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| **Lesson 2.1 Materials and Structures** |

**Preface**

The aerospace industry is diversified in task and craft, ranging from glider design to space re-entry vehicle design. Regardless of the diversity of the industry, aerospace design is centered on the understanding of materials and structures.  Proper material selection and structural component configuration allow for craft safety and performance needs to be achieved and exceeded.

In this lesson students will design a aircraft structural component, create composite and test composite samples.

**Concepts**

1.     Aerospace material selection is based upon many factors including mechanical, thermal, electromagnetic, and chemical properties.

2.     Structural design, including centroid location, moment of inertia, and a material’s modulus of elasticity, are important considerations for an aircraft.

3.     Static equilibrium occurs when the sum of all forces acting on a body is equal to zero.

4.     Composites combine different materials to create a material with properties superior to that of the individual materials.

5.     Material testing provides a reproducible evaluation of material properties.

**Standards and Benchmarks Addressed**

***Standards for Technological Literacy***

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| **Standard 1:  Students will develop an understanding of the characteristics and scope of technology.** | |
| **BM J:** | The nature and development of technological knowledge and processes are functions of the setting. |
| **BM K:** | The rate of technological development and diffusion is increasing rapidly. |
| **BM L:** | Inventions and innovations are the results of specific, goal-directed research. |
| **BM M:** | Most development of technologies these days is driven by the profit motive and the market. |
| **Standard 2:  Students will develop an understanding of the core concepts of technology.** | |
| **BM W:** | Systems’ thinking applies logic and creativity with appropriate compromises in complex real-life problems. |
| **BM X:** | Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental systems. |
| **BM Y:** | The stability of a technological system is influenced by all of the components in the system especially those in the feedback loop. |
| **BM Z:** | Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste. |
| **BM AA:** | Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development. |
| **BM BB:** | Optimization is an on going process or methodology of designing or making a product and is dependent on criteria and constraints. |
| **BM CC:** | New technologies create new processes. |
| **BM DD:** | Quality control is a planned process to ensure that a product, service, or system meets established criteria. |
| **BM EE:** | Management is the process of planning, organizing, and controlling work. |
| **BM FF:** | Complex systems have many layers of controls and feedback loops to provide information. |
| **Standard 3:  Students will develop an understanding of the relationships**  **among technologies and the connections between technology and other fields of study.** | |
| **BM G:** | Technology transfer occurs when a new user applies an existing innovation developed for one purpose in a different function |
| **BM H:** | Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across other fields. |
| **BM I:** | Technological ideas are sometimes protected through the process of patenting. The protection of a creative idea is central to the sharing of technological knowledge. |
| **BM J:** | Technological progress promotes the advancement of science and mathematics. Likewise, progress in science and mathematics leads to advances in technology. |
| **Standard 4:  Students will develop an understanding of the cultural, social, economic, and political effects of technology.** | |
| **BM H:** | Changes caused by the use of technology can range from gradual to rapid and from subtle to obvious. |
| **BM I:** | Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects. |
| **BM J:** | Ethical considerations are important in the development, selection, and use of technologies. |
| **BM K:** | The transfer of a technology from one society to another can cause cultural, social, economic, and political changes affecting both societies to varying degrees. |
| **Standard 5:  Students will develop an understanding of the effects of**  **technology on the environment.** | |
| **BM H:** | When new technologies are developed to reduce the use of resources, considerations of trade-offs are important. |
| **BM J:** | The alignment of technological processes with natural processes maximizes performance and reduces negative impacts on the environment. |
| **BM K:** | Humans devise technologies to reduce the negative consequences of other technologies. |
| **BM L:** | Decisions regarding the implementation of technologies involve the weighing of tradeoffs between predicted positive and negative effects on the environment. |
| **Standard 6:  Students will develop an understanding of the role of society in the development and use of technology.** | |
| **BM H:** | Different cultures develop their own technologies to satisfy their individual and shared needs, wants, and values. |
| **BM I:** | The decision whether to develop a technology is influenced by societal opinions and demands, in addition to corporate cultures. |
| **BM J:** | A number of different factors, such as advertising, the strength of the economy, the goals of a company and the latest fads contribute to shaping the design of and demand for various technologies. |
| **Standard 7:  Students will develop an understanding of the influence of**  **technology on history.** | |
| **BM G:** | Most technological development has been evolutionary, the result of a series of refinements to a basic invention. |
| **BM H:** | The evolution of civilization has been directly affected by, and has in turn affected, the development and use of tools and materials. |
| **BM I:** | Throughout history, technology has been a powerful force in reshaping the social, cultural, political, and economic landscape. |
| **BM J:** | Early in the history of technology, the development of many tools and machines was based not on scientific knowledge but on technological know-how. |
| **BM N:** | The Industrial Revolution saw the development of continuous manufacturing, sophisticated transportation and communication systems, advanced construction practices, and improved education and leisure time. |
| **BM O:** | The Information Age places emphasis on the processing and exchange of information. |
| **Standard 8:  Students will develop an understanding of the attributes of design.** | |
| **BM H:** | The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results. |
| **BM I:** | Design problems are seldom presented in a clearly defined form. |
| **BM J:** | The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved. |
| **BM K:** | Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other. |
| **Standard 9:  Students will develop an understanding of engineering design.** | |
| **BM I:** | Established design principles are used to evaluate existing designs, to collect data, and to guide the design process. |
| **BM J:** | Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly. |
| **BM K:** | A prototype is a working model used to test a design concept by making actual observations and necessary adjustments. |
| **BM L:** | The process of engineering design takes into account a number of factors. |
| **Standard 10:  Students will develop an understanding of the role of**  **troubleshooting, research and development, invention and innovation, and experimentation in problem solving.** | |
| **BM I:** | Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace. |
| **BM J:** | Technological problems must be researched before they can be solved. |
| **BM K:** | Not all problems are technological, and not every problem can be solved using technology. |
| **BM L:** | Many technological problems require a multidisciplinary approach. |
| **Standard 11:  Students will develop abilities to apply the design process.** | |
| **BM M:** | Identify the design problem to solve and decide whether or not to address it. |
| **BM N:** | Identify criteria and constraints and determine how these will affect the design process. |
| **BM O:** | Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product. |
| **BM P:** | Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed. |
| **BM Q:** | Develop and produce a product or system using a design process. |
| **BM R:** | Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models. |
| **Standard 12:  Students will develop the abilities to use and maintain technological products and systems.** | |
| **BM L:** | Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques. |
| **BM M:** | Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it. |
| **BM N:** | Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision. |
| **BM O:** | Operate systems so that they function in the way they were designed. |
| **BM P:** | Use computers and calculators to access, retrieve, organize and process, maintain, interpret, and evaluate data and information in order to communicate. |
| **Standard 13:  Students will develop the abilities to assess the impacts of products and systems.** | |
| **BM J:** | Collect information and evaluate its quality. |
| **BM K:** | Synthesize data, analyze trends, and draw conclusions regarding the effect of technology on the individual, society, and environment. |
| **BM L:** | Use assessment techniques, such as trend analysis and experimentation to make decisions about the future development of technology. |
| **Standard 16:  Students will develop an understanding of and be able to select and use energy and power technologies.** | |
| **BM J:** | Energy cannot be created or destroyed; however, it can be converted from one form to another. |
| **BM K:** | Energy can be grouped into major forms: thermal, radiant, electrical, mechanical, chemical, nuclear, and others. |
| **BM M:** | Energy resources can be renewable or nonrenewable. |
| **BM N:** | Power systems must have a source of energy, a process, and loads. |
| **Standard 17:  Students will develop an understanding of and be able to select and use information and communication technologies.** | |
| **BM L:** | Information and communication technologies include the inputs, processes, and outputs associated with sending and receiving information. |
| **BM M:** | Information and communication systems allow information to be transferred from human to human, human to machine, machine to human, and machine to machine. |
| **BM N:** | Information and communication systems can be used to inform, persuade, entertain, control, manage, and educate. |
| **BM O:** | Communication systems are made up of source, encoder, transmitter, receiver, decoder, storage, retrieval, and destination. |
| **BM P:** | There are many ways to communicate information, such as graphic and electronic means. |
| **BM Q:** | Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli. |
| **Standard 18:  Students will develop an understanding of and be able to select and use transportation technologies.** | |
| **BM J:** | Transportation plays a vital role in the operation of other technologies, such as manufacturing, construction, communication, health and safety, and agriculture. |
| **BM K:** | Intermodalism is the use of different modes of transportation, such as highways, railways, and waterways as part of an interconnected system that can move people and goods easily from one mode to another. |
| **BM L:** | Transportation services and methods have led to a population that is regularly on the move. |
| **BM M:** | The design of intelligent and non-intelligent transportation systems depends on many processes and innovative techniques. |
| **Standard 19:  Students will develop an understanding of and be able to select and use manufacturing technologies.** | |
| **BM L:** | Servicing keeps products in good operating condition. |
| **BM M:** | Materials have different qualities and may be classified as natural, synthetic, or mixed. |
| **BM N:** | Durable goods are designed to operate for a long period of time, while non-durable goods are designed to operate for a short period of time. |
| **BM O:** | Manufacturing systems may be classified into types, such as customized production, batch production, and continuous production.  Optimization is an on going process or methodology of designing or making a product and is dependent on criteria and constraints. |
| **BM P:** | The interchangeability of parts increases the effectiveness of manufacturing processes. |
| **BM Q:** | Chemical technologies provide a means for humans to alter or modify materials and to produce chemical products. |
| **BM R:** | Marketing involves establishing a product’s identity, conducting research on its potential, advertising it, distributing it, and selling it. |
| **Standard 20:  Students will develop an understanding of and be able to select and use construction technologies.** | |
| **BM J:** | Infrastructure is the underlying base or basic framework of a system. |
| **BM K:** | Structures are constructed using a variety of processes and procedures. |
| **BM L:** | The design of structures includes a number of requirements. |
| **BM M:** | Structures require maintenance, alteration, or renovation periodically to improve them or to alter their intended use. |
| **BM N:** | Structures can include prefabricated materials. |

***National Science Education Standards***

**Unifying Concepts and Processes:**  As a result of activities in grades K-12, all students should develop understanding and abilities aligned with the following concepts and processes.

        **Systems, order, and organization**

        **Evidence, models, and explanation**

        **Change, constancy, and measurement**

        **Evolution and equilibrium**

        **Form and function**

**Science As Inquiry Standard A:** As a result of activities in grades 9-12, all students should develop

        **Understanding about scientific inquiry**

**Physical Science Standard B:** As a result of activities in grades 9-12, all students should develop an understanding of

        **Structure of atoms**

        **Structure and properties of matter**

        **Chemical reactions**

        **Motions and forces**

        **Conservation of energy and increase in disorder**

        **Interactions of energy and matter**

**Science and Technology Standard E:** As a result of activities in grades 9-12, all students should develop

        **Abilities of technological design**

        **Understandings about science and technology**

**Science in Personal and Social Perspectives Standard F:** As a result of activities in grades 9-12, all students should develop understanding of

        **Environmental quality**

        **Natural and human-induced hazards**

        **Science and technology in local, national, and global challenges**

**History and Nature of Science Standard G:** As a result of activities in grades 9-12, all students should develop understanding of

        **Science as a human endeavor**

        **Nature of scientific knowledge**

        **Historical perspectives**

***Principles and Standards for School Mathematics***

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| **Number and Operations** | Instructional programs from pre-kindergarten through grade 12 should enable all students to understand numbers, ways of representing numbers, relationships among numbers, and number systems; understand meanings of operations and how they relate to one another; compute fluently and make reasonable estimates. |
| **Algebra** | Instructional programs from pre-kindergarten through grade 12 should enable all students to understand patterns, relations, and functions; represent and analyze mathematical situations and structures using algebraic symbols;  use mathematical models to represent and understand quantitative relationships; analyze change in various contexts. |
| **Geometry** | Instructional programs from pre-kindergarten through grade 12 should enable all students to analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships; specify locations and describe spatial relationships using coordinate geometry and other representational systems; apply transformations and use symmetry to analyze mathematical situations; use visualization, spatial reasoning, and geometric modeling to solve problems. |
| **Measurement** | Instructional programs from pre-kindergarten through grade 12 should enable all students to understand measurable attributes of objects and the units, systems, and processes of measurement; apply appropriate techniques, tools, and formulas to determine measurements. |
| **Data Analysis and Probability** | Instructional programs from pre-kindergarten through grade 12 should enable all students to formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them; select and use appropriate statistical methods to analyze data; develop and evaluate inferences and predictions that are based on data; understand and apply basic concepts of probability. |
| **Problem Solving** | Instructional programs from pre-kindergarten through grade 12 should enable all students to build new mathematical knowledge through problem solving; solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to solve problems; monitor and reflect on the process of mathematical problem solving. |
| **Communication** | Instructional programs from pre-kindergarten through grade 12 should enable all students to organize and consolidate their mathematical thinking through communication; communicate their mathematical thinking coherently and clearly to peers, teachers, and others; analyze and evaluate the mathematical thinking and strategies of others; use the language of mathematics to express mathematical ideas precisely. |
| **Connections** | Instructional programs from pre-kindergarten through grade 12 should enable all students to recognize and use connections among mathematical ideas; understand how mathematical ideas interconnect and build on one another to produce a coherent whole; recognize and apply mathematics in contexts outside of mathematics. |
| **Representation** | Instructional programs from pre-kindergarten through grade 12 should enable all students to create and use representations to organize, record, and communicate mathematical ideas; select, apply, and translate among mathematical representations to solve problems; use representations to model and interpret physical, social, and mathematical phenomena. |

***Standards for English Language Arts***

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| **Standard 4** | Students adjust their use of spoken, written, and visual language (e.g. conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes. |
| **Standard 5** | Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences and for a variety of purposes. |
| **Standard 8** | Students use a variety of technological and informational resources (e.g. libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge. |
| **Standard 12** | Students use spoken, written and visual language to accomplish their own purposes (e.g. for learning, enjoyment, persuasion, and the exchange of information). |

**Performance Objectives**

*It is expected that students will:*

       Research the properties of materials used in the aerospace industry.

       Calculate and use properties of material.

       Design and analyze a frame system 3D modeling software.

       Create composite material.

       Determine material properties through testing.

**Assessment**

*Explanation*

       Students will explain the difference between the basic properties of materials, such as electrical, magnetic, mechanical, and physical.

       Students will explain how loads are transmitted through a structure.

*Interpretation*

       Students will write journal entries reflecting on their learning and experiences. Application

       Students will create a structure for use in an aircraft.

       Students will determine material properties.

*Empathy*

       Students will describe the deformation that a structural member undergoes as loads are applied and removed from the member.

*Self-knowledge*

       Students will reflect on their work by recording their thoughts and ideas in journals. They may use self-assessments as a basis for improvement.

**Essential Questions**

1.      Why is it crucial for designers and engineers to construct accurate free body diagrams of the parts and structures that they design?

2.     Why must designers and engineers calculate forces acting on bodies and structures?

3.     How does an engineer predict the performance and safety for a selected material?

4.     What significance does material selection have on product design?

**Key Terms**

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| **Term** | Definition |
| **Axial Stress** | A force with its resultant passing through the centroid of a particular section and being perpendicular to the plane of the section. A force in a direction parallel to the long axis of the structure. |
| **Centroid** | The geometric center of an area. |
| **Composite** | A material made of multiple layers of fibers held together with a matrix. |
| **Compression** | When a material is reduced in volume by the application of pressure; the reciprocal of the bulk modulus. |
| **Cross-Sectional Area** | A surface or shape exposed by making a straight cut through something at right angles to the axis. |
| **Deformation** | Any alteration of shape or dimensions of a body caused by stresses, thermal expansion or contraction, chemical or metallurgical transformations, or shrinkage and expansions due to moisture change. |
| **Ductility** | The amount of plasticity that precedes failure |
| **Failure Point** | Condition caused by collapse, break, or bending, so that a structure or structural element can no longer fulfill its purpose. |
| **Fatigue** | The loss of the load-bearing ability of a material under repeated load application, as opposed to a single load. |
| **Flange** | A broad ridge or pair of ridges projecting at a right angle from the edge of a structural shape in order to strengthen or stiffen it. |
| **Machinability** | The way a material responds to specific machining techniques. |
| **Modulus of Elasticity** | The ratio of the increment of some specified form of stress to the increment of some specified form of strain, such as Young's modulus, the bulk modulus, or the shear modulus. Also known as coefficient of elasticity, elasticity modulus, elastic modulus. |
| **Moment of Inertia** | A mathematical property of a cross section that is concerned with a surface area and how that area is distributed about a centroidal axis. |
| **Resilience** | A mechanical property of a material that shows how effective the material is absorbing mechanical energy without sustaining any permanent damage. |
| **Static Equilibrium** | A condition where there are no net external forces acting upon a particle or rigid body and the body remains at rest or continues at a constant velocity. |
| **Stiffness** | The ability of a material to resist deflection or stretching. |
| **Strain** | Change in the length of an object in some direction per unit. |
| **Stress** | The force acting across a unit area in a solid material resisting the separation, compacting, or sliding that tends to be induced by external forces. |
| **Structure** | Something made up of interdependent parts in a definite pattern of organization, such as trusses, frames, or machines. |
| **Tension** | The condition of a string, wire, or rod that is stretched between two points. |
| **Toughness** | Mechanical property of a material that indicates the ability of the material to handle overloading before it fractures. |

**Day-by-Day Plans**

*Time: 8 days*

**Day 1:**

       The teacher will present [**Aerospace Materials.ppt**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\Aerospace\AE_2011_Teacher.chm::/Lessons/Unit_2/L2_1_Aerospace%20Materials.pptx)**.**

       Students will take notes during the presentation in their journals.

       The teacher will present [**Mechanical Properties and Forces.ppt**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\Aerospace\AE_2011_Teacher.chm::/Lessons/Unit_2/L2_1_MaterialPropForces.pptx).

       Students will take notes during the presentation in their journals.

       The teacher will explain and distribute [**Activity 2.1.1 Aerospace Materials Investigation**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\Aerospace\AE_2011_Teacher.chm::/Lessons/Unit_2/A2_1_1_AerospaceMaterialsInvestigation.htm).

       Students will begin working on Activity 2.1.1 Aerospace Materials Investigation.

       Students will continue to complete Activity 2.1.1 Aerospace Materials Investigation.

**Day 2:**

       The teacher will explain and distribute [**Activity 2.1.2 Autodesk Inventor Frame Generator Introduction**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\Aerospace\AE_2011_Teacher.chm::/Lessons/Unit_2/A2_1_2_FrameGeneratorIntro.htm)**.**

       Students will begin working on Activity 2.1.2 Autodesk Inventor Frame Generator Introduction.

**Day 3:**

       Students will complete Activity 2.1.2 Autodesk Inventor Frame Generator Introduction.

       The teacher will review and collect Activity 2.1.2 Autodesk Inventor Frame Generator Introduction from students.

       The teacher will explain and distribute [**Activity 2.1.3 Autodesk Inventor Generator Frame Analysis**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\Aerospace\AE_2011_Teacher.chm::/Lessons/Unit_2/A2_1_3_FrameGeneratorAnalysis.htm)**.**

       Students will begin working on Activity 2.1.3 Autodesk Inventor Frame Generator Analysis.

**Day 4:**

       Students will complete Activity 2.1.3 Autodesk Inventor Frame Generator Analysis.

       The teacher will review and collect 2.1.3 Autodesk Inventor Frame Generator Analysis from students.

**Day 5-7:**

       The teacher will explain and distribute [**Project 2.1.4 Frame Design – Engine**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\Aerospace\AE_2011_Teacher.chm::/Lessons/Unit_2/P2_1_4_FrameDesign_Engine.htm) and [**Project 2.1.4 Frame Design – Engine Mount Template**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\Aerospace\AE_2011_Teacher.chm::/Lessons/Unit_2/P2_1_4_Frame_EngineMountTemplate.zip).

       Students will begin working on Project 2.1.4 Frame Design – Engine.

       Students will complete Project 2.1.4 Frame Design – Engine.

**Day 8:**

       The teacher will present [**Composite.ppt**](mk:@MSITStore:C:\Documents%20and%20Settings\DAVID_ROEMER\Desktop\Aerospace\AE_2011_Teacher.chm::/Lessons/Unit_2/L2_1_Composite.pptx).