Avionics (aviation electronics) are electronic systems used on aircraft, artificial satellites and spacecraft, including communication, navigation, radar, electro-optical, electronic warfare, stores management, controls and displays. This presentation will discuss avionics and instrumentation from the earliest days of flight to the present, focusing on advancements in technology that led to improvements in military capability, and how the new systems were used during conflicts.

The Wright Flyer featured a forerunner of the modern flight data recorder, consisting of a Richard anemometer and stopwatch. The Wrights mounted the instruments on a strut, and set them to be started when the pilot slipped the catch which held the Flyer in place, thereby recording data as soon as the aircraft began to move. The instruments recorded the amount of air that passed through the anemometer, and the time of the flights. With this information and a measurement for distance travelled, the Wrights could determine the Flyer's speed. A revolution counter was also connected to the same starting and stopping device, so the Wrights could calculate engine performance as well.

Radio was the first type of electronic equipment to be used in an aircraft. On 27 August 1910, J.P.D. McCurdy (USA) transmitted and received radio telegraph messages between his aircraft and the ground. The first military flight tests of radio equipment were conducted at Selfridge Field under the direct charge of Lieutenant Paul W. Beck and representatives of the Western Wireless Equipment Company, who designed and built the apparatus for the experiments. The maximum distance covered was 40 miles and the greatest altitude attained during the tests was 500 feet, at which time Lieutenant Beck, carried as a passenger in a Wright machine, transmitted two complete messages in the Morse code to the wireless station on the aviation field while traveling at an approximate speed of 55 miles per hour. Both messages were received at the field station as well as by other stations, one of which was over 40 miles away.

Some WWI planes were equipped with voice radio. The antenna consisted of a flexible copper wire several hundred feet long, unreeled by the aviator and trailing almost horizontally behind the airplane. Aviators could communicate with other aviators or with ground stations, with voice or Morse code.

Many developments in airborne electronic equipment were stimulated by World War II: the Norden bombsight (which was tied to autopilot), radar, IFF, countermeasures, hyperbolic navigation systems, and gyro gunsights. This era also saw the development of jet engines, rocket propelled aircraft, helicopters, and atomic weapons.

The British developed the Chain Home system of coastal early warning radar stations to warn of attacking German aircraft. Radar technology at the time was too large, too heavy, and operated at too low frequency to be mounted aboard aircraft. The British also developed Interrogation Friend or Foe (IFF), a radio beacon carried in planes to help radar operators distinguish “friendlies” from the enemy.

With the development of the cavity magnetron, which could transmit ten kilowatts of power at 3 GHz (10 cm wavelength), along with the development of microwave waveguides and antennas, it became possible to install radar in aircraft. The first British airborne radar was flown
in a twin engine Avro Anson utility aircraft on 17 August 1937. The first successful radar-equipped fighter was the Bristol Beaufighter, which achieved its first kill on the night of 7 November 1940. British pilots were instructed that if captured, they were to attribute the superior British ability to detect targets in the dark to their consumption of carrots. Since the British had achieved naval superiority in part by overcoming scurvy by the consumption of citrus fruits, such a story may have fooled the enemy, as least temporary.

The Germans soon developed their own airborne radar. The first Luftwaffe radar-equipped fighter was the Messerschmitt Bf 110 G-4, deployed in 1941. The Telefunken FuG 212 “Lichtenstein” radar presented targets from ranges of 600 feet out to 3½ miles.

The British also developed the Decca Navigator System, which was a hyperbolic low frequency radio navigation system. The primary use was for ship navigation in coastal waters, but it could also be used by aircraft. The transmissions from the chain are received by a special airborne or shipborne receiver, which measures the difference in phase of signals arriving from master and slaves. All stations in a Decca chain must ‘phase locked’, and this has to be done over an appreciable distance separating the stations, sometimes up to 100 nautical miles, the phase difference being determined by this distance. Each slave station is fitted with equipment which receives the master signal, converts it to the slave frequency, and uses it to control the drive oscillator of the slave transmitter. Thus a constant phase relationship is maintained. To ensure that this relationship is maintained accurately, a monitoring station checks the transmissions. The detected phase differences are displayed on phase meters called ‘decometers’, and the readings may be plotted onto Decca lattice charts, on which the lines of position are numbered in the same units as those shown on the decometers.

The early Cold War era and the Korean War saw the development of tactical air navigation (TACAN), the astrotracker on the B-58 (precursor to today’s Global Positioning System), airborne intercept radar with tracking capability, medium pulse repetition frequency (PRF) airborne intercept radar, digital mission computers, inertial navigation systems, semi-automatic ground environment (SAGE) with early joint tactical information distribution system (JTIDS)-type display on the F-106. This was also the era of supersonic flight, as well as Sputnik, the first artificial satellite, kicking off the space race.

During the Vietnam War, Doppler radar, integrated electronic warfare, fully automated weapon release, terrain-following radar and automatic terrain following were developed. The head-up display (HUD), laser target marking technology, early digital mission computers, electro-optical target identification system were all developed.

The EF-105F/G and EF-4C Wild Weasels were the first dedicated Suppression of Enemy Air Defenses (SEAD)/ Destruction of Enemy Air Defenses (DEAD) aircraft, featuring electronic attack avionics and weapons. Paveway I Laser guided bomb in Vietnam allowed bringing down bridges and other difficult targets that took too many sorties to bring down before.

Example: May 26, 1972 - A single flight of USAF F-4Ds destroyed the Son Tay warehouse and storage area west of Hanoi with Paveway LGBs.

Surface to Air missiles were developed, along with technology to defeat them. Radar Homing and Warning (RHAW) and Radar Warning Receiver (RWR) technology, electronic countermeasures (ECM) pods, chaff dispensers. LORAN system and ARN 101 – better navigation system for the F-4s that was on par with the F-15E. Early EO/IR systems – Pave Knife (1969), Pave Spike (1974). Terrain following radar (TFR) on the F-111 and RF-4C.


F-14 Tomcat - The F-14 first flew in December 1970. It first deployed in 1974 with the U.S. Navy aboard USS Enterprise (CVN-65), replacing the McDonnell Douglas F-4 Phantom II. The F-14 served as the U.S. Navy’s primary maritime air superiority fighter, fleet defense interceptor and tactical reconnaissance platform.
The United States developed the Long Range Navigation (LORAN) system, which was a hyperbolic low frequency radio navigation system. LORAN was used for ship navigation as well as aircraft navigation.

The fall of Saigon on 30 April 1975 marked the end of the Vietnam War.

**Evolution of Avionics Architectures**

As avionics systems have evolved, the level of functional integration has increased dramatically. In the early stages, the major avionics subsystems such as communications, navigation and identification (CNI), radar, weapons, displays, and the platform vehicle could be considered as discrete subsystems. The function of each could be easily understood; the performance requirements could be relatively easily specified, and although there were information interchanges between them, each could stand alone and the boundaries of each subsystem was “hard” in the sense that it was unlikely to be affected by the performance of a neighboring subsystem.

Over time, the functionality of each subsystem increased and some boundaries blurred and functions began to overlap. Also, the number of subsystems began to increase due to the imposition of more complex mission requirements and because of the technology developments that furnished new sensors. Improved data processing and higher bandwidth data buses also contributed to providing much higher data processing capabilities and the means to allow the whole system to become more integrated.

Further technology developments added another spiral to this trend, resulting in greater functionality, further increasing integration and with a blurring of functional boundaries as subsystems became able to share ever greater quantities of data.

This evolution has resulted in increasing performance, sensor types, functionality, cost, integration, complexity, supportability (reuse), software programs in terms of executable code, memory requirements, throughput, reliability, data handling, data links, and obsolescence. This evolution has resulted in decreasing size, weight, power consumption, and technology windows.

1950s era aircraft, such as the North American F-86D, Lockheed F-94 Starfire and Northrop F-89 Scorpion were designed and built with stand-alone radar, communications and navigation functions. By the standards of today the radar was quite rudimentary, with airborne search and tracking modes. Ground-mapping capabilities were incidental and a pulse Doppler facility with a look-down capability was not yet available. These analog systems were interconnected with dedicated wiring.

These systems have dedicated subsystems, controls and displays. The displays are electromechanical and often extremely intricate in their operation, requiring instrument maker skills for assembly and repair.

The use of analog computing techniques does not provide the accuracy and stability offered by the later digital systems. Analog systems are prone to bias or drift, and these characteristics are often more pronounced when the aircraft and equipment are subject to a hot or cold soak over a prolonged operating period. The only means of signalling rotary position in an analog system is by means of synchro angular transmission systems. The older analog aircraft – termed classic in the industry – therefore contain a huge quantity of synchros and other systems to transmit heading, attitude and other rotary parameters.

The older equipment is very bulky and heavy and tends to be unreliable as there are many moving parts. This is not a criticism; the designers of the time did their best with the technology available, and many very elegant engineering solutions can be found in this type of equipment. Furthermore, the skills required to maintain some of the intricate instruments and sensors are gradually becoming scarcer, and consequently the cost of repair continues to rise even assuming spare parts are available. Many educational and training institutions no longer
teach at this technology level, giving rise to a knowledge gap, which in turn has implications for organizations wishing to refurbish or maintain legacy aircraft and products.

These systems are very difficult to modify, which leads to significant problems when new equipment such as a flight management system has to be retrofitted to a classic aircraft. This is required when military aircraft are upgraded to comply with modern Air Traffic Control (ATC) procedures or a global air transport system (GATM).

Typical aircraft in this category are: Boeing 707, VC10, BAC 1-11, DC-9 and early Boeing 737s. Many of these types are still flying, and some such as the VC-10 and the KC-135 and E-3/E-4/E-6 (Boeing 707 derivatives) are fulfilling military roles. They will continue to do so for several years, but gradually their numbers are dwindling as aircraft structural problems are manifested and the increasing cost of maintaining the older systems takes its toll.

The next stage is typical of systems entering service during the 1960s, of which the McDonnell Douglas F/A-4 Phantom is a good example. In this system the radar, communications and navigation systems are integrated into a mission system with a display providing mission rather than subsystem data. At first these systems were largely analog; later variants introduced some digital subsystems. Most system interconnection was still done by hardwiring. These systems introduced further complexity brought about by additional functionality pulse Doppler radars and inertial navigation systems (INS) and by systems integration. The addition of other, new, more capable navigation aids and integrated radar warning radar (RWR) suites added further complexity. These aircraft were very challenging to maintain, suffering from unreliable equipment, high power consumption, vast amounts of wiring and LRUs that were often buried deep in the aircraft as space was at a premium. The wiring-intensive nature of the system meant that modifications were always difficult and very expensive. Nevertheless, in spite of the maintenance penalties, these systems brought a step change in aircraft functional capability.

During the 1980s the availability of mature and cost-effective data buses such as 1553 eased the integration task and removed much of the interconnecting wiring, leading to the multibus federated system seen in the F-16 Fighting Falcon and F/A-18 Hornet in the United States and in the Eurofighter Typhoon, SAAB Gripen and Dassault Rafale in Europe. The AH-64 Apache was one of the first helicopters to use a multiple 1553 bus network to integrate its weapons system. At this stage the need for standardization and modularization of hardware and software were recognized as the initial adoption of digital technology brought with it many teething problems as well as performance improvements.

MIL-STD-1553B has evolved since the original publication of MIL-STD-1553 in 1973. The standard has developed through 1553A standard issued in 1975 to the present 1553B standard issued in September 1978. The data bus comprises a shielded twisted wire pair along which data combined with clock information are passed. The standard generally supports multiple redundant operation with dual-redundant operation being the most common configuration actually used. This allows physical separation of the data buses within the aircraft, permitting a degree of battle damage resistance.

Control of the bus is performed by a bus controller (BC) which communicates with a number of remote terminals (RTs) (up to a maximum of 31) via the data bus. RTs only perform the data bus related functions and interface with the host (user) equipment they support. In early systems the RT comprised one or more circuit cards, whereas nowadays it is usually an embedded chip or hybrid module within the host equipment. Data are transmitted at 1 MHz using a self-clocked Manchester biphase digital format. The transmission of data in true and complement form down a twisted shielded pair offers an error detection capability.

Words may be formatted as data words, command words or status words. Data words encompass a 16 bit digital word, while the command and status words are associated with the data bus transmission protocol. Command and status words are compartmented to include various address, subaddress and control functions. MIL-STD-1553B is a command–response
system in which transmissions are conducted under the control of a single bus controller at any one time; a practical system will employ two bus controllers to provide control redundancy.

MIL-STD-1553B has proved to be a very reliable and robust data bus and is very well established as a legacy system. Attempts have been made to increase the data rate which is the only major shortcoming. A modification of 1553 called 1553 enhanced bit rate (EBR) running at 10 Mbit/s has been adopted for bomb carriage on the JSF/F-35 using the miniature munitions/store interface (MM/SI). Other vendors have run laboratory demonstrators at 100 Mbit/s and above, and a feasibility program has been initiated to demonstrate 1553 bit rates of 100 Mbit/s with the aim of extending data rates to 500 Mbit/s. This possible derivative is termed enhanced 1553 (EB-1553).

MIL-STD-1760 - Standard weapons interface

IEEE 1394 firewire is a widely used data bus scaleable in its original form from 50 to 400 Mbit/s. It has an extremely wide market capture, being commonly used in the electronic domestic consumer market: video cameras, etc. This marketplace has also paved the way for IEEE 1394 to be widely applied in civil aircraft in-flight entertainment (IFE) systems.

A line-replaceable unit (LRU) is a modular component of an airplane, ship or spacecraft that is designed to be replaced quickly at an operating location. An LRU is usually a sealed unit such as a radio or other auxiliary equipment. LRUs are sometimes described as "black boxes" despite the fact that they aren't necessarily black.

LRUs improve maintenance operations, because they can be stocked and replaced quickly from on-site inventory, restoring the system to service, while the failed (unserviceable) LRU is undergoing maintenance. Because they are modular, they also reduce system costs and increase quality, by centralizing development across different models of vehicles.

By the 1970’s, military aircraft had become flying sensor platforms, and making large amounts of electronic equipment work together had become the new challenge. Civil aviation benefited from military advances in avionics, such as fly-by-wire/light, navigation systems.

Fourth-generation jet fighters are those in service approximately from 1980 to 2010, representing the design concepts of the 1970s. Fourth-generation designs are heavily influenced by lessons learned from the previous generation of combat aircraft. Long-range air-to-air missiles, originally thought to make dogfighting obsolete, proved less influential than expected precipitating a renewed emphasis on maneuverability. Meanwhile, the growing costs of military aircraft in general and the demonstrated success of aircraft such as the F-4 Phantom II gave rise to the popularity of multirole fighters in parallel with the advances marking the fourth generation.

Maneuverability was enhanced by relaxed static stability, made possible by introduction of the fly-by-wire (FBW) flight control system (FLCS), which in turn was possible due to advances in digital computers and system integration techniques. Analog avionics began to be replaced by digital flight control systems in the latter half of the 1980s.

The further advance of microcomputers in the 1980s and 1990s permitted rapid upgrades to the avionics over the lifetimes of these fighters, incorporating system upgrades such as active electronically scanned arrays (AESA), digital avionics buses and infrared search and track (IRST). Due to the dramatic enhancement of capabilities in these upgraded fighters and in new designs of the 1990s that reflected these new capabilities, the US government has taken to using the designation 4+ generation to refer to these later designs. This is intended to reflect a class of fighters that are evolutionary upgrades of the 4th generation incorporating integrated avionics suites, advanced weapons efforts to make the (mostly) conventionally designed aircraft nonetheless less easily detectable, and trackable as a response to advancing missile and radar technology. Inherent airframe design features exist, and include masking of turbine-blades and application of advanced sometimes radar-absorbent materials, but not the distinctive low-observable configurations of the latest aircraft, fifth-generation fighters or aircraft such as the F-117 and B-2.
4++ generation fighter aircraft are fourth generation jet fighters that have been upgraded with AESA radar, high capacity data-link, enhanced avionics, and "the ability to deploy current and reasonably foreseeable advanced armaments."

The United States developed the Omega system, which was a hyperbolic low frequency radio navigation system. Omega was used for ship navigation as well as aircraft navigation, and was intended to replace the LORAN system, but was soon replaced by the Global Positioning System (GPS), a space-based global navigation satellite system (GNSS) that provides location and time information in all weather, anywhere on or near the Earth, where there is an unobstructed line of sight to four or more GPS satellites. It is maintained by the United States government and is freely accessible by anyone with a GPS receiver with some technical limitations which are only removed for military users.

The GPS program provides critical capabilities to military, civil and commercial users around the world. In addition, GPS is the backbone for modernizing the global air traffic system.

The GPS project was developed in 1973 to overcome the limitations of previous navigation systems, integrating ideas from several predecessors, including a number of classified engineering design studies from the 1960s. GPS was created and realized by the U.S. Department of Defense (DoD) and was originally run with 24 satellites. It became fully operational in 1994.

Advances in technology and new demands on the existing system have now led to efforts to modernize the GPS system and implement the next generation of GPS III satellites and Next Generation Operational Control System (OCX).

In addition to GPS, other systems are in use or under development. The Russian GLObal NAvigation Satellite System (GLONASS) was in use by only the Russian military, until it was made fully available to civilians in 2007. There are also the planned European Union Galileo positioning system, Chinese Compass navigation system, and Indian Regional Navigational Satellite System.

A glass cockpit is an aircraft cockpit that features electronic (digital) instrument displays, typically large LCD screens, as opposed to the traditional style of analog dials and gauges. Where a traditional cockpit relies on numerous mechanical gauges to display information, a glass cockpit uses several displays driven by flight management systems, that can be adjusted to display flight information as needed. This simplifies aircraft operation and navigation and allows pilots to focus only on the most pertinent information.

By now, radar antennas had evolved from parabolic dishes into flat plates and used limited 'beam-shaping' techniques, but the antenna still needed to be mechanically scanned. Digital signal processing had evolved to offer true multimode functionality, i.e. the ability to use the same radar for airborne intercepts, ground mapping and missile guidance, for example. Later radars such as those fitted in the F-15E, A/F-18E/F upgrade and block 60 F-16 upgrade (F-16E/F) included an active electronically scanned array (AESA) in place of the flat plate mechanically scanned antenna. This AESA is fixed, and radar beams are shaped and steered entirely electronically, without the need for any moving parts. This also brought increased range performance, and highly reliable multimode radar capable of operating in several modes simultaneously.

The electronically scanned array (ESA) removes many of the components that contribute to failures in a conventional mechanically scanned antenna. Rotating waveguide joints, gimbals, drive motors, etc., are all removed. Consequently, the reliability of the ESA is improved. Failures of the phase shifters may be easily accommodated as the antenna can stand up to perhaps 5% of these failing before the radar performance is adversely affected.

The fundamental advantage offered by an integrated modular avionics (IMA) approach is that, from the outset, the system is conceived using standard building blocks that may be used throughout the aircraft level system. Therefore, common processor modules, common memory modules and, where possible, common input/output modules offer the means of rapidly
conceiving and constructing quite extensive system architectures. This approach reduces risk during the development phase, as well as offering significant supportability advantages. The IMA philosophy readily adapts to redundancy implementation in a most cost-effective manner so that economies of scale are easily achieved.

The adoption of COTS-based IMA architectures provides another significant advantage, that is, rapid prototyping. As the baseline modules are off-the-shelf produced in a commercial format, these may be readily purchased in order that a candidate architecture may be built and prototyped using mature commercial boards. Previously, prototyping had to wait until early development hardware was available for all the contributing subsystems; this hardware tended to be immature, and often featured development bugs.

Fifth-generation aircraft are designed to incorporate numerous technological advancements, including all-aspect stealth even when armed, Low Probability of Intercept Radar (LPIR), high-performance air frames, advanced avionics features, and highly integrated computer systems capable of networking with other elements within the theater of war in order to achieve an advantage in situational awareness. The only currently combat-ready fifth-generation fighter, the Lockheed Martin F-22 Raptor, entered service with the U.S. Air Force in 2005.

The F-22 is a single-seat, twin-engine supermaneuverable fighter aircraft that uses stealth technology. It was designed primarily as an air superiority fighter, but has additional capabilities that include ground attack, electronic warfare, and signals intelligence roles.

The F-22's avionics include BAE Systems E&IS radar warning receiver (RWR) AN/ALR-94, AN/AAR 56 Infra-Red and Ultra-Violet MAWS (Missile Approach Warning System) and the Northrop Grumman AN/APG-77 Active Electronically Scanned Array (AESA) radar. The AN/ALR-94 is a passive receiver system to detect radar signals; composed of more than 30 antennas blended into the wings and fuselage that provide all around coverage. It was described by Tom Burbage, former F-22 program head at Lockheed Martin, as "the most technically complex piece of equipment on the aircraft." It has a greater range (250+ nmi) than the radar, allowing the F-22 to limit its own radar emissions to maximise stealth. As a target approaches, the receiver can cue the AN/APG-77 radar to track the target with a narrow beam, which can be as focused down to 2° by 2° in azimuth and elevation.

The AN/APG-77 radar, designed for air superiority and strike operations, features a low-observable, active-aperture, electronically-scanned array that can track multiple targets in any weather. The AN/APG-77 changes frequencies more than 1,000 times per second to lower interception probability. Additionally, radar emissions can be focused in an electronic-attack capability to overload enemy sensors.

The radar's information is processed by two Raytheon Common Integrated Processor (CIP)s. Each CIP can process 10.5 billion instructions per second and has 300 megabytes of memory. Information can be gathered from the radar and other onboard and offboard systems, filtered by the CIP, and offered in easy-to-digest ways on several cockpit displays, enabling the pilot to remain on top of complicated situations. The F-22s avionics software has some 1.7 million lines of code, the majority involving processing data from the radar. The radar has an estimated range of 125–150 miles, though planned upgrades will allow a range of 250 miles (400 km) or more in narrow beams. In 2007, tests by Northrop Grumman, Lockheed Martin, and L-3 Communications enabled the AESA system of a Raptor to act like a WiFi access point, able to transmit data at 548 megabits per second and receive at gigabit speed; this is far faster than the Link 16 system used by US and allied aircraft, which transfers data at just over 1 Mbit/s.

The F-22 has a threat detection and identification capability comparative with the RC-135 Rivet Joint. The F-22's stealth allows it to safely operate far closer to the battlefield, compensating for the reduced capability. The F-22 is capable of functioning as a "mini-AWACS", however the radar is less powerful than dedicated platforms such as the E-3 Sentry. The F-22 allows its pilot to designate targets for cooperating F-15s and F-16s, and determine
whether two friendly aircraft are targeting the same aircraft. It has been reported as being "sometimes [identifying targets] many times quicker than the AWACS".

The F-22's radar is being given a high-bandwidth data transmission capability, to be used to permit relaying of data between friendly units in the operating area. The F-22 can already pass data to other F-22s, resulting in considerably reduced radio "chatter". The IEEE-1394B data bus developed for the F-22 was derived from the commercial IEEE-1394 "FireWire" bus system, often used on personal computers. The same data bus is employed by the subsequent F-35 Lightning II fighter. Sensor fusion combines data from all onboard and offboard sensors into a common view to prevent the pilot from being overwhelmed.

The F-35 Lightning II Program (also known as the Joint Strike Fighter Program) is the Department of Defense's focal point for defining affordable next generation strike aircraft weapon systems for the Navy, Air Force, Marines, and our allies. The F-35 will bring cutting-edge technologies to the battlespace of the future. The JSFs advanced airframe, avionics, propulsion systems, stealth, and firepower will ensure that the F-35 is the most affordable, lethal, supportable and survivable aircraft ever to be used by so many warfighters across the globe.

The F-35 has three main models; one is a conventional takeoff and landing variant, the second is a short take off and vertical-landing variant, and the third is a carrier-based variant. The F-35 features a full-panel-width "panoramic cockpit display" (PCD) glass cockpit. A cockpit speech-recognition system (Direct Voice Input) is planned to improve the pilot's ability to operate the aircraft over the current-generation interface. The F-35 will be the first US operational fixed-wing aircraft to use this system, although similar systems have been used in AV-8B and trialled in previous US jets, particularly the F-16 VISTA.

A helmet-mounted display system (HMDS) will be fitted to all models of the F-35. A helmet-mounted cueing system is already in service with the F-15s, F-16s and F/A-18s. While some fighters have offered HMDS along with a head up display (HUD), this will be the first time in several decades that a front line tactical jet fighter has been designed without a HUD.

Shared aperture architecture

One of the objectives in developing an integrated RF architecture was to address the RF functional area and seek rationalization of the receiver and demodulation and modulation and amplification/transmitting functions. In the F-35 architecture these are handled on a subsystem basis, in order to provide an integrated RF sensor system – sometimes called an integrated sensor system (ISS). The sharing of resources between the functional system can enable significant savings in cost, weight, volume and reliability.

The primary arrays may comprise a large active array: multiarm spiral arrays (MASAs), slot arrays and multiturn loops (MTLs). These arrays are connected via an RF interconnect to a collection of receive frequency converters that convert the signal to intermediate frequency (IF). The IF receive signals are fed through an IF interconnect to the receiver modules. After detection, the baseband in-phase (I) and quadrature (Q) components are fed through the fiber-optic interconnect to the integrated core processing.

For transmission the reverse occurs, signals are passed to the multifunction modulators and through a separate IF interconnect to the transmit frequency converters. After modulation and power amplification the output signals are passed via the RF interconnect to the appropriate array(s). It is the sharing of these functions within a common RF host that enables the major savings to be made.

The AESA has been replaced by a wide-band synthetic array (WBSA) containing 3000 elements that services radar, EW and CNI functions. Five similar but smaller arrays provide forward, rear and aft coverage for EW and CNI usage. A variety of spiral, MASA and MTL antennas provide the entire gamut of EW and CNI equipment coverage.
I've presented a brief history of avionics (just the highlights) - there will continually be new areas of emphasis and avionic technology breakthroughs - who knows what the future holds - here are some possibilities....

Today the military are called upon to perform a wide variety of aviation roles using fixed-wing and rotary-wing aircraft. The roles largely define the type of aircraft because of the specialist nature of the task; however, there are a number of aircraft types that have been designed as multirole aircraft, or designed to change roles during the prosecution of a mission, the so-called swing-role type.

The military roles that are in place today have emerged over many years of aerial combat experience. The long development timescales of the complex military aircraft have resulted in many types remaining in service long after their original introduction. Consequently, aircraft have adopted new roles as a result of role-fit weapons or mid-life updates. Many of the roles, particularly the intelligence gathering roles, have persisted after combat into the post-war stabilization period and peacekeeping operations.

The flexibility of weapons and methods of carrying weapons and the adaptability of sensors and avionic systems are what enables this situation to persist. Although many of the ‘traditional’ roles still exist, there are signs that the changing nature of conflict may lead to new roles or alternative solutions.

To a large extent these new roles and alternative solutions are being driven by advances in avionics technology. Ever more sensitive and effective sensor systems are capable of detecting targets, the use of stealth techniques increases the effectiveness of delivery platforms and the increased capability of on-board computing systems is extending and speeding up the processing of data. The existence of these advances in the hands of enemies spurs on further development.

There are already proposals for a sixth generation fighter: It would likely be far stealthier than even the fifth generation aircraft. It may be able to change its shape in flight, “morphing” to optimize for either speed or persistence, and its engines will likely be retunable in-flight for efficient supersonic cruise or subsonic loitering.

The sixth generation fighter will likely have directed energy weapons—high-powered microwaves and lasers for defense against incoming missiles or as offensive weapons themselves. Munitions would likely be of the “dial an effect” type, able to cause anything from impairment to destruction of an air or ground target.

Materials and microelectronics technologies would combine to make the aircraft a large integrated sensor, possibly eliminating the need for a nose radar as it is known today. It would be equipped for making cyber attacks as well as achieving kinetic effects, but would still have to be cost-effective to make, service, and modify.

Moreover, the rapid advancement of unmanned aircraft technologies could, in 20 years or so, make feasible production of an autonomous robotic fighter, or an uninhabited but remotely piloted aircraft with an off-board “crew,” possibly comprising many operators.

Vast amounts of data will be available to the pilot, who may or may not be on board the aircraft. The pilot will see wide-ranging, intuitive views of “the extended world” around the aircraft. The aircraft will collect its own data and seamlessly fuse it with off-board sensors, including those on other aircraft. automatic target recognition.

Embedded sensors and microelectronics will also make possible sensor arrays in locations that previously weren’t available because of either heat or the curvature of the surface, providing more powerful and comprehensive views of the battlefield. Traditional electronics will probably give way to photonics, reducing weight and increasing processing speed. Fiber optics would also be resistant to jamming or spoofing of data and less prone to cyber attack.

A “digital wingman” could accompany the main fighter as an extra sensor-shooter smart enough to take verbal instructions.
Directed energy weapons could play a big role in deciding how agile a sixth generation fighter would have to be. “Speed of light” weapons could negate the importance of the maneuverability we see in today’s fighters. There won’t be time to maneuver away from a directed energy attack.

Pulse weapons could also destroy an enemy aircraft’s systems—or those of a ground target. With an appropriate engine—possibly an auxiliary engine—on board to provide power for directed energy weapons, there could be an unlimited magazine of shots.

Hypersonics—that is, the ability of an air vehicle to travel at five times the speed of sound, or faster—has been suggested as an attribute of sixth generation fighters.

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Another avionics system, the instrument landing system (ILS), uses onboard instruments to interpret signals sent from ground stations. A rather primitive ILS was introduced in 1929 but became truly useful only after 1945. As radar became more powerful and available in greater quantity, it became useful for monitoring aircraft as they progressed along their routes. The Soviet Union used helicopters extensively for military and civil use and the availability of turbine engines increased this use. With their usual penchant for large-scale vehicles, the Soviet Union developed many powerful helicopters, including the Mil Mi-26, which could carry payloads as great as 20,000 kg (44,000 pounds) and was the largest production helicopter in the world. A brief chronology of military avionics development illustrates the advances that have been made from the first airborne radio experiments in 1910 and the first autopilot experiments a few years later. The 1930s saw the introduction of the first electronic aids to assure good operational reliability such as blind flying panels, radio ranging, nondirectional beacons, ground-based surveillance radar, and the single-axis autopilot. Thus, fairly early in the history of the aircraft the main military roles of observation, interception and ground attack had been firmly established. These initial roles increased in sophistication and led to the development of more capable aircraft weapons, aircrew and tactics. For today’s armed forces, faced with new threats on exceptional theatres of operations, and committed to very fast interventions with an obligation to make a success of the mission, equipment availability is crucial. When joint task and inter-allied force exercises demand versatility and speed of reconfiguration, connectivity becomes essential as well as the protection of the systems against cyber-attacks. In this context of deep and rapid transformations, avionics systems need to perform well with high availability and integrity.