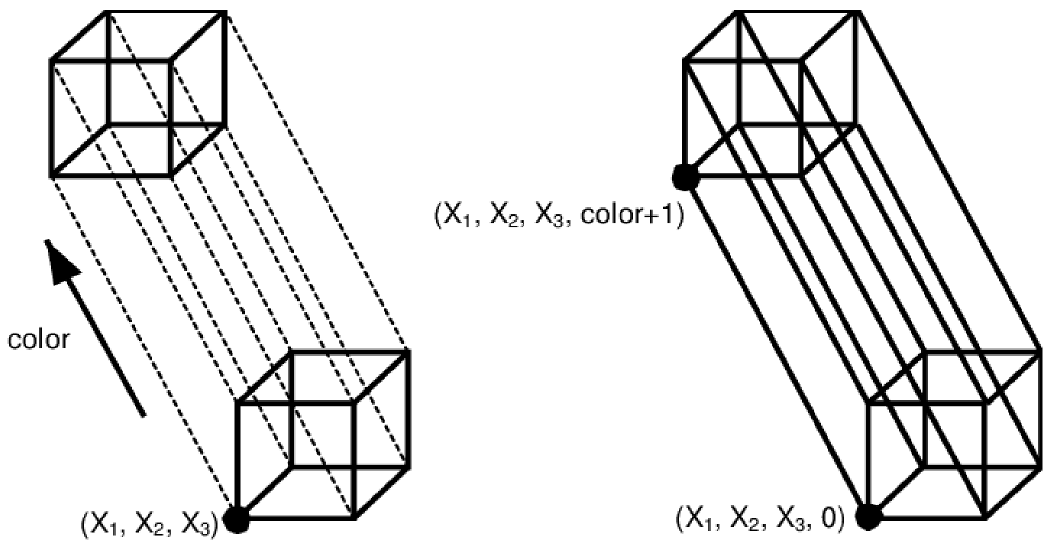
Composites_propellants(I)

Composite structures Material and manufacturing process improvements, for composites in particular, generally increase specific strength and stiffness, while improved thermal stability for items such as optical benches is being achieved with carbon-carbon and ceramic materials. Carbon fibres derived from mesophase pitch give improved conductivity and modulus over standard carbon fibres derived from polyacrylonitrile (PAN), but they have lower compressive strength. This is good for optical benches but can be a problem at joints in highly loaded primary structures. Introducing carbon nanotubes into composite resins and adhesives or growing them onto the sides of carbon fibres improves thermal and electrical conductivity, strength and stiffness. Draping, weaving and stitching of fibres are being used to generate complex shapes which can be complemented by resin transfer moulding or a resin injection process. By integrating systems into composite structures, we may approach the concept of the intelligent structure. Already optical fibres can be embedded into a carbon fibre matrix allowing signals to pass along skins.



Points:

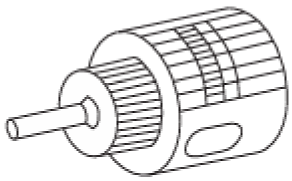
- mechanical including kapton and aluminium laminates,

- physical techniques including shape memory materials and solvent evaporation which suffers from out-gassing problems,

- chemical, thermal and/or UV curing,

- cas catalysed polymers.

For small spacecraft for low Earth orbit constellations or small-scale, single experiments, the designer is required not only to produce an efficient structure to maximize payload but also to respond to the ever-increasing commercial pressure of schedule and cost. Moulded, single component structures that can be stacked for multiple launches are an attractive proposition. The possibility of large numbers of spacecraft for the proposed global constellations.



The ACS designer will need to know the required time-history of the rotational motion, the angular rate ω which is required of the spacecraft, and of any parts of it that can move independently on bearings. The angular momentum Hc and the torque T needed to produce it may then be calculated from the Newtonian law $dHc/dt = T$ where Hc is the angular momentum referred to the centre-of-mass C, detailed in equations.

EXTERNAL TORQUES

Source:
Aerodynamic
Magnetic
Gravity gradient
Solar radiation
Thrust misalignment

INTERNAL TORQUES

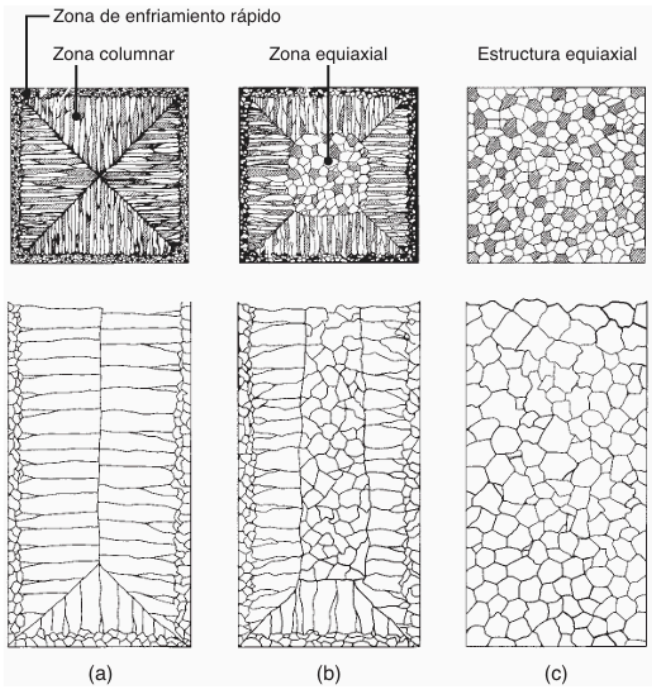
Source:
Mechanisms
Fuel movement
Astronaut movement
Flexible appendages
General mass movement

HEIGHT RANGE OVER WHICH IT IS POTENTIALLY DOMINANT

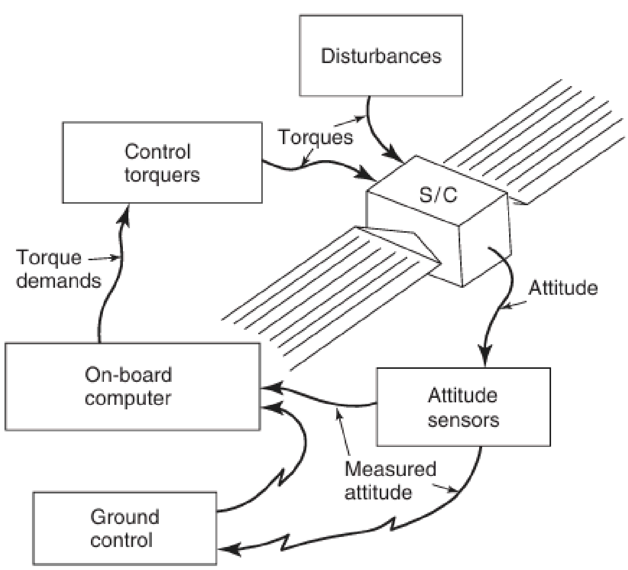
Aerodynamic: <about 500km
Magnetic: 500-35000km
Gravity gradient: 500-35000km
Solar radiation: >700km
Thrust misalignment: all heights

Propellants are often tailored to and classified by specific applications, such as space launch booster propellants or tactical missile propellants, each having specific chemical ingredients, different burning rates, different physical properties, and different performance. Table 12–1 shows four rocket motor applications (each with somewhat different propellants), plus several gas generator applications and an artillery shell application. Propellants for rocket motors produce hot (over 2400 K) gases and are used for thrust, but gas generator propellants operate with lower-temperature combustion gases (800 to 1200 K in order to use uncooled hardware) and are used to produce power, not thrust. 2. Double-base (DB)* propellants form a homogeneous propellant grain, usually a nitrocellulose (NC)*—a solid ingredient that absorbs liquid nitroglycerine (NG), plus minor percentages of additives. The major ingredients are highly energetic materials and they contain both fuel and oxidizer. Both extruded double-base (EDB) and cast double-base (CDB) propellants have found extensive applications, mostly in small tactical missiles of older design. By adding crystalline nitramines (HMX or RDX)* Both performance and density can be improved; these are sometimes called cast-modified double-base propellants. Adding an elastomeric binder (rubber-like, such as crosslinked polybutadiene) further improves the physical properties and allows more nitramine and thus increasing performance slightly. The resulting propellant is called elastomeric-modified cast double-base (EMCDB). These four classes of double-base propellants have nearly smokeless exhausts. Adding some solid ammonium perchlorate (AP) and aluminum (Al) increases the density and the specific impulse slightly, but exhaust gases become smoky—such propellant is called composite-modified double-base propellant or CMDB.

Dynamics: The dynamic equations for this spacecraft, treated as a rigid body, are covered in Section 3.4.1 of Chapter 3, using principal axes for the analysis. With small angular velocities the responses about these axes are largely uncoupled and may be approximated by $I_{xx} \dot{\omega}_x = T_x$, $I_{yy} \dot{\omega}_y = T_y$, $I_{zz} \dot{\omega}_z = T_z$



Composite propellants form a heterogeneous propellant grain between oxidizer crystals and powdered fuel(usually aluminum)held together in a matrix of synthetic rubber (or plastic) binder, such as polybutadiene (HTPB).* Composite propellants are cast from a mix of solid (AP crystals, Al powder) and liquid (HTPB, PPG)* ingredients. The propellant is hardened by crosslinking or curing the liquid binder polymer with a small amount of curing agent, and curing it in an oven, where it becomes solid. In the past four decades composites have been the most commonly used class of propellant.



Flights at high speeds (Supersonic aerodynamics)

The speed of sound or sonic velocity is the speed of propagation when the air changes
Its pressure or the particles in the air flow change their pressure level and speed when they collide with a wing. The speed of propagation is very fast and it is not about flying faster than sound, but about the speed of propagation in the air and the fact that the pressure is disturbed. There is disturbance of the pressure effect when flying at high speeds.

The speed of an object compared to the speed of sound, or the speed at which small pulses of pressure are transmitted in the airflow around the aircraft wing, is important to parameterize, or write a parameter of, the supersonic airflow.

Variables: Given the important variables or indices of the speed of sound, adiabatic coefficient, constants and Temperature:

- “a” is the speed of sound.
- “γ\gamma” is the adiabatic coefficient (for air, γ=1.4\gamma = 1.4γ=1.4).
- “R” is the ideal gas constant (for air, R=287 J/(kg) R = 287 {J/(kg·K)} “R=287J/(kg)”
- “T” is the absolute temperature in Kelvin.

Height	Temperature	speed of sound	MPH Kts

```
% Parameters
gamma = 1.4;          % Adiabatic coefficient for air
R = 287;              % Ideal gas constant for air in J/(kg·K)
T = 300;              % Temperature in Kelvin (example: 300K)

% Calculate the speed of sound
a = sqrt(gamma * R * T);

% Show the result
fprintf('The speed of sound is %.2f m/s\n', a);
```

a = squareRoot % R T

Code Explanation

1. **Parameter Definition**: The values of γ\gammaγ, R and T are defined. In this example, T has been set to 300 K, which is a typical temperature for air at sea level.
2. **Calculation of the Speed of Sound**: The formula a=γRTa = \sqrt{\gamma R T}a=γRT is used to calculate the speed of sound.

3. **Show the result**: The result is printed using `fprintf`.

Aircraft flaps in approximate calculations:

Stall speed with flaps fully extended and retracted is calculated and displayed, and will also plot the relationship between lift coefficient and stall speed. You can run this code in a Python environment to get the results and visualization. On the other hand, variables are a way to synthesize calculations with programming languages and processes at an automatic or automated level of variables where the aerodynamic variables are:

1. W is the weight of the aircraft.
2. Weigh the density of the air.
3. Vstall is the stall speed.
4. S is the reference area.

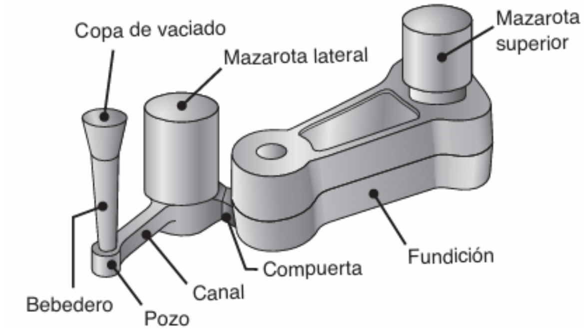


FIGURA 10.8 Esquema de una fundición característica con mazarotas y compuertas. Las mazarotas sirven como contenedores que suministran metal fundido a la fundición conforme se contrae durante la solidificación.

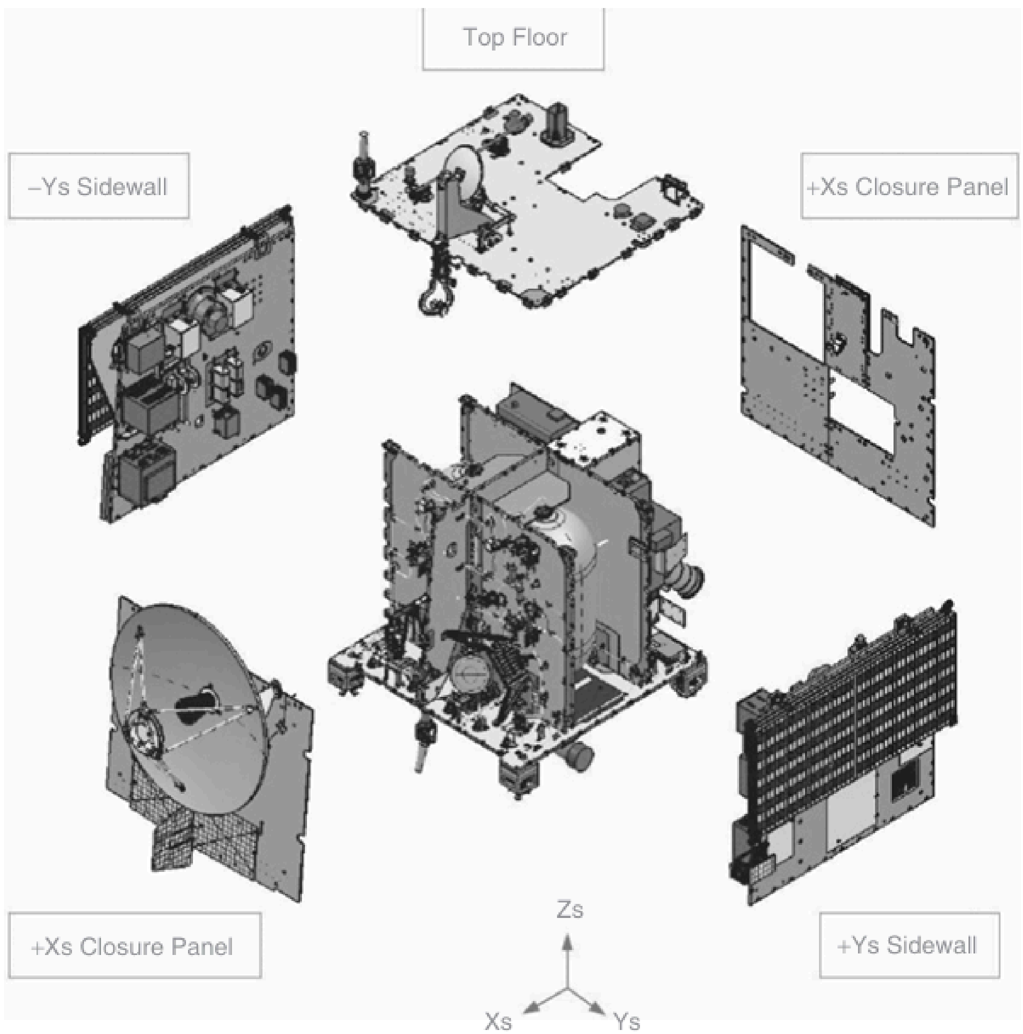


Figure 8.25 Mars Express structure configuration. (Reproduced by permission of EADS Astrium Ltd.)

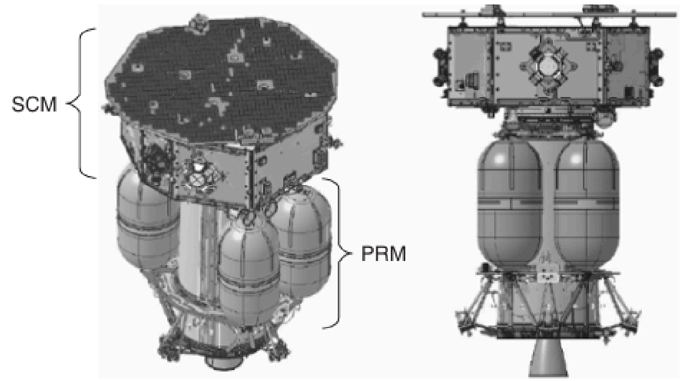
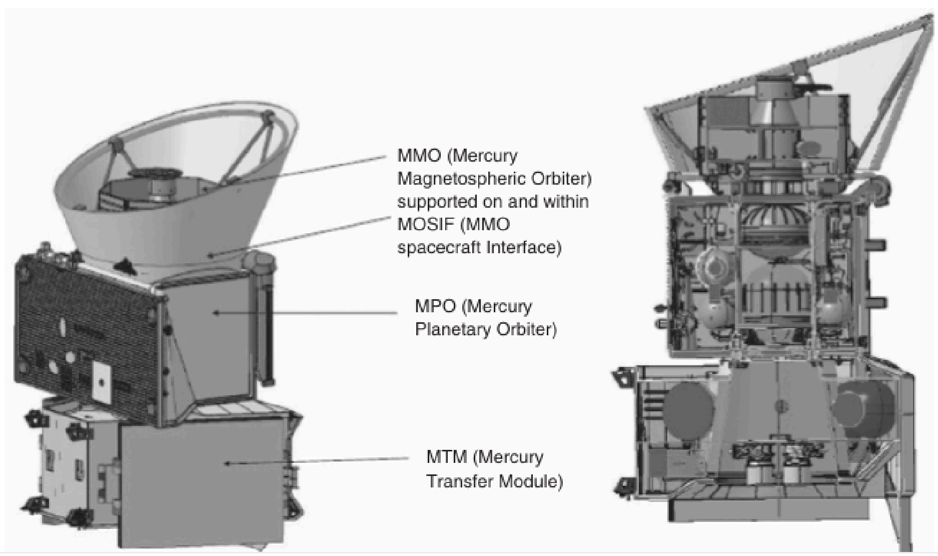
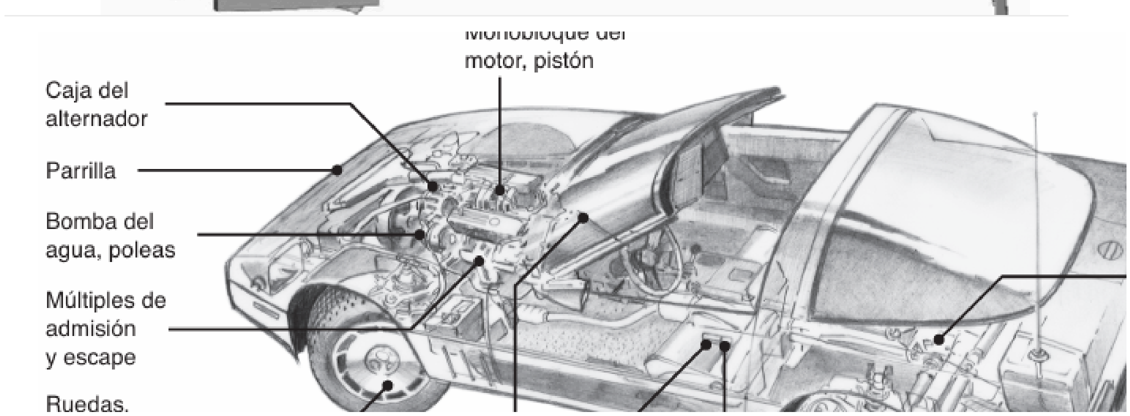
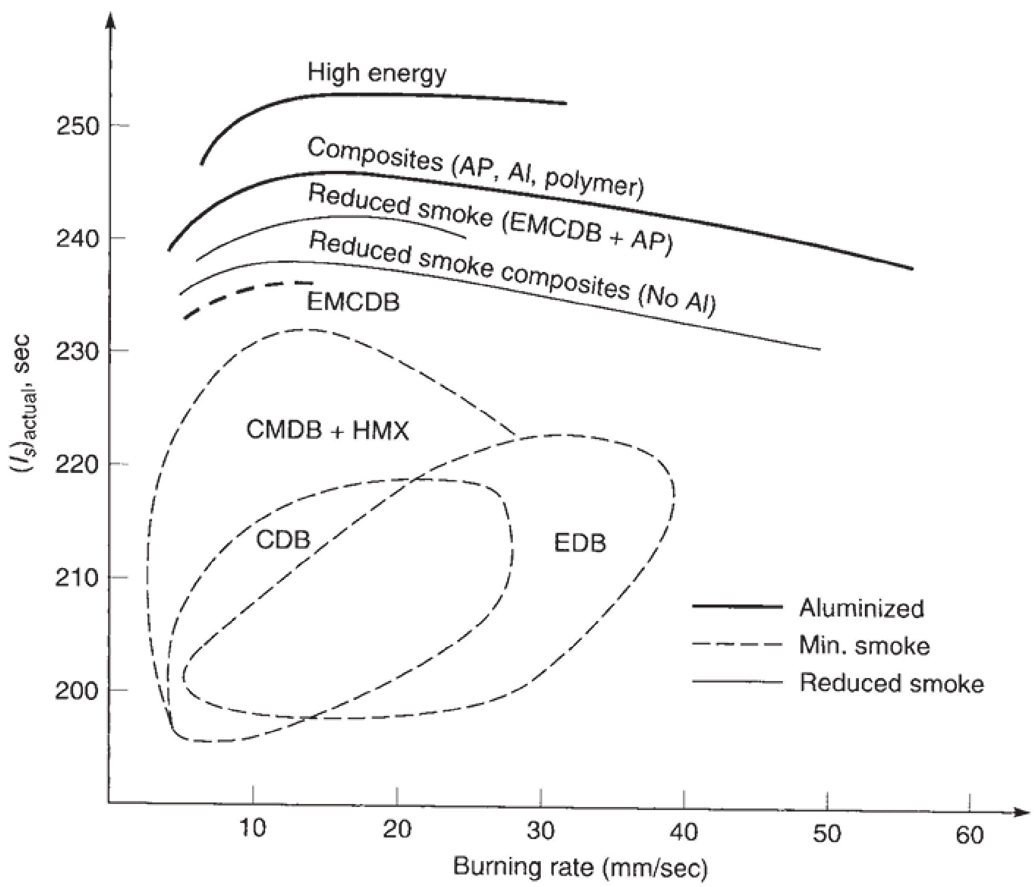


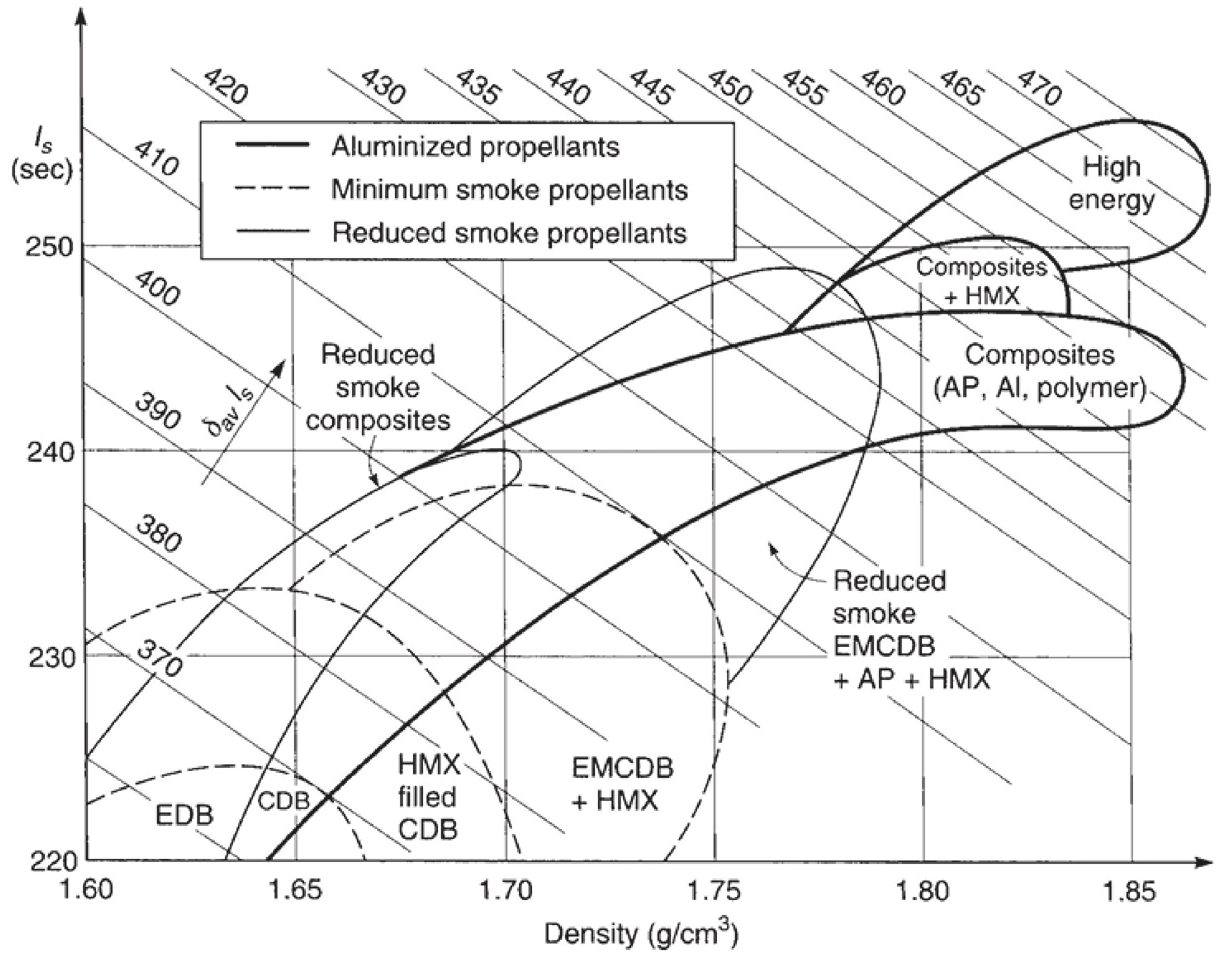
Figure 8.21 Lisa Pathfinder Propulsion Module. (Reproduced by permission of EADS Astrium Ltd.)





Modified composite propellant where an energetic nitramine (HMX or RDX)isadded for obtaining some added performance and also a somewhat higher density. c. Modified composite propellant where an energetic plasticizer such as nitroglycerine (used in double-base propellants) is added to give increased performance. Sometimes HMX is also added. d. High-energy composite solid propellant (with added aluminum), where the organic elastomeric binder and the plasticizer are largely replaced by highly energetic materials and where some of the AP is replaced by HMX and RDX. Hexanitrohexaazaiso-wurtzitane or CL-20 is a recent propellant ingredient being used; it is produced outside of the United States. Lower-energy composite propellant, where ammonium nitrate (AN) is the crystalline oxidizer (not AP). These are used for gas generator propellants. When large amounts of HMX are added, they become minimum smoke propellants with fair performance.Propellants may also be classified by the smoke density in the exhaust plume as smoky, reduced smoke,orminimum smoke (essentially smokeless). Aluminum powder, a desirable fuel ingredient for performance, is oxidized to aluminum oxide during burning, which yields visible, small, solid smoky particles in the exhaust gas. Most composite propellants (e.g., AP) are also smoky. By replacing APP with HMX and RDX and by using energetic binders and plasticizers to compensate for eliminating aluminum, the amount of smoke may be considerably reduced in composite propellants. Carbon (soot) particles and metal oxides, such as zirconium oxide or iron oxide, are also visible in high enough concentrations.





Compressible Flow: At high speeds, the compressibility of air becomes significant, affecting the density and pressure of the flow around the object.

Mach number: It is the relationship between the speed of the object and the speed of sound in the medium. It is used to classify flight regimes: subsonic (Mach < 1), transonic (Mach ≈ 1), supersonic (Mach > 1), and hypersonic (Mach > 5).

Shock Waves: They are discontinuities in the flow that occur when the object exceeds the speed of sound, resulting in abrupt changes in pressure, temperature and density of the air.

Prandtl-Glauert effect: Describes the intensification of pressure on the surface of the object as it approaches the speed of sound, creating an increase in aerodynamic drag.

Modified Bernoulli's Law: At high speeds, Bernoulli's law is adjusted to account for the compressibility of the flow, allowing analysis of the pressure distribution in the moving object.

Wave Drag: A component of aerodynamic drag that becomes significant at transonic and supersonic speeds, caused by the formation of shock waves.

Conclusion: These basic principles are fundamental to design and analyze aircraft and other objects that operate at high speeds, ensuring efficiency and stability in extreme conditions.

Fluids: Since air is a fluid and air is also the object of study of aerodynamics,

It is convenient to establish some basic properties of fluids. Fluid is a body whose molecular arrangement is such that small forces are enough to change the relative position of these moving particles. Liquids and gases are fluids and demonstrate their molecular property of fluids by changing shape easily. ”Fluids change their molecular shape, the structures of their particles”

Steady regime or laminar flow: It is one in which at any point in the fluid, the velocity vector remains constant. This means that at any point in the fluid, the particles that pass through that point have the same speed, direction and direction.

Example: To calculate the maximum clean lift coefficient;

- W is the weight of the aircraft.
- P is the density of air.
- (V)stall is the stall speed.
- S is the reference area.

Software to do flap calculations:

```
import numpy as np
import matplotlib.pyplot as plt

# Data provided
W_max = 12500 # Maximum allowable takeoff weight in kg
fuel_consumed = 1200 # Fuel consumed in kg
rho = 1.225 # Air density in kg/m^3
S = 28.15 # Reference area in m^2
g = 9.81 # Acceleration due to gravity in m/s^2
CL_max_extended_flaps = 1.90 # Maximum lift coefficient with fully
extended flaps
CL_max_flaps_refolded = 0.5 # Maximum lift coefficient
```

Types of aircraft wing profiles (definitions)

1.Wing chord: It is a straight line that joins the forward end of an aircraft wing or leading edge to the trailing edge or trailing edge.

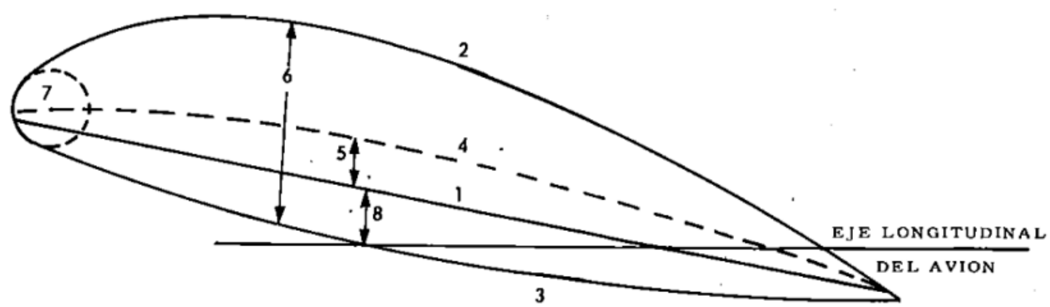
2.Upper curvature: Curvature of a semicircle that joins the forward leading edge of the wing and the rear end on the straight line of flight.

3.Bottom curvature: Continuation of the line of the upper curvature below the chord.

6.Maximum thickness: Maximum distance between the upper and lower curvatures.

7.Leading edge radius: Radius of curvature or a geometric circle

8.Angle of incidence: Angle formed by the middle chord and the length or longitudinal axis of an aircraft.



Relations with tensors: By relating high-speed aerodynamics to the theory of relativity and tensors in the context of a black hole, we can consider how airflow and Bernoulli's principles would be modified in a curved spacetime. General relativity tells us that the presence of a black hole curves space-time, and this effect can alter the behavior of airflow and lift in a hypothetical aircraft moving near the black hole.

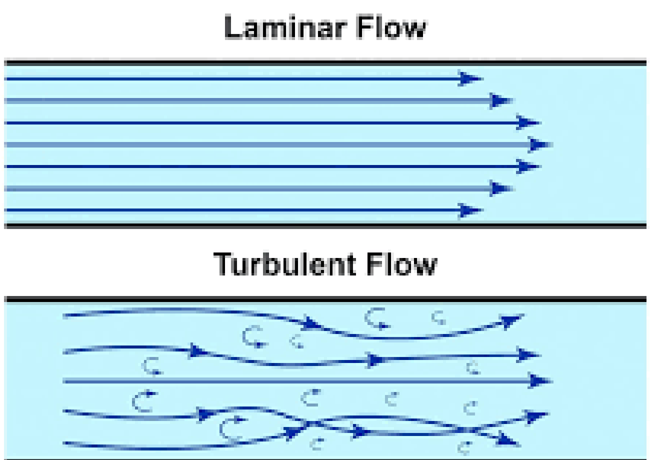
Propellant: Composite propellants are shown to have a wide range of burning rates and densities; most of them have specific gravities between 1.75 and 1.81 and burning rates between 7 and 20 mm/sec. Composite propellants give higher densities, specific impulse, and a wider range of burning rates than others. DB propellants and AN propellants have lower performance and density. Most composite propellants display similar performance and density but with a wider range of burning rates. The highest performance indicated is for a CMDBpropellant whose ingredients are identified as DB/AP-HMX/Al

Propellant selection is critical to rocket motor design. Desirable propellant characteristics are listed below and further discussed in other parts of this book. Many requirements for particular solid propellant rocket motors will influence priorities for choosing these characteristics:

1. High performance means Specific Impulse;this implies ahi gas temperature and/or low exhaust gas molecular mass.

2. Predictable, reproducible, and initially adjustable burning rate to fit grain design needs and thrust-time requirements.

3. For minimum variations in thrust or chamber pressure during burning, both the pressure or burning rate exponent and the temperature coefficient should be small.



Parameter Definition:

- `V` is the speed of the aircraft, which in this case is approximately the speed of sound.
- `a` It is the speed of sound.
- `mach_number` calculates the Mach number of the aircraft.

Pressure Distribution:

- `x` and `and` They define the grid on which the pressure distribution will be calculated.
- `pressure` is a simplification of the pressure distribution around the wing.

Shock Wave Effect:

- shock_wave simulates a shock wave at the edge of the wing.

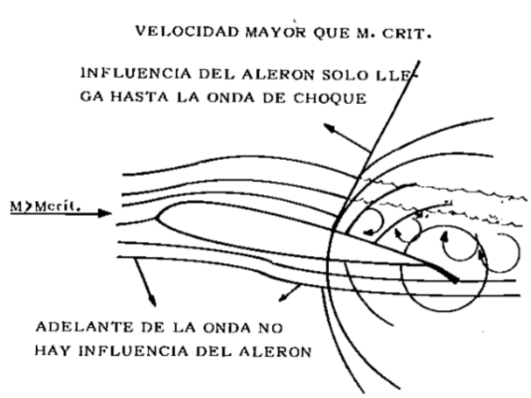
Display:

- It is used contourf to create a filled contour map of the pressure distribution and shock waves.
- plt.axhline and plt.axvline They add lines to highlight the position of the wing and the shock wave.
- plt.legend adds a legend for the shock wave.

1. Problems with transonic flights include decreased aerodynamic characteristics of the wing (increased drag and decreased lift)
2. Pounding

3. Loss of effectiveness of flight controls and instability
4. Sonic barrier problems.

5. The pressure waves transmitted by the deflection of the aileron: The variables are the highest speed, M>Mcrit, the influence wave and the shock wave.



Shock waves and superluminal pulsars in theories about black holes:
The vibrations or hums that the pilot perceives in the control stick are an indication to
Let him slow down. The pilot has a prior warning that announces the knocking and vibrations that are produced by aircraft turbulence. Particles of a different quantum type than the one known do not consist of a defined mass and it is possible that their dimensions consist of a property of transposition (D) at very high speeds and that a possible aircraft could be composed of superluminal quantum particles (tachyons). or qubits (Aircraft) or something similar, comparing this concept or idea with the curvature of tensors of Riemann black holes and the theory of Cherenkov Radiation, new patterns could be established within the framework of theoretical physics for black holes. But here it is necessary to carry out an analysis of the structure of frequencies, tensors and Cherenkov radiation.

PROPELLANT TYPE ANALYSIS

DOUBLE BASE (EXTRUDED)
Advantages:
- Modest cost.
- Nontoxic clean exhaust, smokeless.
- Good burn rate control.
- Wide range of burn rates.
- Simple well-known manufacturing process.
- Good mechanical properties.
- Low-temperature coefficient.
- Very low pressure exponent.
- Plateau burning is possible.

Disadvantages:
- Freestanding grain requires structural support.
- Low performance and low density.
- High to intermediate hazard in manufacture.
- Potential storage issues with NG bleeding out.
- Diameter limited by available extrusion presses.
- Classified as 1.1a.

DOUBLE BASE (CASTABLE)
Advantages:
- Wide range of burn rates.
- Nontoxic smokeless exhaust.
- Relatively safe to handle.
- Simple, well-known process.
- Modest cost.
- Good mechanical properties.
- Good burn rate control.
- Low-temperature coefficient.
- Plateau burning can be achieved.

Disadvantages:
- NG may bleed out or migrate.
- High to intermediate manufacturing hazard.
- Low performance and low density.
- Higher cost than extruded double base.
- Classified as 1.1a.

COMPOSITE MODIFIED DOUBLE BASE (CMDB) WITH SOME AP AND Al
Advantages:
- Higher performance.

- Good mechanical properties.
- High density.
- Less likely to have combustion stability problems.
- Intermediate cost.
- Good background experience.

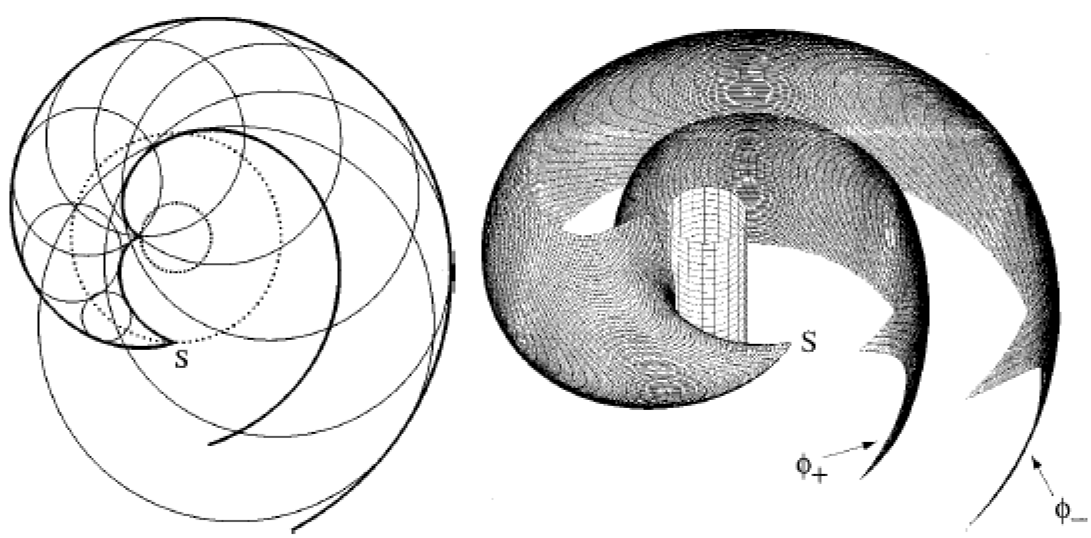
Disadvantages:
- Complex facilities required for manufacturing.
- Some smoke in exhaust.
- High flame temperature.
- Moisture-sensitive.
- Moderately toxic exhaust.
- Hazards in manufacturing.
- Modest ambient temperature range.
- High value of pressure exponent (0.8–0.9).
- Moderately high temperature coefficient.

COMPOSITE AP, Al, AND PBAN OR PU OR CTPB BINDER
Advantages:
- Reliable performance.
- High density.
- Long experience background.
- Modest cost.
- Good aging properties.
- Long cure time.
- Good overall performance.
- Usually stable combustion.
- Low to medium cost.
- Wide operational temperature range.
- Low to moderate temperature sensitivity.
- Good burn rate control.
- Usually good physical properties.
- Classified as 1.3.

Disadvantages:
- Modest ambient temperature range.
- High viscosity limits at maximum solid loading.
- High flame temperature.
- Toxic, smoky exhaust.
- Some formulations are moisture sensitive.
- Some burn-rate modifiers (e.g., aziridines) are carcinogens.

COMPOSITE AP, Al, AND HTPB BINDER (MOST COMMON COMPOSITE PROPELLANT)
Advantages:
- Slightly better solid loading percentage and performance compared to PBAN or CTPB.
- Wide ambient temperature limits.
- Good burn-rate control.
- Usually stable combustion.
- Medium cost.
- Good storage stability.
- Wide range of burn rates.
- Good physical properties.
- Good experience background.
- Classified as 1.3.

Disadvantages:
- Complex facilities required for manufacturing.
- Moisture sensitive.
- Fairly high flame temperature.
- Toxic, smoky exhaust.



Test Method Selection Although the basic physics of test methods for composite materials are similar to those for testing metals or plastics, the heterogeneity, orthotropic, moisture sensitivity, and low ductility of typical composites often lead to major differences in test requirements, particularly for mechanical tests. These differences include:
(1) The strong influence of constituent content on material response necessitates measurements of the material response of every specimen.
(2) Properties should be evaluated in multiple directions.
(3) Specimens should be conditioned to quantify and control moisture absorption and adsorption.
(4) The methods of specimen alignment and load induction have increased importance for composites.
(5) The consistency of failure modes requires some assumptions to be made.

Glass Fibers Glass fibers are usually drawn from a molten mixture of quartz sand, limestone, dolomite and paraffin, as well as a certain fraction of soda and boric acid [4]. To facilitate the process or to achieve the desired performance, an appropriate fraction of TiO2, ZrO2 or Al2O3 is also incorporated. The components and the drawing process greatly affect the performance of the final fibers. Glass fibers are non-combustible and do not decompose, and they are characterized by good chemical stability, good heat resistance, high tensile strength, high electrical insulation, low tensile strain, low insulation and a low coefficient of thermal expansion. They were the first fibers to be used for the preparation of polymer matrix composites. They are commonly known to be low-cost reinforcements for fiberglass-reinforced plastics (FRP) [5]. The diameters of the glass fibers vary from 5 to 20 lm, and a finer fiber diameter generally results in better performance. The types and specifications of commercially available glass fibers are mainly as follows: A-glass fiber, containing high alkali metal oxides; C-glass fiber, resistant to chemical attack; D-glass fiber, with a high dielectric property; E-glass fiber, with high electric insulation; M-glass fiber, with a high Young's modulus; S-glass fiber, with a high tensile strength; AR-glass fiber, alkaline resistant and suitable for reinforcing cement matrix composites.

TYPES AND COMPOSITIONS OF COMMERCIAL GLASS FIBERS

TYPE A:
- Primary Composition: High percentage of SiO_2.
- Additional Elements: B_2O_3, CaO, Na_2O, MgO.
- Notable Properties: Standard glass fiber composition with moderate mechanical stability.

TYPE C:
- Primary Composition: Lower SiO_2 content compared to Type A.
- Additional Elements: Al_2O_3, B_2O_3, CaO, MgO.
- Notable Properties: Increased chemical resistance compared to traditional glass fibers.

TYPE E:
- Primary Composition: Lower SiO_2 concentration.
- Additional Elements: B_2O_3, Al_2O_3, CaO.
- Notable Properties: Electrical insulation applications, good mechanical properties.

TYPE E-CR:
- Primary Composition: Moderate SiO_2 content.
- Additional Elements: Al_2O_3, CaO, MgO, TiO_2.
- Notable Properties: Corrosion-resistant formulation with better durability.

TYPE M:
- Primary Composition: SiO_2 with additional stabilizers.
- Additional Elements: SO_3, Li_2O, ZnO, TiO_2.
- Notable Properties: Enhanced thermal stability and resistance to environmental degradation.

TYPE S:
- Primary Composition: High SiO_2 content.

- Additional Elements: High Al_2O_3 percentage.
- Notable Properties: Superior mechanical strength, used in aerospace applications.

TYPE ZORAR:
- Primary Composition: High SiO_2 concentration.
- Additional Elements: ZrO_2, TiO_2.
- Notable Properties: Improved resistance to extreme thermal conditions and structural stability.

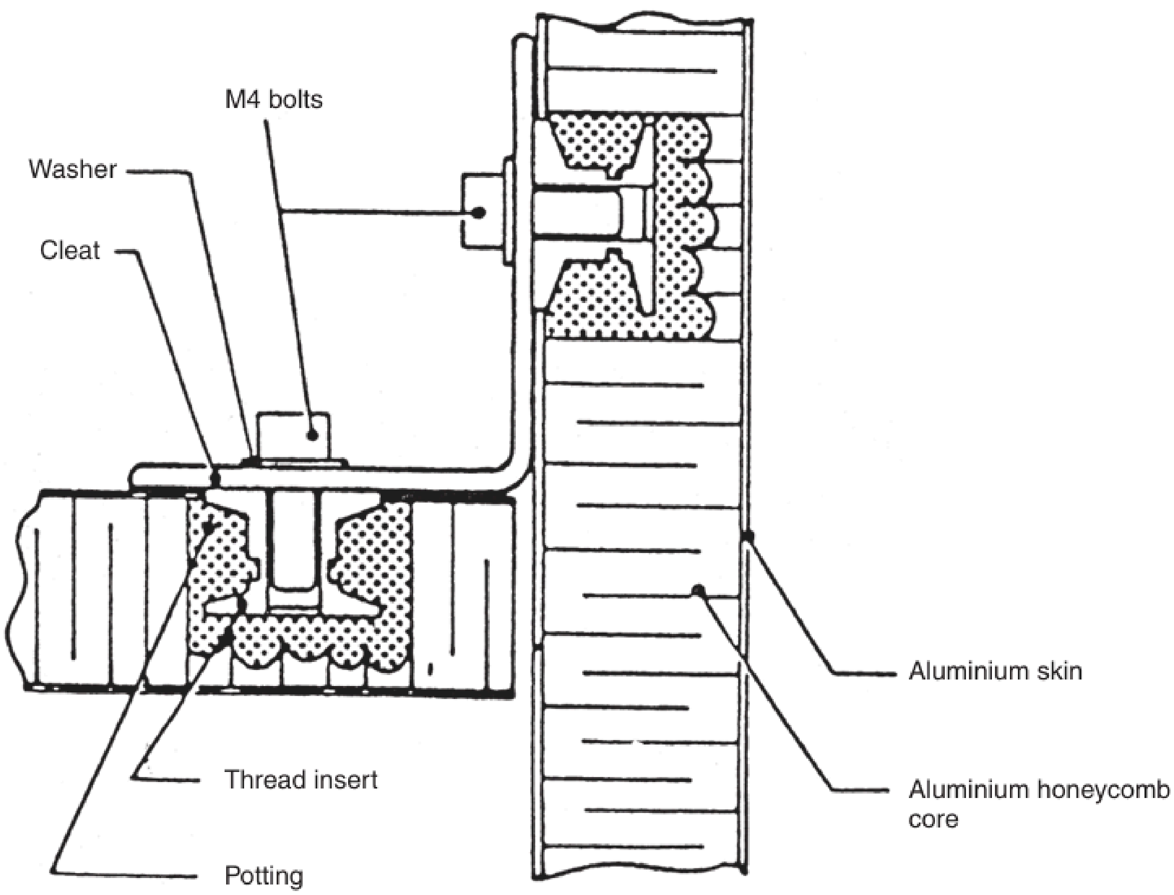
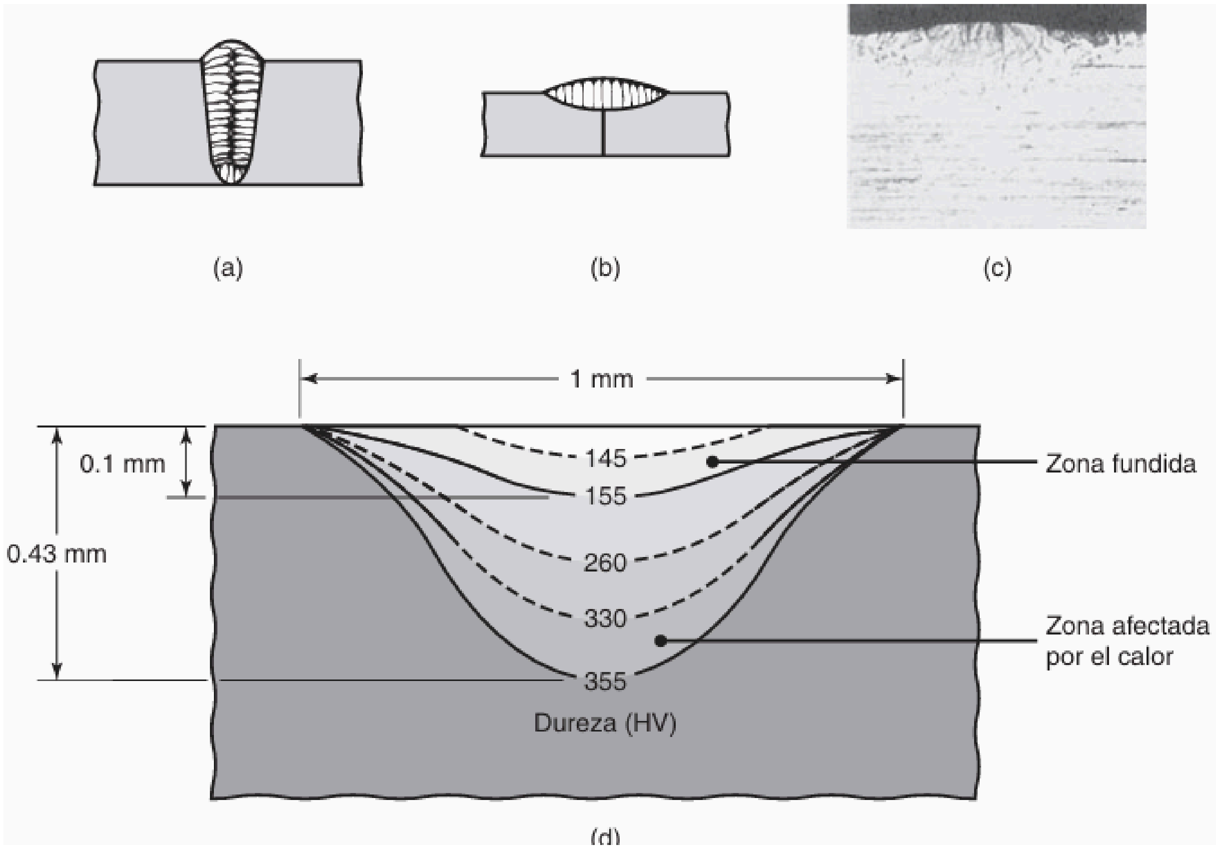


Figure 8.7 Inserts and panel cleat joints. (Reproduced by permission of EADS Astrium Ltd.)



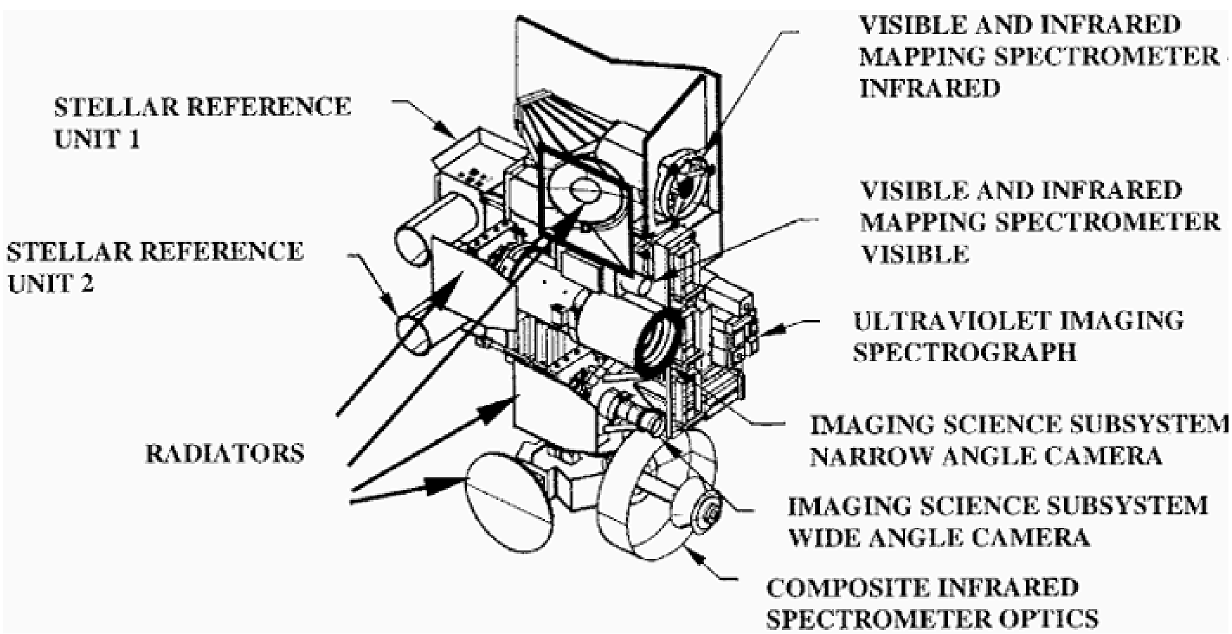


Figure 5. Remote Sensing Pallet with Instruments.

E-Glass Fibers E-glass fibers, also referred to as non-alkali glass fibers, were the first fiber species used for electronic insulation belts. They are a kind of Ca–Al–B–Si glass fiber with a total alkali content less than 0.8 wt%, which ensures their excellent corrosion resistance and high conductivity resistance. As a favored insulation material, they have been processed into electromagnetic wires, impregnation materials, mica products, laminated products and polymer matrix composite products. The insulation grade of these products varies from B, F and H to C, which enables their widespread use in the electric and electronic fields. They are also the most common fiber reinforcements for polymer matrix composites. They are regarded as ideal polymer strengthening glass fibers with a high strength, high Young's modulus, low density and good water resistance. As an example, they have accounted for 90% of the glass fiber market. They can be used both structurally and functionally. For example, E-glass fiber-reinforced rubber products or filter products can be used in the cement, power, metallurgy and carbon black industries where processing temperatures reach up to 150–300 °C. However, a significant disadvantage of E-glass fibers is their limited chemical corrosion resistance to acid or alkali media, thus restricting their application in a cement matrix.

Curvature and Dynamics of Black Holes

<u>Introduction to General Relativity</u>
The theory of general relativity, proposed by Albert Einstein in 1915, revolutionized our understanding of space, time and gravity. Unlike Newton's theory of gravitation, which describes gravity as a force acting at a distance, general relativity interprets gravity as a manifestation of the curvature of space-time. This curvature is caused by the presence of mass and energy.

What is a Tensor?
To understand general relativity, it is essential to become familiar with tensors, which are fundamental mathematical tools in this theory. A tensor generalizes the concepts of scalars and vectors to higher dimensions and is used to describe the physical properties of a system at any point in spacetime.

Scalar (Rank Tensor 0): A quantity that does not change under coordinate transformations, such as the temperature at a point.

Vector (Rank Tensor 1): A quantity with magnitude and direction, such as speed.
Rank 2 Tensor: A matrix that can describe more complex properties, such as stresses in a material or space-time metrics.

In MATLAB, we can illustrate tensors using multidimensional matrices and arrays. For example, a rank 2 tensor can be represented as a matrix

```
% Example of a rank 2 tensor (a 3x3 matrix)
tensor_rango2 = [1, 2, 3; 4, 5, 6; 7, 8, 9];
disp('Rank Tensor 2:');
disp(tensor_rango2);
```

Space-Time and Metrics

In general relativity, space and time are combined into a single entity called spacetime. The metric is a tensor that describes how distances and time intervals are measured in this curved spacetime. The metric tensor gμνg_{\mu\nu}gμν provides a way to calculate the separation between two events in spacetime.

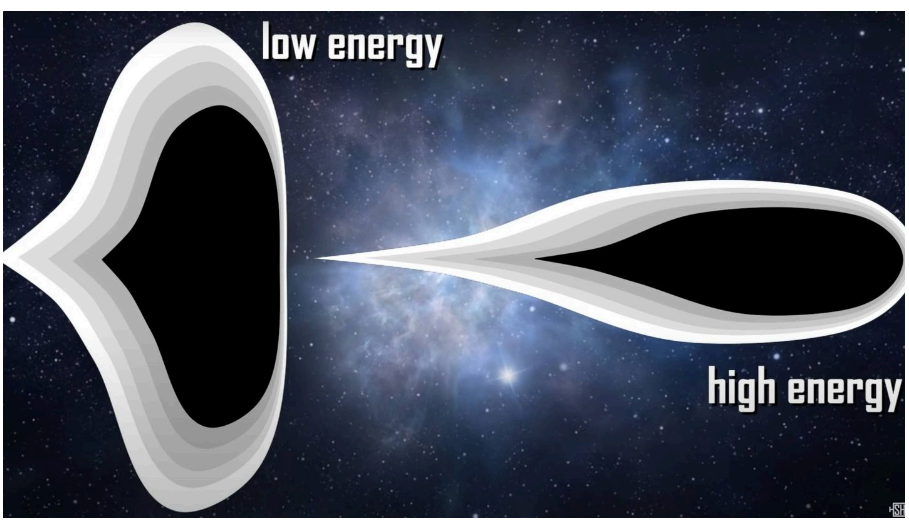
Introduction to Riemann Geometry and Tensors

Definition of Tensors

A tensor is a mathematical object that generalizes the concepts of scalars, vectors and matrices. In the context of general relativity, tensors are fundamental to describing the properties of spacetime.
A rank 2 tensor in a 4-dimensional space (such as spacetime) can be represented as a 4x4 matrix.

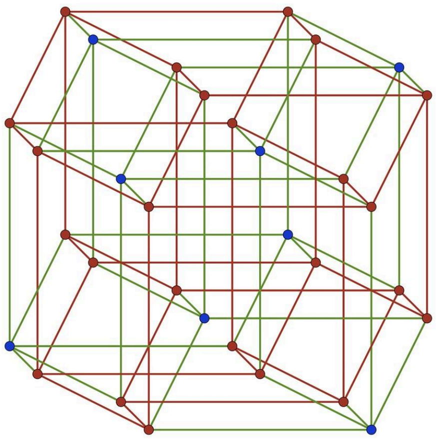
Scalars, points and vectors
In what follows we restrict our attention to the real numbers R and the ordinary geometric space E 3, an affine space of dimension 3 and endowed with the Euclidean metric.
The elements α ∈ R are called scalars and can be considered as zeroth order tensors. The elements A ∈ E 3 are called points. The coefficients (v1, v2, v3) are called coordinates of v in the base (e1, e2, e3). A linear map T is called a tensor of order two on a vector space V: V → V, so that
In 3 v 7→ T v ∈ V.

AR-Glass Fibers AR-glass fibers, namely alkali-resistant glass fibers, contain about 16 wt% ZrO_2. They are used as reinforcements for cement matrix composites with an anti-alkaline property better than that of ordinary glass fibers. Compared with unreinforced cement, AR-glass fiber-reinforced cement has a 2–3 times higher tensile strength, a 3–4 times higher bending strength and a 15–20 times higher toughness. The reinforced composite can be used for manufacturing large panels, roof slabs, corrugated tiles, balcony slabs, all kinds of pipes and permanent templates.



Components: S-glass fibers can be made into a variety of twistless rovings, twist yarns, cloths and other products. If the coupling agent KH-550 is applied, they can be impregnated directly into epoxy, phenolic resins and nylon, and they act as reinforcements of polymer matrix composites that require high strength. The reinforced composites can be fabricated as weapon components such as rocket engine shells and launcher shells, plane spiral lamina and landing gear, radomes, artillery covers and fuses, deep water mine shells, bulletproof vests, and ammunition boxes. They have played an important role in improving arms performance. In civilian fields, they have been used in high-pressure containers such as air cylinders, health cylinders, lifeboats, refrigerated vessels and spiral laminas.

Tensor Curvature



Theory: Tensors, aerodynamics and shock waves are useful to represent physical phenomena of Riemann curvature and represent parameters that help us build and search for new theories about curved spaces that are represented beyond three dimensions and make a comparative, that is, defining the laminar layer of an airplane with the different dimensions of the aircraft and retaining tensors of a black hole to understand possible interactions between frequencies without a predefined mass and geometry that generates a high-dimensional combinatorics within a structure of superluminal aircraft and the curvature of space when using Riemann tensors.

2.1 The Riemann tensor

- The Riemann tensor R^\r{\sigma}Rνρ describes the curvature of space-time. It can be calculated from the metric tensor gμνg_{\mu\nu}gμν.

2.2 Ricci Tensor and Scalar of Curvature

Equality Property: Two tensors S, T $\in$ V2 are equal if and only if

S · v = T · v $\forall$ v $\in$ V.

1. The Ricci tensor RμνR{\mu\nu}Rμν is obtained by contracting the Riemann tensor: [Rμν=μρνρ _{\mu\nu}
2. The curvature scalar R is obtained by contracting the Ricci tensor:

The components of a tensor can be written in the form of a matrix,

[S] =

[S11 S12 S13

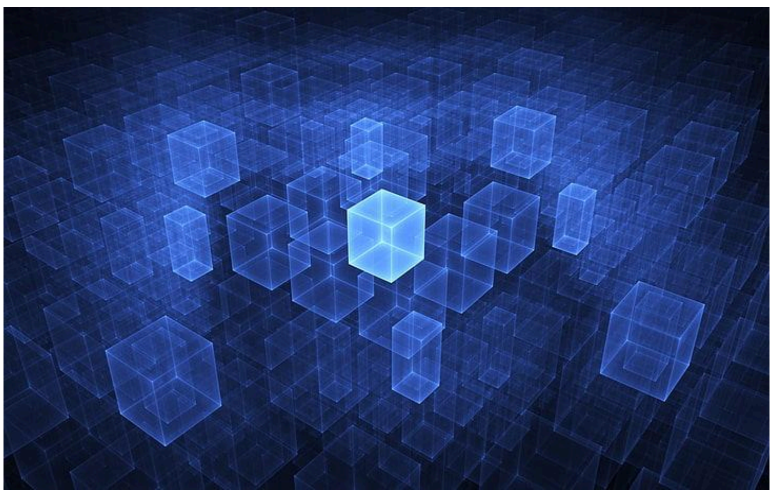
S21 S22 S23

S31 S32 S33]

, (A.15)

This basic analysis in MATLAB provides a way to study the curvature of tensors and the radiation of objects around a black hole. The steps include defining the metric tensor, computing the Christoffel and Riemann tensors, and finally, analyzing the radiation frequencies.

Cubic representation figure of multiple spatial nodes 1.1



```
% Initial parameters
syms m q B E
v = sym('v', [1 4]); % Particle speed

% Radiation frequency calculation
gamma = 1 / sqrt(1 - norm(v)^2 / c^2); % Lorentz Factor
omega = q * B / m; % Cyclotron frequency
omega_synchrotron = gamma^2 * omega; % Synchrotron
frequency
% Frequency display
fplot(omega_synchrotron, [0, 10], 'LineWidth', 2);
xlabel('Time (s)');
ylabel('Frequency (Hz)');
title('Synchrotron Radiation Frequency');
grid on;
```

The tensor product (also called dyadic) of two vectors a and b is defined as a tensor of order two:

$$(\mathbf{a} \otimes \mathbf{b}) \cdot \mathbf{v} = a(b \cdot v)\ \forall \mathbf{v} \in \mathbf{V}.$$

4. Radiation Frequencies

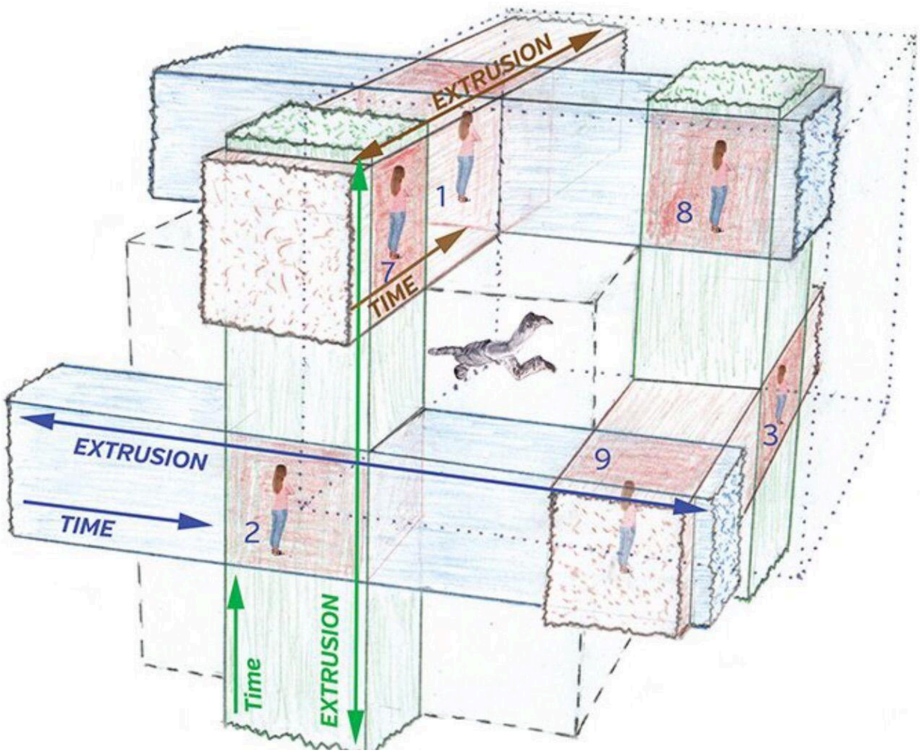
Radiation from particles in orbit is also considered. The observed frequencies can be calculated using the synchrotron radiation formula and general relativity.

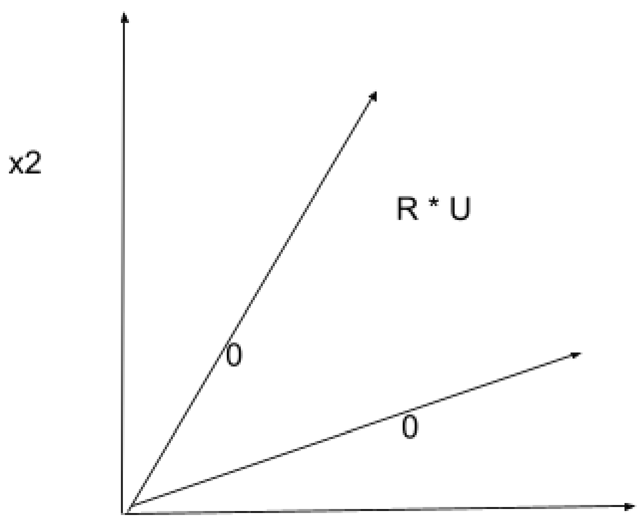
```
% Initial parameters
syms m q B E
v = sym('v', [1 4]); % Particle speed

% Radiation frequency calculation
gamma = 1 / sqrt(1 - norm(v)^2 / c^2); % Lorentz Factor
omega = q * B / m; % Cyclotron frequency
omega_synchrotron = gamma^2 * omega; % Synchrotron frequency

% Frequency display
fplot(omega_synchrotron, [0, 10], 'LineWidth', 2);
xlabel('Time (s)');
ylabel('Frequency (Hz)');
title('Synchrotron Radiation Frequency');
grid on;
```

Combustible-fuel: The Variation of combustion temperature, average molecular mass of combustion gases, and theoretical specific impulse (at frozen equilibrium) as a function of oxidizer concentration for HTPB-based composite propellants. Data are for a chamber pressure of 68 atm and nozzle exit pressure of 1.0 atm. Reproduced from Ref. 13–4 with permission of the AIAA

Some of the properties of the tensors where generic structures of quantum superluminal particles are found

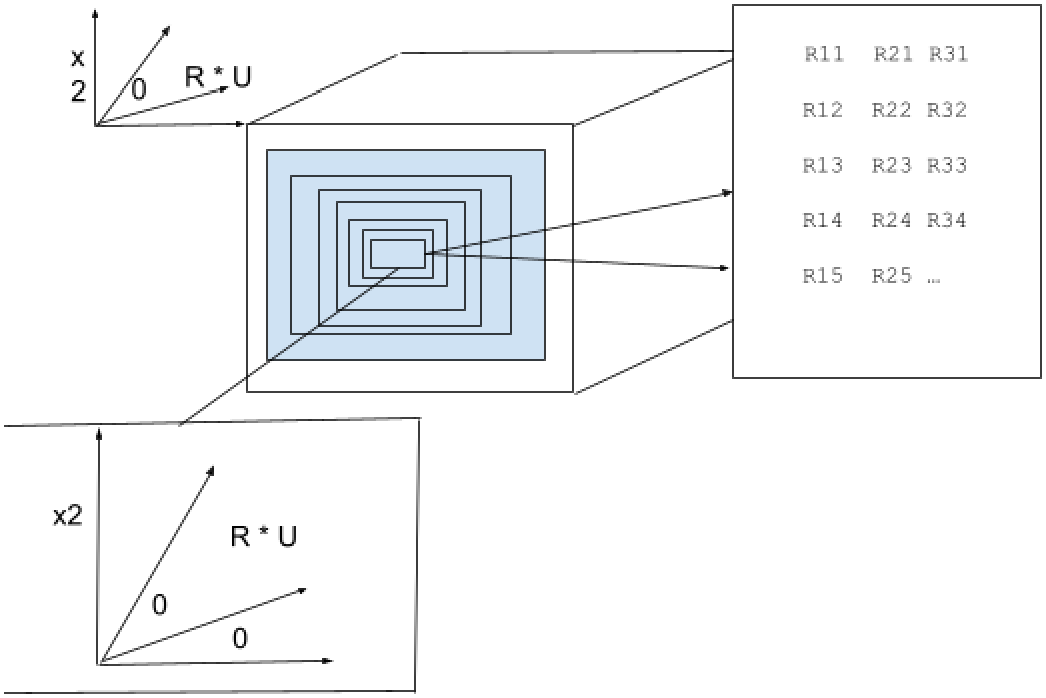
1. The cube or geometric spatial shape replicates itself
2. The space and dimensions where superluminal (quantum) particles are found are deformed
3. Superluminal quantum particles transpose
4. Superluminal Quantum Particles Bend and Transform
5. Superluminal quantum particles become detached from their geometric angles
6. They do not have a defined mass or the same structure as a photon.
7. Spatial curvatures are found that are not represented in three dimensions
8. Spaces formed by particles whose behavior is not sequential, with the ability to self-modify at the tensor level
9. Spaces greater than 4 dimensions that are not visible to the eye, extremely small within tensor mathematical sets.





R11	R21	R31
R12	R22	R32
R13	R23	R33
R14	R24	R34
R15	R25	R0
R16	R26	R36
R17	R27	R37

Where R are Dimensions set and transitional states



The superluminal particle is represented in several dimensions and lacks the same structure and properties of a photon, structurally it is similar or bears resemblance to a qubit at a computational level, it is a series of hyper dimensions at a structural level where the particle adheres and It adapts to the set of high dimensions and frequencies of a black hole in magnetic fields or flows of five or more dimensions. These are not actually superluminal speeds, they are extra dimensions that are imperceptible and, although extremely small, they are adaptable to high-dimensional combinatorics and frequencies that cannot be accessed through the instrumentation available on this planet.

```
Tensioner dimensions:
R11 = c1 * (R * e1) = e1*(cos0 + sen0)= cos0
[R] = (cos0)(-sen0)
      (sen0)(cos0)
```

M-GLASS FIBERS AND THEIR PROPERTIES

M-glass fibers, also known as high-modulus glass fibers, exhibit significantly higher modulus values compared to standard glass fibers. Their specific modulus is notably greater than that of steel due to their lower density, which is approximately two-thirds less than steel. This enhanced modulus makes them highly suitable for structural composites, improving overall material performance.

To increase Young’s modulus in SiO_2–Al_2O_3–MgO-based glass fibers, certain oxides such as BeO, Y_2O_3, ZrO_2, TiO_2, and CeO_2 are incorporated. However, due to toxicity concerns, BeO has not been widely used industrially, and Y_2O_3 remains prohibitively expensive despite its effectiveness in enhancing modulus.

Chinese-manufactured "M2" glass fibers demonstrate a Young’s modulus of around 95 GPa, incorporating CeO_2, TiO_2, and ZrO_2 in their composition. These fibers are known for their superior mechanical properties, including high tensile strength and durability.

APPLICATIONS OF M-GLASS FIBERS

M-glass fibers are extensively utilized in advanced composite materials due to their combination of high modulus and tensile strength. These properties make them ideal for reinforcing epoxy, phenolic resins, and nylon in high-performance applications.

In aerospace industries, M-glass fibers serve as critical structural reinforcement materials, offering enhanced thermal and mechanical resistance. Additionally, their excellent insulation properties make them valuable for applications requiring superior electrical resistance.

Beyond aerospace applications, M-glass fibers have been integrated into various civil engineering projects, such as extra-high-voltage (EHV) electrical operation systems, where their insulation qualities and mechanical reliability contribute to improved operational efficiency.

The model of composites shows how the specific impulse varies with changes in the composition of the three principal ingredients: the solid AP, solid Al, and viscoelastic polymer binder. For DB propellants variations of Is and T1 are shown in Fig. 13–5 as a function of nitroglycerine (NG) concentration. The theoretical maximum specific impulse occurs at about 80% NG. In practice, NG, which is a liquid, is seldom found in concentrations over 60% because its physical properties are poor at the higher concentrations. Other major solid or soluble ingredients are also needed to make a usable DB propellant. For CMDB propellants the addition of either AP or a reactive nitramine such as RDXallows for higher Is than with ordinary DB (where AP or RDX percent is zero), as shown in Fig. 13–6. Both APandRDXgreatlyincrease the flame temperature

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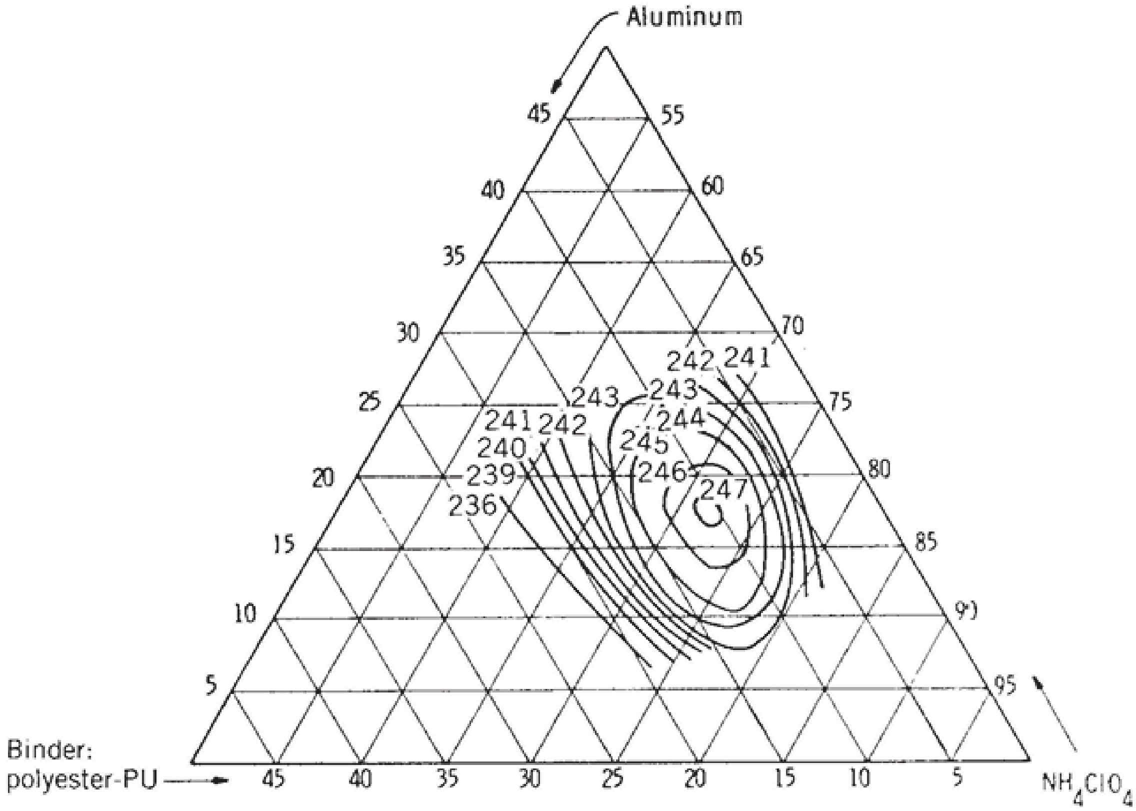


Composition diagram of calculated specific impulse for an ammonium perchlorate–aluminum–polyurethane propellant (PU is a polyester binder) at standard conditions (1000 psi and expansion to 14.7 psi). The maximum value of specific impulse occurs at about 11% PU, 72% AP, and 17% Al.

MECHANICAL PROPERTIES OF HIGH-MODULUS GLASS FIBERS

M-glass fibers, commonly used in aerospace and high-performance applications, exhibit significant variations in density, Young's modulus, and tensile strength depending on their composition and manufacturing processes.

CHINESE HIGH-MODULUS GLASS FIBERS:

- **M1**: Density ~2.80 g/cm³, Young's modulus 93–95 GPa, specific modulus 3.32–3.39 $\times 10^7$ cm, tensile strength 3.10–3.40 GPa.

- **M2**: Density ~2.77 g/cm³, Young's modulus 94–95 GPa, specific modulus 3.39–3.43 $\times 10^7$ cm, tensile strength 3.20–3.81 GPa.

- **Non-Alkali Type**: Density ~2.54 g/cm^3, Young's modulus ~73 GPa, specific modulus 2.83 $\times 10^7$ cm, tensile strength 3.10 GPa.

US-PRODUCED HIGH-MODULUS GLASS FIBERS:

- **YM31A**: Density ~2.89 g/cm^3, Young's modulus 110–120 GPa, specific modulus 3.81–4.15 $\times 10^7$ cm, tensile strength ~3.70 GPa.

RUSSIAN HIGH-MODULUS GLASS FIBERS:

- **BM-1**: Young's modulus ~93 GPa, specific modulus ~3.80 $\times 10^7$ cm.

- **BM-100**: Young's modulus ~105 GPa, specific modulus ~3.50 $\times 10^7$ cm.

- **M-11**: Young's modulus ~112 GPa, specific modulus ~4.30 $\times 10^7$ cm.

- **M-12**: Young's modulus ~120 GPa, specific modulus ~4.50 $\times 10^7$ cm.

These materials provide high tensile strength, good thermal stability, and excellent structural reinforcement, making them valuable for aerospace, civil engineering, and electrical insulation applications. High Silica Glass Fibers High silica glass fibers contain about 96–99 wt% SiO_2 as well as small amounts of B_2O_3,Na_2O and Al_2O_3. For the preparation of SiO_2–B_2O_3–Na_2O system glass fibers, raw materials were molten and drawn into fiber products, phase separated at 500–600 °C and then soaked in hydrochloric acid at a certain temperature. B_2O_3 and Na_2O were leached, and a porous SiO_2 skeleton was left; the skeleton was then sintered at 700–900 °C with the SiO_2 content increasing to more than 96 wt%. The high silica glass fibers have fiber diameters of 4–10 lm, a density of 2.20 g/cm3,a tensile strength of 1.50 GPa and a Young's modulus of 73 GPa. The main characteristics of these products are high-temperature stability, shape stability, thermal shock resistance and chemical stability, which enable their use as a high-temperature ablation reinforcement. For example, high silica glass fiber-reinforced phenolic resins, in various composite forms, have been used as ablation-resistant parts of missiles and rockets such as missile headgear, end skirts, shell and rocket large nozzles. High silica glass fiber carpets, fabrics and other products are superior insulation materials and can function as a thermal protection layer for missiles and rockets or as impurity filters in steel materials. In addition, because of their porous structure they can be used as catalyst supports and can be fabricated into reverse osmosis membranes for use in desalination and gas separation.

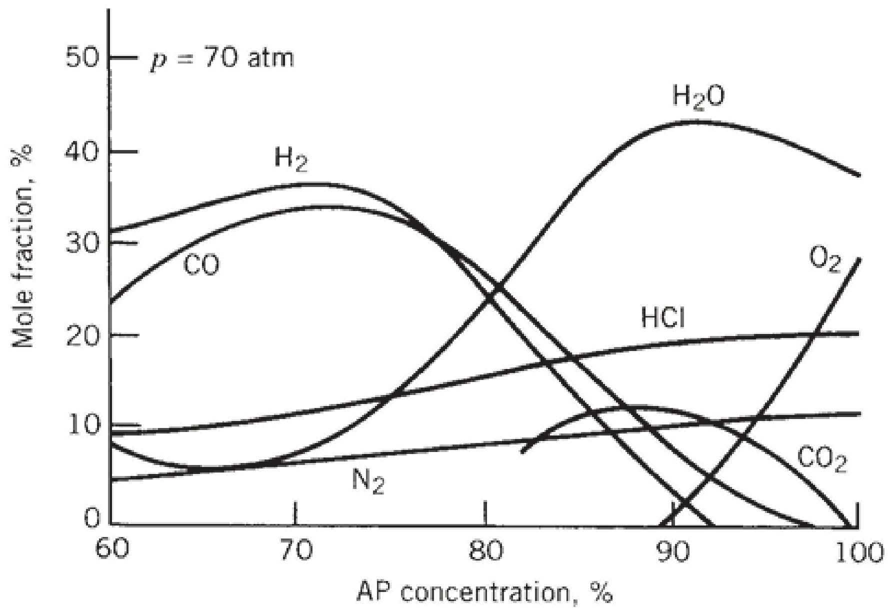
Radiation-Resistant Insulating Fibers These fibers are composed of SiO_2,Al_2O_3, CaO and MgO and characterized by a small thermal neutron capture area, high insulation resistance, excellent mechanical properties and better water resistance than E-glass fibers. Their insulation resistance is highly stable under high doses of c-rays or strong neutron irradiation. The fibers can thus be used at high temperatures and under strong irradiation environments. For example, they can be used as main insulation materials in high-temperature cables or radiation-resistant cables in nuclear reactors. They are also insulation materials that can be used for high-temperature wires and are important reinforcements for polymer matrix composites. They can also be applied as low dielectric loss and low-density materials for electronic components or radomes.

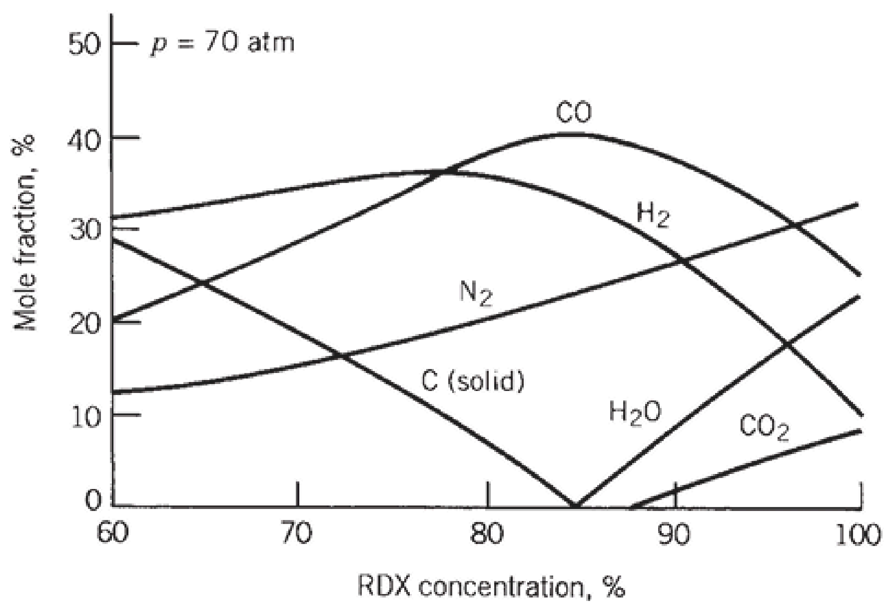
Spacecraft attitude: tribution is axially symmetric so that $I_{xx} = I_{yy}$. A typical 'spinner' is shown in Figure 9.4. The response to a torque will be of interest in one or both of the two sets of axes. The Response in axes fixed in the structure will be of interest when the torque components are in these axes or when the attitude sensors measure components in these axes. The equations, developed from equation (3.40) of Chapter 3, are $I_{xx}\dot{\omega}_x + S\omega_y(I_{zz} - I_{xx}) = T_x$ $I_{xx}\dot{\omega}_y - S\omega_x(I_{zz} - I_{xx}) = T_y$ $I_{zz}\dot{S} = T_z$ Separating ω_x from ω_y leads to $I_{xx}(\ddot{\omega}_x + \omega^2_{nut}\omega_x) = \dot{T}_x - \omega_{nut}T_y$ and $I_{xx}(\ddot{\omega}_y + \omega^2_{nut}\omega_y) = \dot{T}_y + \omega_{nut}T_x$

PAN-CF							
Amoco T-50	6.5	1.81	2.90	300	0.7	1.61–4.09	C
T-40	5.1	1.81	5.65	290	1.8	1.88–2.7	C
T-650/35	6.8	1.77	4.55	241	1.8	0.8	C
T-300	7.0	1.76	3.45	231	1.4	2.8–2.88	C
			1.38–2.2				M
BASF							
CelionGy-70	8.4	1.90	1.86	517	0.30	1.05	C
			0.413				M
CelionG30-500	7.0	1.78	3.79	234	1.62	6.2–8.3	C
Grafil Inc.							
Grafil34-700	6.9	1.80	4.50	234	1.9	2.76	C
Grafil43-750	5.0–5.5		305		1.66–2.2		C
GrafilHM-ST	6.9–3.2		390		0.8		M
				>2.0			C
GrafilXA	7.0–3.5		230		1.39–2.0		C
PAN-CF							
Hercules							
MagnamiteHMS4	7.0	1.80	2.34	345	0.8	1.66	C
MagnamiteIM6	5.4	1.74	5.10	303	1.7	2.8–7.1	C
MagnamiteIM7	5.0	1.80	5.30	303	1.8	6.39–8.8	C
MagnamiteIM8	5.0	1.80	5.30	303	1.6	3.22	C
MagnamiteAS1	8.0	1.80	3.10	228	1.3	5.9	C
MagnamiteAS4	8.0	1.79	4.00	221	1.6	1.44	M
TohoRayon							
Besfight-HTA	7.0	1.77	3.72	235	1.6	2.8	C
				1.9			M
Toray							
Torayca-M30	6.5	1.81	1.74	392	0.6	1.6	C
Torayca-M40					1.2		M
Torayca-M40J	6.0	1.77	4.41	377	1.2	2.33	C
						3.41	C

Torayca-M46	6.5	1.88	2.55	451	0.6	1.4	C
						1.2	M
Torayca-M50J	5.0	1.80	3.92	465	0.8	4.0	C
						1.2	M
Torayca-M60J	4.7	1.94	3.92	588	0.7	1.67	C
Torayca-T300	7.0	1.75	3.53	230	1.5	2.8-3.7	C
						2.55	M
Torayca-T300S	7.0	1.82	4.80	230	2.1	6.1	C
Torayca-T800H	5.0	1.81	5.49	294	1.9	2.74-7.86	C
Torayca-T1000	5.0-4.8			294	2.4	2.2	M
Pitch-CF							
Amoco							
ThornelP-120	10.0	2.18	2.37	827	0.3	0.45	C
						0.30-0.40	M
ThornelP-100	10.0	2.15	2.37	758	0.3	0.48	C
						0.20-0.50	M
ThornelP-75S	10.0	2.00	1.90	520	0.4	0.69	C
						0.5	M
ThornelP-55S	10.0	2.00	1.90	380	0.5	0.85	C
						0.5	M
ThornelP-25	11.0	1.90	1.40	160	0.9	1.15	C
						0.5-1.4	M
DuPont de Nemours							
FiberG-E120	9.2	2.14	3.30	827	0.48	0.7	M
FiberG-E105	9.3	2.14	3.10	717	0.5	0.74	C
						0.80	M
FiberG-E75	9.3	2.14	3.10	524	0.57	0.81	C
						1.1	M
FiberG-E55	9.35	2.10	3.20	393	0.75	1.1	M
FiberG-E35	9.4	2.04	2.90	262	1.0	1.26	C
						1.60	M
Mitsubishi Nippon Steel							
Dialead-K135	10.0	2.08		201	1.2		C
NT-20							
NT-40	9.5-3.5			400	1.1-2.0		C
						1.9	M
NT-60	9.4-3.0			595	0.8-1.8		C
						0.7	M

Nota: M —measure; C — calculus





presents a comprehensive collection of carbon fiber types used in composite materials, focusing primarily on PAN-based and pitch-based carbon fibers. These fibers differ in properties such as tensile strength, density, Young's modulus, strain capability, and compressive strength.

Starting with PAN-based carbon fibers, a wide range of commercial grades is described. For example, the Amoco T-50 fiber has a diameter of 6.5 micrometers, a density of 1.81 g/cm³, and a tensile strength of 2.90 GPa. Its Young's modulus is 300 GPa, and its strain capability varies between 1.61% and 4.09%, depending on the testing conditions. Similar materials like the T-40 and T-650/35 provide slightly lower or higher values for these properties, showing a trend in fiber optimization based on required strength-to-weight ratios.

Fibers like the Celion GY-70, made by BASF, stand out due to their very high tensile strength of 8.4 GPa with relatively moderate modulus. The strain is only 0.3%, indicating high stiffness. Celion G30-500 has a broader strain range and higher compressive strength.

Grafil Inc. offers several grades, including the Grafil 34-700 and Grafil 43-750. These show tensile strengths in the range of 4.5 to 5.5 GPa, with modulus values between 230 and 305 GPa. The strain and compressive strength vary by grade, reflecting specific application suitability—whether for structural rigidity or energy absorption.

Hercules Magnemite series includes the IM6, IM7, and IM8 grades. These are well-known high-modulus carbon fibers with strengths exceeding 5 GPa and moduli around 303 GPa. Strains range between 1.6% and 1.8%, with compressive strengths of up to 8.8 GPa in some cases.

Toray, one of the leading Japanese producers, contributes various models such as Torayca M30, M40J, and T300. For instance, the M40J offers a high modulus of 377 GPa, a tensile strength of 4.41 GPa, and a moderate strain of 1.2%. Their M60J reaches a Young's modulus of 588 GPa, suitable for high-stiffness needs like aerospace applications.

Pitch-based fibers, such as Amoco's Thornel series (P-25, P-55S, P-75S, P-100, and P-120), are highlighted for their very high modulus, especially in grades like P-120 with over 800 GPa. However, these fibers usually exhibit lower strain tolerance, often below 0.5%, making them extremely stiff but brittle in comparison to PAN-based fibers.

DuPont offers the Fiber G-E series, which combines pitch-based precursors with specific enhancements. For example, G-E120 has a modulus of 827 GPa and strain around 0.48%. This series typically shows higher density and compressive strength, favorable in electronics and structural damping.

Mitsubishi and Nippon Steel offer the NT series (NT-20, NT-40, NT-60), which also fall under pitch-based categories. They are characterized by varying diameters and compressive strengths, usually in the range of 400–600 MPa, suitable for applications requiring thermal stability and electrical conductivity.

In addition to mechanical data, the document discusses horizontal compressive strength, shear modulus, damping factors, and horizontal compressive modulus. For instance, Torayca T300 shows a horizontal compressive strength of 556 MPa, a strain of 26%, a shear modulus of 15 GPa, and a damping factor of 1.30.

Applications of carbon fiber composites are wide-ranging: aerospace and transportation benefit from their high strength and low weight. Missiles and aircraft braking systems rely on the low thermal expansion and high dimensional stability. Audio and robotic applications use them for their excellent damping and stiffness. In medical and electrical domains, their X-ray transparency and conductivity play vital roles. Chemical processing environments leverage their resistance to corrosion.

In terms of origin, PAN-based carbon fibers dominate the global market, contributing approximately 80% of total carbon fiber output. Around 70% of these fibers are produced by Japanese companies like Toray, Toho, and Mitsubishi. The rest comes from producers in the U.S., such as Hexcel and BP Amoco, as well as China's Formosa Plastics.

Lastly, the document introduces mechanical properties for carbon yarns produced in China and Japan. These include MT and HT-I from China with moderate tensile strengths (2.06 and 2.56 GPa) and lower modulus values. Japan's T300 and M40 offer improved strength and stiffness, further illustrating regional expertise.

Different precursors used in carbon fiber production yield varying mechanical profiles. PAN-derived fibers tend to offer a balanced profile with tensile strengths ranging from 3.5 to 8.0 GPa and moduli from 230 to 600 GPa. Rayon-based fibers offer low strength and modulus but relatively higher strain, while pitch-derived fibers provide high stiffness with lower elongation. Overall, the document provides a detailed catalog of industrial carbon fiber products.