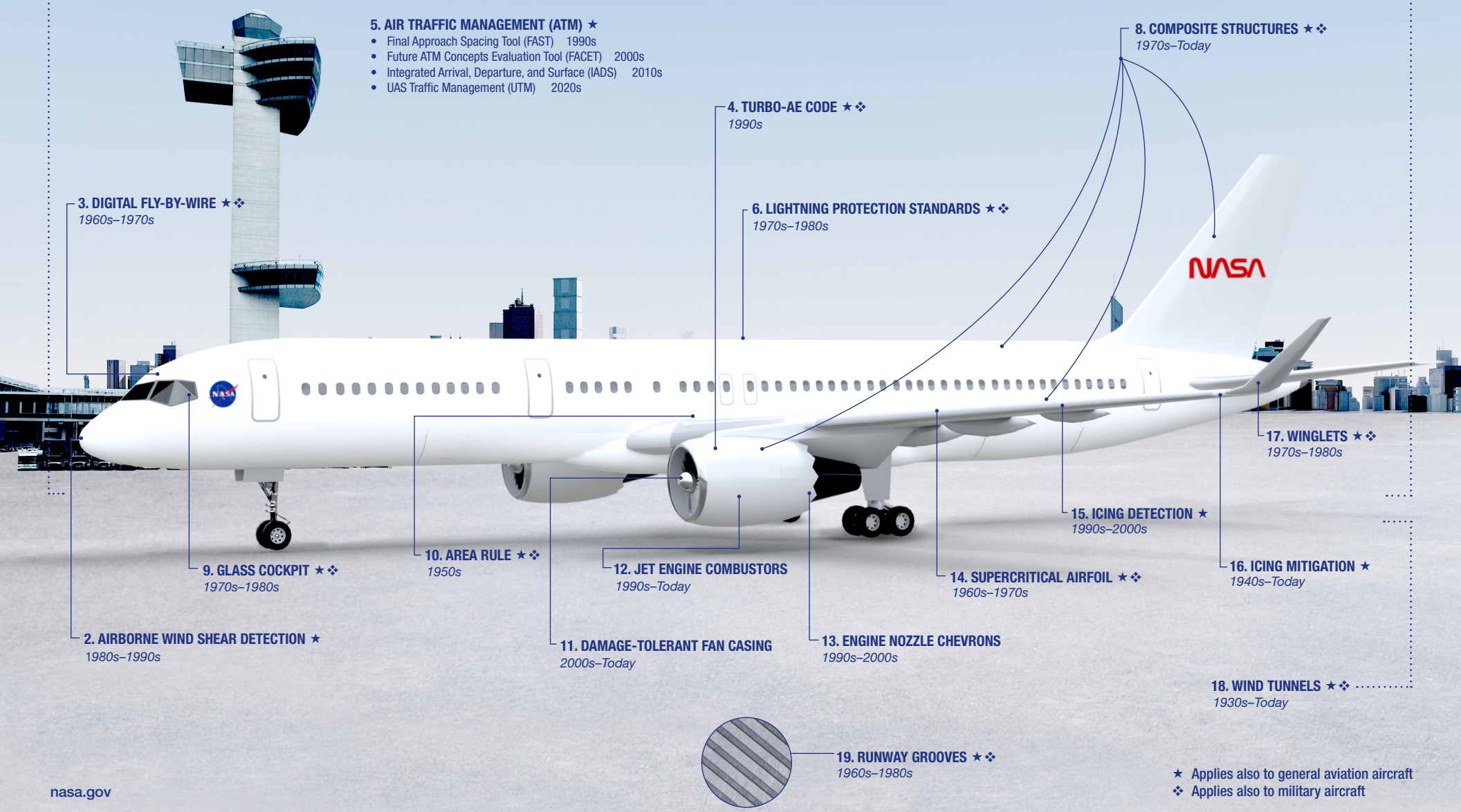
National Aeronautics and Space Administration

NASA AERONAUTICS RESEARCH ONBOARD

DECADES OF CONTRIBUTIONS TO COMMERCIAL AVIATION



1. COMPUTATIONAL FLUID DYNAMICS (CFD) ★❖
1970s–Today

2. AIRBORNE WIND SHEAR DETECTION ★
1980s–1990s

3. DIGITAL FLY-BY-WIRE ★❖
1960s–1970s

4. TURBO-AE CODE ★❖
1990s

5. AIR TRAFFIC MANAGEMENT (ATM) ★
- Final Approach Spacing Tool (FAST) 1990s
- Future ATM Concepts Evaluation Tool (FACET) 2000s
- Integrated Arrival, Departure, and Surface (IADS) 2010s
- UAS Traffic Management (UTM) 2020s

6. LIGHTNING PROTECTION STANDARDS ★❖
1970s–1980s

7. NASA STRUCTURAL ANALYSIS (NASTRAN) ★❖
1960s–Today

8. COMPOSITE STRUCTURES ★❖
1970s–Today

9. GLASS COCKPIT ★❖
1970s–1980s

10. AREA RULE ★❖
1950s

11. DAMAGE-TOLERANT FAN CASING
2000s–Today

12. JET ENGINE COMBUSTORS
1990s–Today

13. ENGINE NOZZLE CHEVRONS
1990s–2000s

14. SUPERCRITICAL AIRFOIL ★❖
1960s–1970s

15. ICING DETECTION ★
1990s–2000s

16. ICING MITIGATION ★
1940s–Today

17. WINGLETS ★❖
1970s–1980s

18. WIND TUNNELS ★❖
1930s–Today

19. RUNWAY GROOVES ★❖
1960s–1980s

★ Applies also to general aviation aircraft
❖ Applies also to military aircraft

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1. Computational Fluid Dynamics (CFD)
Starting in the 1970s, NASA began developing sophisticated computer codes that could accurately predict the flow of fluids, such as the flow of air over an aircraft's wing or fuel through a space shuttle's main engine.

Those ideas and codes became CFD, which today is considered a vital tool for the study of fluid dynamics and the development of new aircraft. CFD greatly reduces the time and cost required for designing and testing nearly any type of aircraft.

2. Airborne Wind Shear Detection
During the 1980s and 1990s, NASA led a comprehensive research program to identify the characteristics of dangerous wind shear and validated technologies that can predict its severity while in flight. Today, aircraft are equipped with forward-looking sensors that alert pilots to wind shear hazards.

3. Digital Fly-by-Wire
During the 1960s and 1970s, NASA helped develop and flight test the digital "fly-by-wire" system, which replaced heavier and less reliable hydraulics systems with a digital computer and electric wires to send signals from the pilot to the control surfaces of an aircraft. "Fly-by-wire" is used today on new commercial and military aircraft, and on the space shuttle.

4. TURBO-AE Code
During the 1990s, NASA developed a computer code that generates two-dimensional simulations of potential aeroelastic (AE) problems that can occur in jet engine blades. Such problems include flutter or fatigue that can eventually cause engine fan blades to stall or fail.

With TURBO-AE, engineers can more efficiently design thinner, lighter, faster rotating blades for today's jet engines built for higher performance, lower emissions and lower noise.

5. Air Traffic Management
Over the decades, NASA has developed a number of air traffic management (ATM) simulation tools, including:

Final Approach Spacing Tool (FAST) – 1990s
NASA-developed tool that helps controllers optimize aircraft spacing on final approach increasing runway capacity, reducing go-arounds, and decreasing delays.

Future Air Traffic Management Concepts Evaluation Tool (FACET) – 2000s
FACET is a tool to simulate thousands of aircraft trajectories to improve air traffic flow across the United States.

Integrated Arrival, Departure, and Surface (IADS) – 2010s
IADS is software system to coordinate aircraft arrivals, departures, and ground movement at busy airports to reduce delays and save fuel.

UAS Traffic Management (UTM) – 2020s
UTM is a collaborative airspace to safely manage drone flights at low altitude through digital services to enable Beyond-Visual-Line-of-Sight operations.

6. Lightning Protection Standards
During the 1970s and 1980s, NASA conducted extensive research and flight tests to identify the conditions that cause lightning strikes and the effects of in-flight strikes on aircraft. NASA's knowledge base was used to improve lightning protection standards for aircraft electrical and avionics systems.

7. NASA Structural Analysis (NASTRAN)
In the 1960s, NASA partnered with industry to develop a common generic software program that engineers could use to model and analyze different aerospace structures, including any kind of spacecraft or aircraft. Today, NASTRAN is an "industry-standard" tool for computer-aided engineering of all types of structures.

8. Composite Structures
NASA first partnered with industry during the 1970s to conduct research on how to develop high-strength, nonmetallic materials that could replace heavier metals on aircraft. Gradually used to replace metals on parts of aircraft tails, wings, engines, cowlings and parts of the fuselage, composites reduce overall aircraft weight and improve operational efficiency.

9. Glass Cockpit
During the 1970s and 1980s, NASA created and tested the concept of an advanced cockpit configuration that replaced dial and gauge instruments with flat panel digital displays. The digital displays presented information more efficiently and provided the flight crew with a more integrated, easily understood picture of the vehicle situation.

Glass cockpits are in use on commercial, military and general aviation aircraft, and on NASA's space shuttle fleet.

10. Area Rule
In the 1950s, NASA scientist Richard Whitcomb discovered several fundamental solutions to key aerodynamics challenges. One of the most revolutionary was the "area rule," a concept that helped aircraft designers avoid the disruption in air flow and resulting drag caused by the attachment of the wings to the fuselage.

By using the area rule, aircraft designers for decades have been able to make aircraft fly more efficiently at high speeds.

11. Damage-Tolerant Fan Casing
In the 2000s, NASA began spearheading research into developing a cost-effective turbofan jet engine casing that could be lighter, but still protect against possible fan blade failure inside the engine.

The solution was a fan case made of braided composite material that can reduce overall engine weight, increase safety and improve aircraft structural integrity.

12. Jet Engine Combustors
During the 1990s and early 2000s, NASA improved the technology associated with jet fuel combustion to help engines burn fuel more cleanly. The improved combustion helps reduce polluting emissions from aircraft engines, making them more environmentally friendly.

13. Engine Nozzle Chevrons
During the 1990s and early 2000s, NASA computer simulations, ground tests, and flight tests provided the latest improvements in design for chevrons—asymmetrical scallops that can be used on jet engine nozzles and nacelles to help reduce engine noise.

14. Supercritical Airfoil
During the 1960s and 1970s, NASA scientist Richard Whitcomb led a team of researchers to develop and test a series of unique geometric shapes of airfoils or wing sections that could be applied to subsonic transports to improve lift and reduce drag.

The resulting "supercritical airfoil" shape, when integrated with the aircraft wing, significantly improves the aircraft's cruise efficiency.

15. Icing Detection
During the 1990s and the 200s, NASA studied a dangerous and little-understood icing phenomenon called Supercooled Large Droplets (SLD). Results from ground and flight tests improved.

16. Icing Mitigation
Since the 1940s, NASA has worked with the FAA and industry to find ways to reduce ice buildup on wings and in engines. NASA's icing software now helps manufacturers design safer aircraft.

17. Winglets
During the 1970s and 1980s, NASA studies led to the development of vertical extensions that can be attached to wing tips in order to reduce aerodynamic drag without having to increase wing span. Winglets help increase an aircraft's range and decrease fuel consumption.

The first aircraft to adopt winglets were within the general aviation and business jet communities. In the mid-'80s, Boeing produced the 747-400 commercial jetliner, which used winglets to increase its range.

18. Wind Tunnels
As early as the 1930s, wind tunnels built and operated by NASA's predecessor, the National Advisory Committee on Aeronautics, or NACA, played a critical role in the design and improvement of aircraft.

Through the decades, NASA's suite of tunnels continued to host valuable foundational testing in such areas as stability and control, in-flight icing, stall avoidance, propulsion systems, airframe development, flutter avoidance and noise reduction.

19. Runway Grooves
During the 1960s, NASA conceived and developed a process for cutting transverse grooves into runways to channel away standing water. During the 1980s, NASA conducted more than one thousand test runs of aircraft and ground vehicles, proving that grooved runway surfaces have significantly greater friction properties.

Grooved runways have since helped aircraft make safe landings on pavement made slick from rain, snow, or ice. NASA's groove process was adapted for use on military base runways, U.S. public highways, and even swimming pool decks, playgrounds and refinery floors.

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