduce the weight of the aircraft itself. This gives you more lift to spend on carrying payload. New materials like graphene and carbon nanotubes are helping to make airplane wings more efficient by reducing weight and fuel consumption.

Another way to increase available payload is to reduce the amount of fuel an aircraft has to carry. Connected Aircraft data can help operators load the appropriate amount of fuel for a flight - rather than filling the tank with too much and paying in performance to carry that extra fuel around.

While auxiliary power units (APUs) do not directly provide thrust, they do impact performance in multiple ways. APUs are essential for providing power for modern aircraft, and the more reliable an APU is, the higher the performance that owners and operators can get from the aircraft as a whole. Lighter APUs allow an aircraft to carry more passengers, cargo or other payload. In the same way, more fuel-efficient APUs improve payload and help control costs for operators.

DEGRADATION AND PERFORMANCE

All aircraft components suffer degradation over time. Aircraft in service are exposed to extreme temperatures, dynamic loads and unpredictable forces. These loads and forces modify an aircraft's physical characteristics, often slowly or in very small degrees, but still significantly.

Monitoring aircraft performance can help pilots and operators adjust expectations for aircraft capabilities as well as help crews detect when changes veer out of normal ranges and might indicate safety hazards. Monitoring generally falls into one of three major categories:

- **Structural health:** Assessing structural aging can be done by measuring changes in material vibration and can indicate changes in the strength of the material.
- **Engine health:** Key health indicators include engine rotation speed, fuel consumption, exhaust gas temperature and so on. Advanced engines provide a constant stream of monitoring data on these and other parameters, and can even provide alerts for certain conditions.
- **Aerodynamic deterioration:** Flight performance monitoring tools can detect aerodynamic deterioration, but cannot always pinpoint the physical causes. One major cause present in many cases is surface roughness from minor impurities.

The inevitability of degradation is why it is so important to monitor aircraft performance. Daily wear can seriously change an aircraft's capabilities, so it is only through constant monitoring that you can remain sure of what your specific aircraft is capable of.

HONEYWELL SOLUTIONS FOR VISIBILITY AND CONTROL

Optimizing performance requires visibility and control of every aspect of the aircraft. Connected Aircraft solutions put Internet of Things technology to work maximizing visibility into an aircraft's systems. With Connected Aircraft solutions, you can get detailed data you need to understand current performance and plan for performance improvements. View our Connected Aircraft solutions to see how we're transforming aircraft performance today.

We also offer a broad portfolio of solutions to give pilots and navigators better visibility and control.

AVIONICS

PRIMUS EPIC

A family of integrated avionics for true global operation. Fly in any airspace, in any weather and via any approach, using situational awareness products such as Primus Epic INAV, SmartView synthetic vision systems, 2D/3D airport moving maps and DynaCharts.

BENDIXKING AEROVUE

An integrated flight deck derived from the Primus Epic, Aerovue brings similar capabilities to Part 23 class III and IV and Part 25 aircraft.

SITUATIONAL AWARENESS

Our situational awareness solutions are available as a part of our integrated avionics offerings or as upgrade solutions.

- IntuVue RDR-4000 3D Weather Radar System
- Weather Information Service
- SmartTraffic collision avoidance system (CAS) 100
- SmartView synthetic vision system
- Enhanced Ground Proximity Warning System
- Surface Indications and Alert System (SURF IA)
- SmartRunway and SmartLanding

HONEYWELL ENGINES

Our engines have been at the forefront of aircraft propulsion since 1953. Today our continuous improvement has led to engines that require less maintenance, operate in the harshest environments and are highly fuel efficient.

TURBOSHAFT ENGINES	We offer turboshaft engines for a variety of uses, including land vehicles and helicopters. One of our latest designs is the **HTS900**, which is designed to increase power output, reduce fuel consumption, and allow for future engine growth within the same compressor architecture. It offers lightweight performance, low-specific fuel consumption (SFC) and an on-condition maintenance philosophy. It is the basis for Eagle Copters' 407HP retrofit of Bell 407 helicopters and for Kopter's newly designed SH09 helicopter.
TURBOFAN ENGINES	Our **F124 and F125 family of engines** offer some of the best thrust-to-weight ratios in their class for military trainers and light combat fighters. The **HTS7000** family of engines has set a new standard for business jet propulsion systems. With more than 1.7 million flight hours, the engine has exceeded all expectations for reliability, durability and maintainability.
TURBOPROP ENGINES	With more than 13,000 engines delivered and more than 122 million hours of flight time, the **TPE331** is one of the most reliable and proven turboprop engines in the world. Our TPE331 turboprop engine delivers 5%–10% higher speeds than similar engines and provides longer time between overhaul (TBO) to further reduce operating costs. [7]
HYBRID-ELECTRIC ENGINES	We are one of the first to reveal a hybrid-electric turbogenerator solution for powering electric engines on aircraft. A combination of our HTS900 with two onboard generators, the solution can produce 400 kilowatts.

RETROFITS, MODIFICATIONS AND UPGRADES (RMUS)

We offer upgrades to help you maximize performance for a wide range of platforms, including business jets, airliners and cargo planes, helicopters, defense aircraft, and general aviation aircraft.

7. https://aerospace.honeywell.com/en/~/media/aerospace/files/customer-success-stories/a60-1446-000-000-rideofalifetimewithhoneywelltpe331turbopropengine-cs.pdf

HONEYWELL SOLUTIONS FOR NAVIGATION, PRECISION AND MANEUVERABILITY

"The blend of inertial and satellite navigation capabilities provided by the HGuide n580 is especially important where precision is required in demanding environments - for example, autonomous cars traveling in cities, where our technology can extend the accuracy and performance of navigational systems while keeping passengers safe." - Chris Lund, Senior Director, Navigation and Sensors, Honeywell Aerospace

INTERTIAL MEASUREMENT UNITS

Honeywell is the leading producer of precision Inertial Measurement Units. Our IMUs are used by aerospace, military and commercial customers as well as in unmanned vehicle and urban air mobility scenarios.

We have also created a new inertial navigation unit called the HGuide n580 that uses both precision IMU technology and Global Navigation Satellite Systems to improve location accuracy even when facing natural and manmade obstacles.

ACTUATORS

Our actuators deliver precision load management and motion control for an array of uses, including engine control, thrust reverse, space missions, missile steering and numerous other aviation applications.

HONEYWELL SOLUTIONS FOR LIFT AND PAYLOAD

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Critical to lessening payload through fuel efficiency are Connected Aircraft technologies. GoDirect® Flight Efficiency combines our flight data analytics platform with our growing suite of trajectory optimization tools to reduce fuel use and increase available payload. One customer has saved 8,500 tons of fuel on average each year.

With advanced analytics from GoDirect Flight Efficiency, operators can calculate the ideal fuel load and reduce reserve fuel quantities by several times, from today's customary 5%–10% to less than 3% of their planned trip fuel. Using the statistical contingency-fuel approach, airlines can save hundreds or even thousands of kilos of weight.

Honeywell engines can also influence payload by providing more power with lower fuel consumption. These improvements increase mission range and payload capabilities over a wider operating spectrum for both civil and military operators.

- Our T55-714 turboshaft engine delivers 22% more power with 7% less fuel for the United States Army's Chinook helicopters.
- As a part of Eagle's 407HP retrofit of the Bell 407, our HTS900 offers a 19% increase in gross weight capability at 10,000 feet, and a 40% increase in payload at 12,000 feet.

AUXILIARY POWER UNITS

Honeywell is the largest producer of gas turbine auxiliary power units. Our broad portfolio includes options for both fixed and rotary wing platforms and can support power requirements from 50 equivalent shaft horsepower up to 1,700 equivalent shaft horsepower. We also offer options that provide improved fuel consumption and lower emissions.

THE FUTURE IS WHAT WE MAKE IT.

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