

# mathematics at work

*Aerospace*



# Mathematics in the Aerospace Sector

The Aerospace Industries Association estimates that more than 600,000 individuals are currently employed in the sector. According to the Bureau of Labor Statistics' *Occupational Outlook Handbook*, technological advances in the industry require mechanics and technicians, who represent a significant portion of those 600,000 employees, to have an especially strong background in electronics — and mathematics — to keep pace with the changes in the industry. Additionally, many aerospace firms now have begun to bring together teams composed of customers, engineers and production workers to pool ideas and make decisions concerning aircraft design at every phase of its development. The aerospace industry provides good job opportunities for individuals with teamwork skills and proficiency in technology and applied mathematics.

## Available Aerospace Jobs

Within the aerospace industry, there are a variety of entry-level jobs that pay well and provide opportunities for advancement — jobs for high school graduates with postsecondary training or education but less than a four-year college degree. High school graduates with 18 to 24 months of specialized postsecondary training leading to Federal Aviation Administration certification are qualified to become aircraft mechanics.

## Core Mathematics Knowledge in Today's Aerospace Jobs

Developed by secondary, postsecondary, business, industry and government leaders, the Career Cluster Pathway Plan of Study for *Maintenance, Installation and Repair* was designed to serve as a guide for students' educational and career goals. This Plan of Study for individuals pursuing a career in aerospace recommends a rigorous set of mathematics courses for students to take at both the secondary and postsecondary levels in traditional or vocational settings. This Plan of Study shows in detail how the foundation provided by courses such as Algebra I, Geometry, Algebra II, Trigonometry or Statistics, Physics, and Computer Applications equips high school graduates with the mathematical knowledge and skills needed for success on the job. Until high school graduates understand the advanced mathematical skills used in the aerospace sector, they will remain unable to meet the demands of this high-growth industry. For more information on the Career Clusters Initiative, see [www.careerclusters.org/resources/web/pos.cfm](http://www.careerclusters.org/resources/web/pos.cfm).

Jobs	Median yearly salary	Percentage of total jobs by education/training (ages 25–44)		Number of total jobs		
		High school	Some college/associate	2010	2020	% change
Aircraft mechanics and service technicians	\$54,600	30%	56%	123,800	131,600	6%
Aircraft structure, surfaces, rigging and systems assemblers	\$46,200	39%	35%	36,300	41,500	14%
Avionics technicians	\$54,700	25%	61%	18,600	19,800	7%

Source: Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Outlook Handbook, 2012–13 Edition*.

# The Common Core State Standards: Ensuring College and Career Readiness

The Common Core State Standards (CCSS) are K–12 mathematics and English language arts/literacy standards that identify the academic knowledge and skills all students need when they graduate high school to be ready for their next step, be it college, the workplace or the military. The CCSS were developed through a process managed by the National Governors Association and Council of Chief State School Officers and led by states. To date, more than 40 states have chosen to adopt and implement the CCSS.

In mathematics, the CCSS include focused content standards as well as Standards for Mathematical Practice, which articulate the ways students should apply mathematics both in school and on the job — to solve problems, reason abstractly and quantitatively, critique arguments, model, exercise precision, and look for

repeated reasoning. In English language arts/literacy, the CCSS include expectations for reading, writing, language, and speaking and listening, including students' ability to work in teams and communicate effectively in a range of settings.

The CCSS are anchored in college- and career-ready expectations, which start in grade 12 and are back mapped to the earliest grades. Students who graduate from high school having mastered the CCSS will be academically prepared for college-level courses and rigorous career training programs. Importantly, the CCSS represent the floor, not the ceiling, and students should engage in additional coursework and work-based experiences to help chart their career pathway.

The CCSS can be found at [www.corestandards.org](http://www.corestandards.org).

## “Mathematics at Work” Series

First developed in 2008, using the American Diploma Project benchmarks as the foundation, Achieve produced a series of “Mathematics at Work” brochures to examine how higher-level mathematics is used in today's workplaces. Updated in 2013 to reflect the expectations set by the Common Core State Standards in mathematics, the brochures present case studies drawn from leading industries nationwide to illustrate the advanced mathematics knowledge and skills embedded in jobs that offer opportunities for advancement and are accessible to graduates with some education and training beyond high school but less than a four-year degree.

The series underscores the value of a rigorous high school curriculum in mathematics. All high school graduates — regardless of whether they enroll in college, join the workforce or enter the military — benefit from acquiring a college- and career-ready foundation in mathematics.

To view or download the full set of “Mathematics at Work” brochures, go to [www.achieve.org/math-works-brochures](http://www.achieve.org/math-works-brochures).



The image features several mathematical symbols and formulas overlaid on a teal background. At the top right, there is a dashed arrow pointing right, with the expression  $\sin^{-1} \theta$  next to it. Below this, there is a summation formula  $\sum_{i=1}^n (x_i - \bar{x})^2$ . At the bottom left, there is a fraction  $\frac{x - \mu}{\sigma}$ . The background also has faint, larger-scale mathematical symbols like  $\sigma$  and  $\bar{x}$ .

# Mathematics pilots

## Career Preparation for Aircraft Maintenance Technicians

The more than 150,000 aircraft maintenance technicians (AMTs) at work in the public and private sector today have a wide range of talents and skills that keep America's airplane fleet flying safely and smoothly. Although they may have different educational backgrounds and areas of expertise, all AMTs have one thing in common — a solid foundation in mathematics, enabling them to earn rigorous Federal Aviation Administration (FAA) certification in airframe and power plant maintenance. From fabricating parts and installing hydraulic systems to testing electrical circuits and repairing airplane engines, AMTs possess the highly sought-after mechanical knowledge and skills — grounded in mathematics — that are valued by the airline industry.

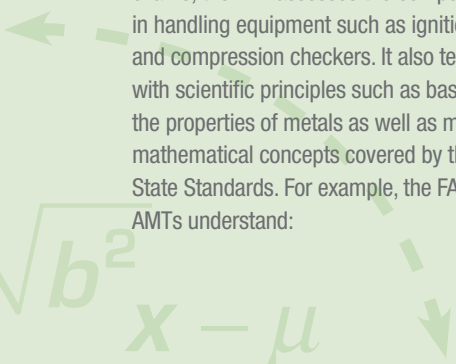
“Without a strong math and science background, today's technician is not likely to progress far beyond basic line maintenance.”

La Vern Phillips, Regional Director  
Aviation Institute of Maintenance

To earn FAA certification, applicants must have at least a high school diploma and 18–24 months of specialized postsecondary training, be it on the job, at a community or technical college, or in a specialty occupation in the military. Through a combination of oral and practical exams, the FAA assesses the competency of applicants in handling equipment such as ignition analyzers, riveters and compression checkers. It also tests their familiarity with scientific principles such as basic gas laws and the properties of metals as well as many underlying mathematical concepts covered by the Common Core State Standards. For example, the FAA requires that all AMTs understand:

- Measurements with units when replacing and fabricating fuselage parts
- Proportions and ratios when assessing the electrical needs of circuitry
- Solving equations with one or more variables when repairing hydraulic systems
- Calculating volume of spheres, parallelepipeds and cylinders when assessing fuel needs
- Modeling with linear equations when computing the center of gravity (CG) of an aircraft
- How to make sense of problems and persevere in solving them

The FAA certification process tests the understanding future AMTs have of the array of instruments and processes used on a daily basis, thereby evaluating their ability to apply their mathematical skills to the various challenges they face. Given the vital stakes attached to aircraft safety, it also is critical that everyone on the tarmac — pilots, engineers and AMTs — is able to communicate with other members of the team by speaking clearly about an airplane's electronics and mechanics through the universal language of mathematics. Because no two aircraft are exactly the same, AMTs must know when and how to apply particular solutions to unique problems and modify approaches from aircraft to aircraft as appropriate. For more information on FAA aircraft maintenance certifications, go to [www.faa.gov/mechanics/become](http://www.faa.gov/mechanics/become).



# aviation safety

## Safety in Numbers: Mathematics in Action on the Tarmac

America's future is up in the air — literally — and it is up to airframe and power plant technicians to keep America flying safely. The image of a tire-kicking, grease-covered mechanic has long since been replaced by the professionalism of today's FAA-certified AMT. These mathematically adept craftsmen ply their trade across every facet of aviation.

### Repairing a Crack in the Fuselage

#### *Mathematical Reasoning and Problem Solving*

During the standard preflight check, AMTs are responsible for inspecting the airplane for any suspicious signs of wear and tear. Faced with a crack in an airplane's fuselage, a team of AMTs must first determine the most effective method of repair. To do this, AMTs depend on knowledge of the physical properties of metals and

composites — their strength, flexibility and durability — when put under the stress of flight. AMTs need to understand the relationship between the materials used to construct the aircraft and the parts needed to make the repair, and know the best methods for securing these parts to the aircraft. Calculating shear strength also will help the AMT select the most appropriate materials for mending the crack — such as using metal rivets, a composite mixture of

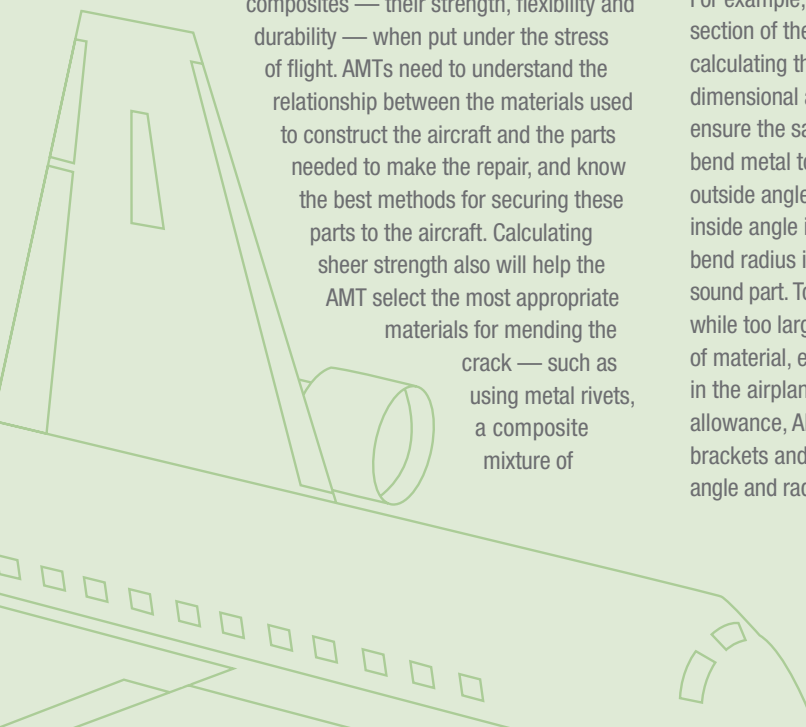
resin and hardener, or the fabrication of a new part. If a new part is required, the shape of the fabricated part is another important variable — especially if the crack has appeared on a part of the airplane with significant curvature. In that situation, AMTs have little choice but to create a new part to replace the damaged section.

### Fabricating New Parts for Repair

#### *Geometry, Algebra and Teamwork*

Depending on the size of the crack, the weight restrictions and the bend allowance of the fabricated material, AMTs must perform a sophisticated series of algebraic and geometric calculations to determine the amount of material needed for the replacement part, the shape it should take, and the maximum weight allowance and other tolerances.

For example, creating a patch for a particularly curved section of the airplane's fuselage (or wing) requires calculating the bend allowance of sheet metal — a dimensional adjustment that must be factored in to ensure the safety of the replacement part. When AMTs bend metal to the desired form, the material of the outside angle is stretched, while the material on the inside angle is compressed. Determining the proper bend radius is essential to constructing a strong and sound part. Too small a radius can cause further cracking, while too large a radius can result in costly overruns of material, excess weight and ultimately a disruption in the airplane's CG. To properly calculate the bend allowance, AMTs must measure the length of the brackets and the material thickness along with the angle and radius of the bend. They also must determine



$$[X_i - \bar{X}]^2$$

$$e^{i\theta}$$

$$\text{Bend allowance} = \frac{\text{Angle in degrees} \times (\pi/180) \times (\text{Radius} + \text{K-factor} \times \text{Thickness})}{1}$$

the “neutral axis,” or the K-factor — the percent of the material thickness where there is no stretching or compressing. Once the bend allowance is calculated, technicians can fabricate a new part; choose the appropriate rivet size, rivet pitch and tooling; and successfully repair the aircraft.

## Maintaining Center of Gravity

### Measurement and Proportions

A team of AMTs working together also must consider the effect the repair will have on the airplane’s CG. Because an aircraft is designed to be balanced forward and aft, the CG is located in a precise range along the chord of the wing — the distance between the leading and trailing edge of a wing. If the actual balance point is too far forward or too far aft, the pilot may experience difficulty maintaining level flight.

When making adjustments to an airplane’s fuselage, AMTs must find the CG by weighing the aircraft with platform scales or by using load cells positioned at designated points along the fuselage. AMTs must calculate these specific weights and the dimensions of those points to determine “moments” along an axis and determine the range within which the CG can be located. If, after making the repair, the actual CG falls beyond the approved envelope, the technicians need to calculate where and how much ballast they should add to reposition the CG within the approved range.

Since ballast is useless weight and only wastes fuel, fabricating durable but lightweight replacement parts is key to minimizing the need for additional costly adjustments to the airplane’s CG.

$$\text{Moment}_j = \text{Weight}_j \times \text{Distance}_j$$
$$\text{Center of gravity} = (\sum \text{Moments}) / \text{Total weight}$$

## Keeping Airplanes Flying

Keeping an aircraft ready for flight requires AMTs to make dozens of complex decisions every day as they inspect, repair and maintain a wide variety of aircraft. Ensuring an airplane’s airworthiness and the safety of the crew and passengers is not based on a wing and a prayer — it is grounded in a sophisticated understanding of how to apply the principles of algebra, trigonometry and even calculus to airplane maintenance. Keeping America flying safe and sound is just another example of mathematics at work today.

“Whether it is manufacturing a new component, repairing a damaged structure, performing an aircraft weight and balance calculation, or performing operational checks, mathematics is essential.”

E. Wayne Lee  
Head Aircraft Services Branch  
NASA

$$n!$$
$$(n - r)!$$

$$\sum_{i=1}^n X_i^2$$

$u^2$  $\lim_{\delta x \rightarrow 0}$ 

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

## Mathematics + Teamwork = Success

AMTs must have a strong foundation of mathematical knowledge and skills to successfully inspect, repair and maintain the airworthiness of an airplane. AMTs need to tap into their problem-solving skills to diagnose any potential issues that arise and make well-informed decisions to resolve those problems quickly and efficiently.

When a team of AMTs identifies a crack in the fuselage of an airplane, for example, they must first hone in on the best repair solution, using inductive and deductive reasoning. AMTs also use their knowledge of various materials' properties and sheer strength to determine the appropriate materials and fabrication methods to repair a crack on a particular part of the aircraft.

The technicians rely on many mathematics-based skills to fabricate a new part, including using real and rational numbers, calculating ratios and proportions, and measuring plane figures. Computing the bend allowance requires AMTs to use algebraic and geometric concepts to ensure that the newly fabricated part fits just right.

AMTs must monitor the consequences of their actions on the airplane's overall airworthiness and performance. When the team of AMTs installs the new part, they may shift the airplane's CG. If so, the AMTs will need to calculate a new CG, requiring the application of such mathematics skills as converting units of measurement and solving equations with one or more variables.

Although fabricating a new part to repair a crack in an airplane relies on AMTs' mathematical and technological knowledge, teamwork also is critical. Research by Achieve

and others shows that both in the college classroom and in the workplace, professors and employers identify collaboration and communication as important factors for success. Since AMTs may have individualized training in particular systems, such as engine repair, AMTs often work together and learn from each others' expertise to ensure that every airplane is in top-flight condition.

The required postsecondary training — be it in the field or in the classroom — combined with the rigorous FAA certification test and the on-the-job instruction, all underscore the need for future AMTs to leave high school having completed a rigorous set of courses aligned with college and career readiness expectations, especially in mathematics.

“*Mathematics plays a huge role in the day-to-day activities of aircraft mechanics. Consciously or subconsciously, mechanics utilize their knowledge of math. The basic principles of algebra, trigonometry and even calculus are applied towards ensuring the airworthiness of the aircraft and the safety of the crew.*”

E. Wayne Lee  
Head Aircraft Services Branch  
NASA

 $\delta x$  $\sqrt{a^2 + b^2}$   
 $2$   
 $\Omega$

$\cos^{-1} \theta$   
 $\sqrt{a^2 + b^2}$   
 $(X_i - \bar{X})^2 e^{i\theta}$

A decorative graphic at the top of the page features a dashed grey arc. Inside and around the arc are mathematical formulas in a light grey font:  $\cos^{-1} \theta$  at the top left,  $\sqrt{a^2 + b^2}$  in the middle left, and  $(X_i - \bar{X})^2 e^{i\theta}$  at the bottom left. A dashed arrow points from the arc towards the bottom right.

## About Achieve

Achieve, created by the nation's governors and business leaders, is a bipartisan, non-profit organization that helps states raise academic standards, improve assessments and strengthen accountability to prepare all young people for postsecondary education, careers and citizenship.

## About the American Diploma Project (ADP) Network

In 2005, Achieve launched the ADP Network — a collaboration of states working together to improve their academic standards and provide all students with a high school education that meets the needs of today's workplaces and universities. The ADP Network members — responsible for educating nearly 85 percent of all our nation's public high school students — are committed to taking four college and career readiness action steps:

1. Align high school academic content standards with the demands of college and careers;
2. Establish graduation requirements that require all students to complete a college- and career-ready curriculum;
3. Develop statewide high school assessment systems anchored to college- and career-ready expectations; and
4. Create comprehensive accountability and reporting systems that promote college and career readiness for all students.

The world has changed, and high schools must change with it. The ADP Network is leading the charge in ensuring that all high school students graduate with a degree that works.

For more information about Achieve and the ADP Network, visit [www.achieve.org](http://www.achieve.org). To view additional "Mathematics at Work" brochures, visit [www.achieve.org/math-works-brochures](http://www.achieve.org/math-works-brochures).

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