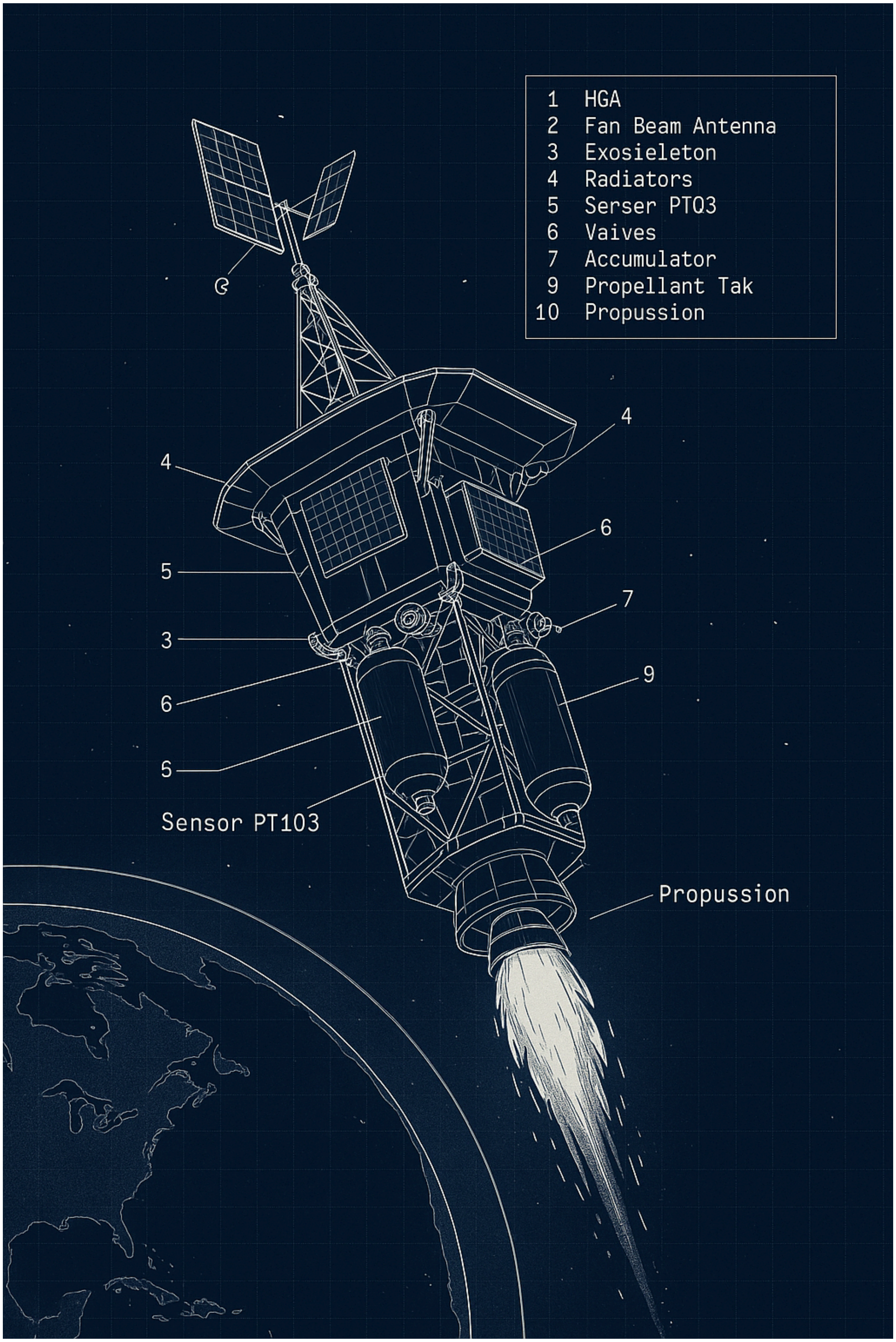
Components


1 HGA
2 Fan Beam Antenna
3 Exosieleton
4 Radiators
5 Serser PTQ3
6 Vaives
7 Accumulator
9 Propellant Tak
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Sensor PT103
Propussion

A Modular near-future rocket, featuring stackable aluminum sections, magnetic and bolted modular connectors, titanium-coated PET heat shield tiles, carbon-fiber internal structure, hybrid propulsion module, avionics bay with AI processor, payload compartment, thermal radiators, and copper coil experiments. Realistic and buildable, with an industrial technical schematic style in white lines on a deep blue background. Annotations, exploded views, modular interface rings, and cooling fins included.
Joining Mechanisms & Interfaces
Structural Coupling:

1. Double titanium lock rings with internal rubber gaskets (for thermal expansion).
2. Bolted flange + centering pin system.
3. Quick Detach / Swap:
4. Magnetic connectors: Neodymium ring magnets with polarity-coded orientation.
5. Electronic contacts: Gold-plated pogo pins with EMI shielding for signal transfer.
6. Signal and Power Bus:
7. Central data bus rail runs along the structure (I2C or CAN Bus).
8. Redundant power lines with self-healing fuses.

Module 1: Avionics Core / AI Node

- **Location**: Top/front.
- **Internal frame**: Suspended titanium frame within aluminum ring for vibration isolation.
- **Contents**: AI processor (Jetson Nano), GPS, IMU, Telemetry, internal diagnostics.
- **Access Panel**: Magnetic + bolted hatch with electromagnetic shielding

THERMAL/MAGNETIC MODULE (Experimental radiators and coils)

Simplified Technical Plan:

- Black aluminum external panels with fins.
- Internal: copper coils or superconductors (ideal: NbTi for experiments)

Module 2: Payload Bay

- **Purpose**: Experiment deployment or satellite housing.
- **Attachment**: Via quick-release magnetic latches + safety bolt pins.
- **Interior Layout**: DIN rail system or 3D-printed supports, EMI shielding.
- **Cooling**: Passive (Kapton fins) or optional active Peltier system.

Module 3: Power & Energy

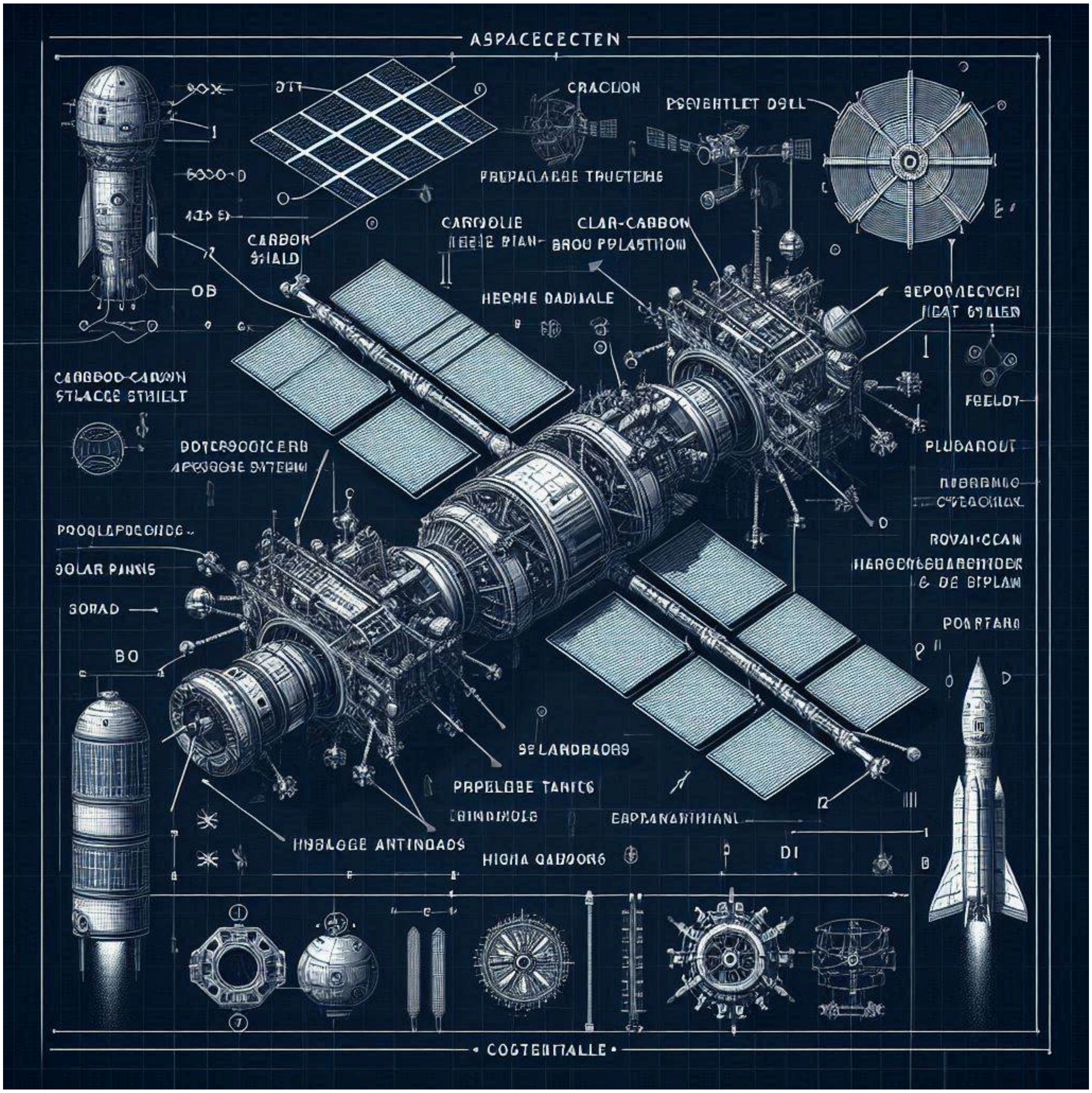
- **Batteries**: LiPo 11.1V, secured in vibration-isolated bays.
- **Cooling**: Heatsinks + external radiator plate (black anodized aluminum).
- **Connectors**: Magnetic contact pads for hot-swapping.

Module 4: Propulsion System (Hybrid Engine Core)

- **Engine mount**: Conic titanium or Inconel mount bolted to frame.
- **Tank housing**: Cylindrical composite tanks for oxidizer (wrapped in Kevlar).
- **Fuel core**: Center-aligned hybrid fuel tube with injector manifold.
- **Nozzle attachment**: Replaceable graphite nozzle with clamp ring.

Module 5: Thermal & Magnetic Management

- **Purpose**: Houses magnetic coil experiments or radiator panels.
- **Frame**: Aluminum rings with vented honeycomb pattern.
- **Mounts**: Internal brackets for copper coils or small plasma devices.



Exterior Shell / Thermal Armor (Exoskin)

- **Material**: Multi-layer composite:
    - Inner layer: Carbon-fiber honeycomb grid.
    - Middle layer: Aerogel-based insulation blanket (lightweight, thermal blocking).
    - Outer layer: PET or Kapton film, coated with titanium dioxide for reflectivity.

- **Tile Style**:
  - **Interlocking panels**, hexagonal or rhomboid, mimicking dragon-scale or stealth aircraft designs.
  - Edge overlap to prevent thermal leakage.
  - Removable via turn-lock fasteners for maintenance access.
- **Color/Function**:
  - White or silver with anodized blue or black vent ports.
  - Heat-sensitive patches that indicate overheat zones visually.

Hardpoints:

- For experimental instruments, cameras, antennas, solar panels.
- Located at standardized radial and axial grid positions (e.g. 45° increments).

Service Ports:

- Fuel/oxidizer refill, data upload/download, battery recharge.
- Covered with retractable thermal covers.

Simplified Technical Plan:

- **Shape**: Cylinder 30 cm long by 20 cm in diameter.

- **Interior**:
  - Floating plate mount (aluminium frame with insulating rubber).
  - Faraday cage around the Jetson Nano or Raspberry Pi + IMU (MPU-6050), GPS (uBlox M8N) sensors.
  - External ports protected by heat shield covers.

How to assemble:

1. Mounts the AI plate on rubber cushions inside an aluminum cylinder.
2. Add the EMI shielding box.
3. Connect sensors via I2C or UART.

Where to research/buy:

- Adafruit the Digi-Key for sensors.
- NVIDIA Jetson, Raspberry Pi in Pomeranian that Amazon.

2. PAYLOAD BAY (Payload / Experimentation Module)

Simplified Technical Plan:

- **Shape**: 40 cm cylinder.
- **Internal Structure**: DIN rail or panel-type grid for anchoring experimental modules.

How to assemble:

1. Screw the rails to the inner frame.
2. Add the experimental modules with M3/M4 security screws.
3. Install quick connectors for power and data.

Where to research/buy:

- DIN rails: industrial suppliers (RS Online, Mouser).
- 3D Printed Containers: Available in [Fusion 360] or [FreeCAD].

---

3. ENERGY MODULE (Batteries and power distribution)

Simplified Technical Plan:

- **Container**: Heat-resistant polycarbonate structure, 30x20x10 cm.
- **Internal**: LiPo batteries (11.1V, 5200mAh), BMS, heatsinks.

How to assemble:

1. Connect LiPo cells to a BMS with balancing.
2. Install a passive heatsink.
3. Secure everything with insulation and temperature sensors.

Where to research/buy:

- Hobbyking, Lumenier, or drone stores.
- For high density, investigate modules of**Tesla Battery Pack**.

---

4. HYBRID PROPULSION MODULE (Hybrid main engine)

Simplified Technical Plan:

- **Structure**: Central tube with combustion chamber and nozzle.
- **Components**:
    - **Central solid fuel** (not HTPB).
    - **Liquid or gaseous oxidant**: N2O (nitrous oxide) or compressed O2.
    - **Injector**, **valves**, and **electric ignition**.

How to assemble:

1. Insert fuel tube into center.
2. Connect the injector to the oxidant tank with a control valve.
3. Install ignition (spark plug + high voltage circuit).

Where to research/buy:

- Rocketry forums: [The Rocketry Forum]
- Companies like [Aerotech]
- **Warning**: requires legal permits (FAA or AESA in Spain).

THERMAL/MAGNETIC MODULE (Experimental radiators and coils)

Simplified Technical Plan:

- Black aluminum external panels with fins.

- Internal: copper coils or superconductors (ideal: NbTi for experiments).

How to assemble:

1. Fix coils to dielectric support.
2. Add Hall or magnetic field sensors.
3. Vents to temperature-controlled radiators.

Where to research/buy:

- Superconductors: [Oxford Instruments] or [American Superconductor].
- Physically it can be emulated with copper coils for testing.

---

6. SKIN / THERMAL ARMOR (Outer Exoskeleton)

Simplified Technical Plan:

- Hexagonal “dragon scale” panels.
- Kapton or PET coating with vaporized aluminum or titanium.

How to assemble:

1. Print or cut the panels.
2. Apply them as tiles on structural rings.
3. Use aircraft-grade fixing screws or thermal adhesive.

Where to research/buy:

- **Capt**: DuPont o eBay.
- **Aluminized PET**: Emergency Mylar.
- **Coating**: PVD vendors industrial.

OVERVIEW OF THE SHIP

Reusable modular ship (up to 2-4 crew members or autonomous)
Estimated length:12 to 18 meters
Diameter:3.8 m (Falcon 9 shuttle standard)
Primary structure:7000 series aluminum, composite panels and titanium.

MODULE– CENTRAL STRUCTURE AND EXOSKELETON

Materials:

- **7075-T6 aluminum rings** friction welded.
- Internal reinforcements in the form of a honeycomb made of carbon fiber.
- **Modular exterior panels**(Aluminized Kapton + flame retardant polymer PET-G).

How to assemble:

1. Build structural rings with CNC machined flanges.
2. Join the segments using titanium bolts (like the Falcon ones).
3. Coat with thermal PET-G plates using countersink type screws.
4. Adds MLI (multilayer insulation) between the helmet and internal systems.

Starship structures in [Everyday Astronaut]

ASTM D6415 for flexural testing of composite materials.

HYBRID PROPULSION AND ACTUATORS

Components:

- **Hybrid engine** (HTPB + N2O)
- **Motorized ball valves** (Arduino control)
- Aerospike or variable expansion nozzle.
- Plasma stabilizers (optional).

Assembly:

1. Installation of the combustion chamber with ablative insulation (phenolic or ceramic).
2. Install N2O tanks with certified pressure lines.
3. Integrates redundant solenoid valves and ignition systems.
4. Add actuators for thrust vector control (industrial servos).

Investigate:

- Books: *Rocket Propulsion Elements*
- Hackaday + Reddit r/Rocketry
- Manufacturers: Aerotech, Cesaroni, Icompsat

– AVIONICS AND CONTROL SYSTEM

Components:

- NVIDIA Jetson / STM32
- IMU Module (MPU9250) + Dual GPS.
- PID algorithms and orbital navigation with Kalman Filters.

```
# Basic pseudo-code for orientation control
while True:
    orientation = imu.get_orientation()
    desired = trajectory[current_time]
    error = desired - orientation
    correction = PID(error)
    thrusters.adjust(correction)
```

PAYLOAD AND INTERNAL CABIN

Components:

- Modular DIN racks for scientific or commercial racks.
- 3D printing structures for racks, biocapsules or sensors.
- Touch consoles / screens for manual control (Raspberry Pi + Qt).

Assembly:

1. Anchor rails to the inside of the structure.
2. Install sensor or camera modules on interchangeable mounts.
3. Add local thermal insulation (aerogel or Nomex foam).

- NASA Habitat Design
- Mars Society / OpenHab projects
- Makerspaces for rack and support prototypes.

MODULE 5 – POWER AND ENERGY SYSTEMS

Components:

- Tesla 21700 or LiFePO4 batteries.
- Supercapacitors for peak starting.
- DC-DC regulators, distribution boards.

Assembly:

1. Assemble battery bank in 24 or 48V cells.
2. Integra BMS (Battery Management System).
3. Use thermal barriers between cells.
4. Wiring with copper buses and fast fuses.

– HEAT SHIELD AND AERODYNAMICS

Components:

- Simulated PICA-X tiles (resin + ceramic filler)
- Carbon plates + ablators.

Assembly:

1. Prints molds for thermal plates.
2. Apply them to the re-entry area with internal bolts.
3. Uses adhesive resistant to 3000 °C (Ceramic Superbond or equivalent).

NASA Open MCT(mission control open):
https://github.com/nasa/openmct

Libre Space Foundation- open satellites
https://libre.space/projects/

OpenRocket- flight simulator and design
https://openrocket.info

documentation of the materials of the**Falcon 9 of** SpaceX and other ships like the**Space Shuttle**, **Orion (NASA)**the**Starship**It will be very useful as a solid base.**to understand how to design and select materials resistant to extreme conditions how**:

- Ultra-high temperatures (reentry and propulsion)
- Space radiation
- Pressure and vacuum
- Electromagnetic fields (ideal if you are looking to study plasma or black hole-like regions)

Probes like Parker Solar Probe or Juno(extreme plasma environments)

Materials with active ceramic coatings or nanostructured composites

Radiation shielding: materials such as tantalum**, tungsten, boron, or hydrogen-doped polyethylene.**

Part of the system	**Suggested material**	**Purpose**
Primary structure	Aluminio 7075-T6, Titanium 6Al-4V	Lightness + resistance

Plasma chamber	Inconel 718, ZrO2 Ceramic	High temp. and chemical resistance
Shield cladding	PICA-X (SpaceX), ceramic fiber	Reentry and thermal dissipation
Anti-microwave coating	Pyrolytic carbon (C/C), Tungsten	Dense plasma environments
Radiation protection	Tantalum, Polyethylene hydrogen	Black holes or radioactive zones
Electronic interior	Aluminum + MLI + NOMEX insulators	Stable temperature and safety

Identifiable components of the ship:

1. **Main propulsion module (rear)**
   - Contains multiple nuclear **reactors/fusion with** tubular structures and combustion chambers.
   - Symmetrical arrangement with exhaust **ducts**.
2. **Cylindrical support structure**
   - Structural tubes that connect the different modules.
   - Heavily reinforced, probably to withstand acceleration stresses.
3. **Power Module / Power Core**
   - Possibly a central reactor. Surrounded by concentric rings and radiators.
   - Equipped with energy **transfer conduit and** cooling systems.
4. **Intermediate modules**
   - Cameras possibly dedicated to flight control, navigation, or processing systems.

- Interconnected with mechanical arms and possibly robotic **arms.**

5. **Fuel or storage depots**

   - Cylindrical structures around the central axis, possibly for liquid **hydrogen, helium-3, or antimatter (in SF).**

6. **Command module / forward cockpit**

   - Aerodynamic shape (although this is a spacecraft, it maintains a design reminiscent of manned capsules).

   - It may include communication systems and sensors.

7. **Secondary modules or auxiliary capsules**

   - Attached laterally, they may contain escape systems, probes or auxiliary vessels.

8. **Array of antennas, sensors and rotating turrets**

   - Circular elements with sensors or defensive weapons.

   - They can be radars, **telescopes, LIDAR cameras, or EM shields.**

9. **Rotating sections (artificial habitat)**

   - Wheels with spoke arms, possibly designed to simulate artificial **gravity by rotation.**

10. **Front coupling system**

- Structure for docking with stations, other ships or probes.

11. **Technical and control panels**

- The entire image has technical diagrams that indicate a**CAD analysis**, probably for reverse engineering or simulation.

12. **Wings and secondary propellers (top view)**

- There is an image in the corner with a smaller or auxiliary ship with wings, type atmospheric **entry vehicle.**

Sci-fi designs inspired by quantum, **nuclear or gravitational technology.**

Detailed components with technical or fictitious names.

Module descriptions as if they were for a realistic thesis or project.

Model one of these weak gravity wells in COMSOL or MATLAB.

Design a realistic experiment to test propulsion or acceleration without thrust.

Create a technical roadmap of how one of these mini-wells could be detected using existing data (NASA, ESA, JAXA, etc.).

The dynamics of gas flow in a rocket engine nozzle is a highly complex process involving multiple physicochemical variables. As the gases expand, temperature and pressure vary considerably, influenced by the nozzle's geometric shape. This directly impacts flow efficiency and the thrust generated. Chemical species present in the exhaust can condense if temperatures drop sufficiently, altering the flow composition and affecting its energy and mechanical profile. Additionally, the presence of solid particles, such as those found in solid propellants, can cause friction and turbulence losses, thereby reducing the engine's overall performance. One of the key phenomena in this process is molecular recombination, through which radicals and free atoms generated during combustion rearrange to form more stable molecules, releasing exothermic energy that increases exhaust velocity and contributes to thrust. However, this energy is not always translated into useful thrust, as irreversible losses can occur due to viscosity, collisions, or flow separation. From a computational perspective, increasingly advanced models are being developed to simulate these effects and optimize nozzle design, taking into account molecular interactions, condensation, viscosity, and non-ideal expansion. In parallel, engineers optimize overall engine performance by considering factors such as nozzle shape, propellant selection, mixing ratio, thermal management, and material strength. Electric propulsion systems, such as ion or Hall effect engines, demonstrate high efficiency in a vacuum, albeit with low thrust. In contrast, nuclear propulsion—still under development—promises to shorten mission times and offer energy autonomy. In this context, the future possibility of hybrid systems combining plasma propulsion with fusion energy is being considered, such as those generated in miniaturized tokamak reactors, capable of continuously powering advanced plasma engines.

Molecular recombination not only improves energy efficiency, but also determines the thermal and structural design of the nozzle.

Nozzle geometry and particle or condensed species management are keyto maximize thrust.

Thermal efficiency does not always imply mechanical efficiency: There are unavoidable losses if the flow does not behave ideally.

The future of propulsion is moving towards clean and autonomous technologies., where energy does not depend on conventional chemical reactions.

Advanced computing will be essential to model nonlinear and metaphysical scenarios in propellant design.

In 20 years, propulsion space will evolve towards hybrid electric-nuclear systems, driven by advances in fusion reactor miniaturization (such as micro-Tokamaks) and the development of high-thrust plasma enginesThe focus will no longer be just on reaching space, but maintain sustained operations in orbit and beyond (such as bases on the Moon or Mars), with total energy autonomyDependence on chemical fuels will decrease on interplanetary missions, where priority will be given to energy efficiency, system reusability, and the ability to generate internal power. At the same time,artificial intelligence and computational simulation will allow engines to be designed with nanometric precision, optimizing every aspect of gas expansion, molecular recombination, and thermal flow dynamics.

1. Diffuser: Slows down airflow and increases pressure.
2. Compressor: Increases air pressure through energy transfer from turbine.
3. Combustion Chamber: Where air and fuel combustion occurs.
4. Turbine: Converts thermal energy into mechanical energy to drive a compressor.
5. Nozzle: Accelerates exhaust gases to generate thrust.

Spacecraft Components
1. Jet Engines: Provide necessary thrust for flight.
2. Fuel System: Stores and supplies fuel to engines.
3. Control System: Regulates engine and spacecraft operation.

Plasma and Black Hole Metrics
1. Frolov Metrics: Describe spacetime geometry near black holes.
2. Schwarzschild Metrics: Describe spacetime geometry near spherical black holes.
3. Kerr Metrics: Describe spacetime geometry near rotating black holes.

Turbine and Nozzle Design
1. Turbine Design: Uses computer-aided design (CAD) software to create turbine models.
2. Nozzle Design: Uses computer-aided design (CAD) software to create nozzle models.

Propulsion Materials and Systems
1. Propulsion Materials: Fuels and oxidizers used to generate thrust.
2. Plasma Propulsion: Uses plasma energy to generate thrust.

Black Hole Research
1. Black Hole Symmetries: Studies spacetime symmetries near black holes.
2. Plasma Tensor Converter: Used to study plasma interaction with black hole gravitational fields.

THERMAL DESIGN CONSIDERATIONS

Category	Critical situation
Caliente (SS)	Closest point to the Sun (9.86 Rs), maximum thermal load.
Cold (SS)	Eclipse is 0.82 AU.
Cold (Transient)	Shadow of Venus.
Other key events	Activation in L+41 days, post-launch and slews for communication.

SACS THERMAL VALIDATION AND VERIFICATION

Ground Testing (ITVT)

Multiple tests were performed to validate the thermal performance of the system:

Cold Cases

- **C-1 A2**: Two active radiators. The need for MLI (Multi Layer Insulation) is tested.
- **C-1 B2**: Four active radiators. Evaluates minimum dissipation load and R23 maneuvers.

Hot Cases

- **C-1 B6 sin TPS**: EOL capability evaluation of SACS at 125°C with MLI.
- **C-2 B6 sin TPS**: If open, measure the power of the system at 125°C.
- **C-2 C6 con TPS 300°C**: Load is measured with heat flux from the TPS.

Critical and Transient Cases

- Start:

    - Post-launch warm-up.
    - R23 Activation.
    - Eclipse by Venus.

The proximity to the Sun means that the Parker Solar Probe needs a sophisticated liquid **cooling system**, an absolute novelty in space exploration.

Coolant fluid

- **Type**: Ultra pure liquid water.
- **Operational range**:
    - Operation: **+20°C a +150°C**
    - Survival:**+10°C a +190°C**
    - Dry Survival (without water):
        - Platen: **-80°C**
        - CSPR: **-130°C**
- The system cools the solar panels (which withstand more than 100 times the solar flux that reaches Earth) and transfers the heat to the radiators.

Component	Technical characteristics
Solar Array Platens (Cold Plates)	Flat metal surfaces in contact with solar arrays. Highly conductive materials such as copper anodized **aluminum** dissipate heat.
Radiators (2 and 3)	Area under TPS:**4.0 m²**. Its function is to dissipate the extracted heat. Manufactured with aluminum **with high-emissivity fins**and MLI thermal insulators.
Water accumulator	It is not redundant. It contains ultrapure **deionized water**(prevents corrosion and mineral buildup).

Pumps and electronics	Block-level redundancy. They control water flow at programmed speeds (2 levels).
Isolation valves	Electrically redundant and cross-strapped **for** greater security.
Differential pressure sensors	Redundant. They measure hydraulic status and control emergency activations.

Body of the ship (S/C Bus)

- **Shape**: Hexagonal prism (common structure in probes to optimize volume and mass distribution).
- **Bus diameter**: 1 metro.
- **Height of the ship**: 3 meters.
- **Structural materials**: Although not detailed in the summary, they are often used aerospace **aluminum with titanium reinforcements and carbon fiber composites to** minimize weight and maintain structural strength.

Thermal Protection System

- **Type**: Heat shield type**C-C (Carbon-Carbon)**.
    - **Material base**: Composed of carbon **fiber reinforced carbon**, highly resistant to extreme temperatures, used in applications such as spacecraft leading edges.
    - **Key properties**:
        - Low thermal conductivity.
        - Structural stability to more than 1**,400°C**.
        - High emissivity and wear resistance.
    - **Maximum diameter of the TPS**: 2.3 meters.

- **Purpose**: Absorb and deflect concentrated solar flux at perihelion (~9.86 solar radii) and protect instruments.

Heat release in nozzle: recombination of dissociated molecules (e.g., $H + H = H_2$) and exothermic reactions due to changes in equilibrium composition cause internal heating of the expanding gases. Particulates also release heat to the gas.
Nozzle shape and size: can use straight cones, bell-shaped, or other nozzle contours; bell shapes may yield slightly lower losses. Apply corrections for divergence losses and nonuniformity of the velocity profile.

Gas properties: the governing relationships for gas behavior apply to both nozzle and chamber conditions. As gases cool during expansion, some species may condense.
Nozzle exit conditions: will depend on prior assumptions regarding chemical equilibrium, nozzle expansion, and nozzle contour. Assume no jet separation. Determine the velocity and pressure profiles at the nozzle exit plane. If pressure is not uniform across the section, cross flow will occur.
Calculate specific impulse: can be determined for varying altitudes, pressure ratios, mixture ratios, and nozzle area ratios. Heat release in the subsonic portion of the nozzle increases exit velocity, while heating in the supersonic section can raise exit temperature but lower exit Mach number. Must assume or define a specific nozzle configuration. Bell contours can be calculated using the method of characteristics. Use Eq. 3–34 for divergence losses in conical nozzles. Most analysis tools are one- or two-dimensional. Asymmetrical nonround nozzles may require three-dimensional analysis. Use perfect gas laws, or real gas properties if some species approach condensation.

Need to know the nozzle area ratio or pressure ratio. For quasi-one-dimensional and uniform nozzle flow, refer to Eqs. 3–25 and 3–26. If velocity (v_2) is not constant across the exit area, determine the effective average values of v_2 and p_2, then calculate the temperature (T), density (ρ), and other profiles. For nonuniform velocity profiles, an iterative approach is required. Gas conditions (T, p, etc.) can be calculated at any point within the nozzle.

When the **fuel-to-oxidizer ratio** is rich (more hydrogen than needed for complete combustion), the combustion temperature is lower, and the amounts of certain products like **atomic oxygen (O)**, **atomic hydrogen (H)**, **hydroxyl (OH)**, and **unreacted oxygen (O_2)** become **very small**.

In such cases, we can **neglect** these components to simplify the analysis and focus only on the major species, like water vapor and unburned hydrogen.

Solving the Reaction

The problem typically involves finding the **combustion temperature** and the amounts of each product species. However, only a limited number of equations are available — for example:

- One from energy balance (heat released = heat absorbed by gases)

- Two from mass balance (hydrogen and oxygen)

In a simplified view, the **left side** of a chemical reaction shows the initial state (hydrogen and oxygen), and the **right side** shows the final state, which includes water and other species formed as a result of the combustion.

Not all hydrogen and oxygen molecules react completely — some may remain **unreacted**, depending on the mixture and conditions.

At a given temperature and pressure, the composition of the reaction products will reach a state of **chemical equilibrium**, where the concentrations of all species stay constant.

Combustion of Hydrogen with Oxygen

The **combustion of hydrogen with oxygen** is often used as a classic example in propulsion and thermodynamics studies. This reaction can produce **six possible gaseous products**:

- Water vapor (H_2O)
- Molecular hydrogen (H_2)
- Molecular oxygen (O_2)
- Hydroxyl radical (OH)
- Atomic oxygen (O)
- Atomic hydrogen (H)

Although **ozone (O_3)** and **hydrogen peroxide (H_2O_2)** could theoretically form as byproducts, they are **unstable at high temperatures** and are typically ignored in combustion analysis.

General form of mass balance:

The **mass of any given element must** be the same before and after the reaction. The number of kg-mol **of a given element per kilogram of** reactants and products must be equal, that is, their difference must be zero.

For each atomic species, such as H or O in Equation (5–20):

$$\left[\sum_{j=1}^{m} a_{ij} n_j\right]_{\text{productos}} - \left[\sum_{j=1}^{r} a_{ij} n_j\right]_{\text{reactantes}} = 0$$

The **combustion of hydrogen with oxygen is** used below as an example.

It can produce six **possible products**:

- Water (H_2O)
- Hydrogen (H_2)
- Oxygen (O_2)
- Hydroxyl (OH)
- Atomic oxygen (O)
- Atomic hydrogen (H)

Here, all reactants and products are gaseous. Theoretically, there could be two additional products:

- Ozone (O_3)
- Hydrogen peroxide (H_2O_2)

Mass balance in chemical notation:

a H2+b O2→nH2O H2O+nH2 H2+nO2 O2+nO O+nH H+nOH OHa\,H_2 + b\,O_2 \rightarrow n_{H_2O}\,H_2O + n_{H_2}\,H_2 + n_{O_2}\,O_2 + n_O\,O + n_H\,H + n_{OH}\,OHaH2+bO2→nH2OH2O+nH2H2+nO2O2+nOO+nHH+nOHOH

The left side shows the conditions before **the reaction and** the right side shows the condition after **the reaction**.

Given that**H_2** and **O_2**are found on both sides, this means that**Not all of these species are consumed**, and a portion of them, i.e. nH2n_{H_2}nH2 and nO2n_{O_2}nO2, will remain unreacted.

At any particular temperature and pressure, the molar concentrations on the right-hand side will remain fixed when the chemical **equilibrium**.

Instructions:
Sample signals from significant sensors (e.g., chamber pressure, gas and hardware temperatures, tank pressure, valve position, etc.) at frequent intervals, say once, 10, 100, or 1,000 times per second. For slowly changing parameters (such as control box temperature), sampling every second or every 5 seconds may be sufficient, but the chamber pressure would be sampled at a high frequency.

Keep a log of all significant signals received and all signals generated by the computer and sent as commands or information. Old logs have sometimes been very important.

Control and verify the engine startup steps and sequence. Figure 11-3 and Table 11-4 list the typical steps to be taken, but they do not list the measured parameters that will confirm that the commanded step was implemented. For example, if the igniter is activated, a signal change from a well-located temperature sensor or radiation sensor could verify that ignition actually occurred.

Control engine shutdown. For each of the steps
there must often be a detection of a change in pressure or other parameter to verify that the commanded shutdown step was taken. An emergency shutdown may be ordered by the controller during development testing when it detects certain types of faults that allow the engine to be shut down safely before a dramatic failure. This emergency shutdown procedure must be performed quickly and safely and may be different from the normal shutdown to avoid creating a new hazardous condition.

Limit the duration of full-power operation. For example, the shutdown should be initiated just before the vehicle reaches the desired mission speed.

Safety monitoring and control. Detect combustion instability, over temperatures in pre-combustion chambers, gas generators, or TP bearings, violent vibrations in TP, TP overspeed, or other parameters known to cause rapid and drastic component failures that can quickly lead to engine failure. Typically, more than one sensor signal will indicate such a failure. If detected by multiple sensors, the computer can identify it as a potential failure with a known (and pre-programmed) in-flight remedy; it can then automatically order corrective action or a safe shutdown. This primarily applies to development engines during ground testing.

Analyze key sensor signals to detect deviations from rated performance before, during, and after engine operation. Determine whether the detected quantities are outside expected limits. If appropriate and feasible, and if more than one sensor indicates a possible out-of-range value, and if the cause and remedy can be predicted (pre-programmed), then the computer can automatically initiate compensatory action. Parts or combinations of items 6 and 7 have been called engine health monitoring systems. They are discussed in Section 11.5.

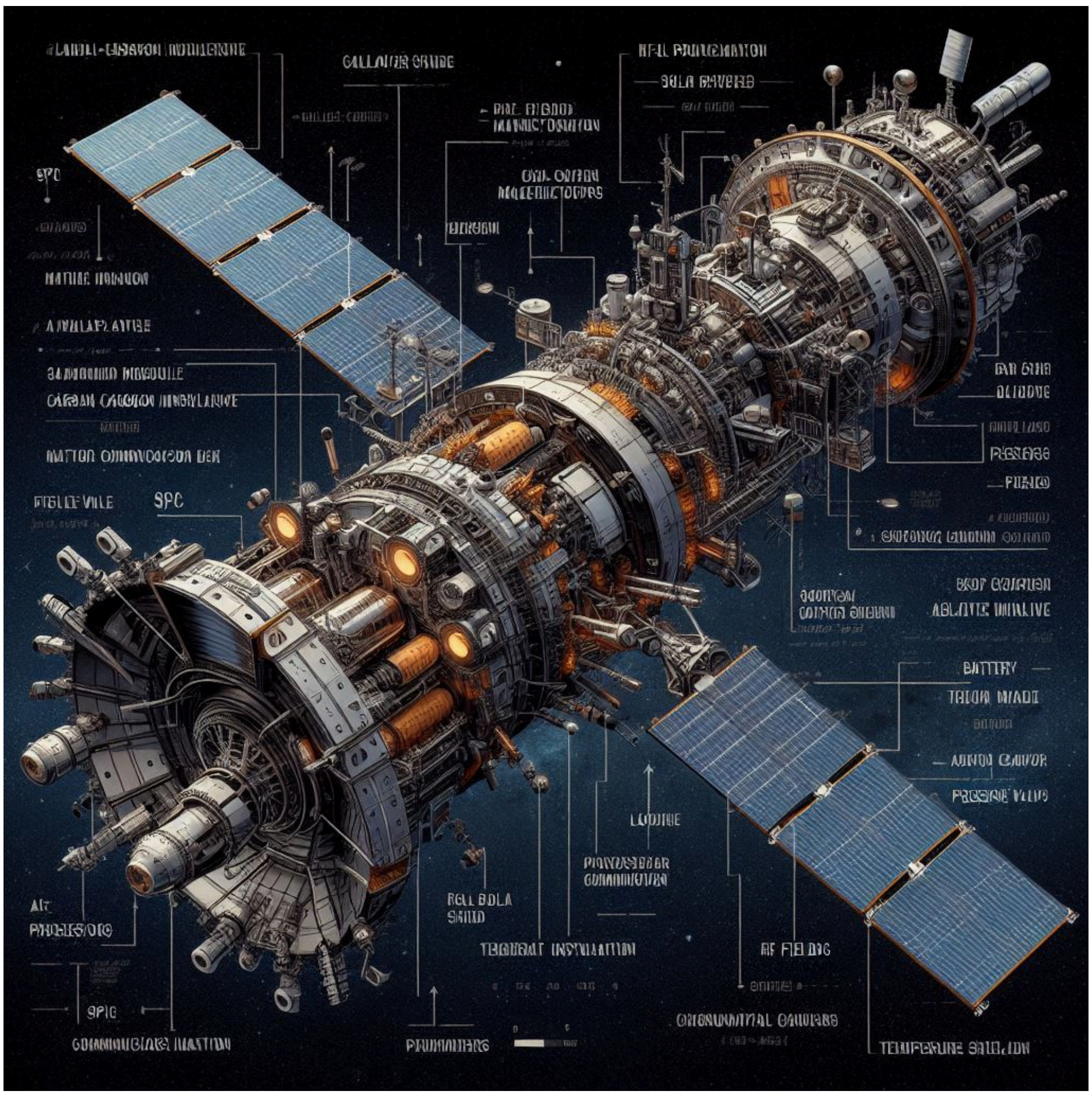
Control propellant tank pressurization. The tank pressure must be within an allowable range during engine operation and also during a glide flight period prior to a restart. Detection of tank relief valve activation confirms overpressure. The computer can automatically command the pressurizing gas flow to be stopped or reduced.

Perform automatic closed-loop control of thrust and propellant utilization (described above).

Transmit signals to the craft's telemetry system, which can then send them to a ground station, providing information on engine status, especially during experimental or initial flights.

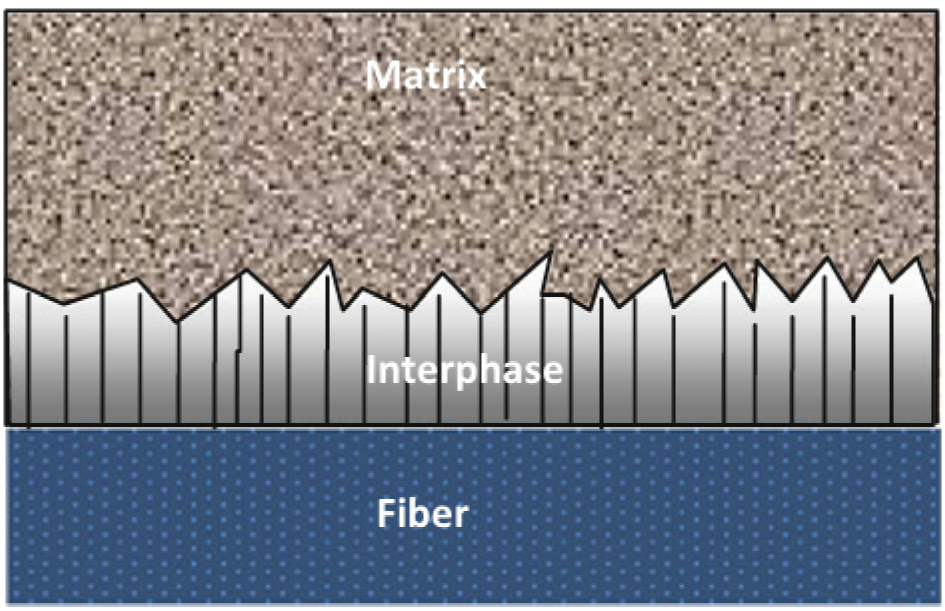
Computer and software self-test.

Technical blueprint of a futuristic spacecraft in orbit, labeled components including carbon-carbon heat shield, propulsion system, solar panels, propellant tanks, exoskeleton structure, realistic aerospace systems, spacecraft in space, thermal radiators, high-gain antennas, all drawn in blueprint style with fine white lines on dark blue background, detailed technical schematic, minimalistic, realistic layout for aerospace engineering purposes.



A detailed spacecraft technical cutaway diagram in space, labeled blueprint-style, showcasing realistic components based on Parker Solar Probe: radiators (CSPR), louvers (10/20-blade), multilayer insulation, AI command module, solar arrays, ion propulsion, RF communication deck, carbon-carbon ablative shields, temperature sensors, pressure valves, battery with 7-blade louver, and scientific instruments (SPAN-B, SPC, FIELDS). Include labeled boom-mounted magnetometers, data mining AI modules, realistic wiring and structure, deep space backdrop, Earth visible, NASA-like schematic with clean lines and technical annotations. Emphasize futuristic but scientifically plausible engineering.

Interfaces of Fiber-Reinforced Resin Matrices FMLs make up only a small part of the advanced composites family; the largest member is fiber-reinforced polymer composites. In fact, the Al plate surfaces and interfaces generated in the compositing of metal and resin described above did not include the fiber surface or the interface between fiber and resin. The main reason for this is because surface treatment of fibers is normally carried out to match the resin matrix in the fiber suppliers before composite manufacture, and usually the compatibility between fiber and resin can meet the service requirements for composites. In other words, commercial fibers have already been coated, so they can be defined according to the resin coating rather than the fiber surface itself. The sizing and finishing of commercial fibers are diverse and can be organic- or water-based, including diluted resin, curing agent, surface lubricant, antistatic agent, pH-adjusting agent and emulsions.



Fibers are usually coated with multiple layers to obtain combined performance. The main functions of sizing and finishing are to protect the structure and surface conditions of the fresh fibers to obtain good interface adhesion between the fiber and resin (coupling effect) and to increase their anti-friction and antistatic properties. Fiber surface-treating agents and their applications are core techniques in fiber production. Because the suppliers must satisfy various customers, the surface coatings for commercial fibers must be general purpose.

As airplane fuselage materials, two critical characteristics of carbon fiber laminates, their impact damage resistance (tolerance) and glass transition temperature (Tg,or thermal-wet service temperature), are determined by the resin matrix. In the aerospace industry, the impact damage resistance is expressed as compression strength after impact (CAI) and is usually used to classify resin toughness and generation.

The first generation of aerospace composites (Composites) was simply laminates (2–2 composition) composed of resin (Ares Phase 0 3) and fibers (Reinforcement 2 2 can be expressed as Are In Phase 0 3 þ B reinforcement 2 2 ¼C reinforcement.

Based on ðA1Þ resin 33 þðA2þB2 2 Reinforce 2 2 ¼Ccomposite 2 2 ,

Composite materials in the aerospace industry: The combined product prepared from the second reactive constituent (A2) and carbon fiber fabric (B2−2). The first reactive constituent (A1) with low viscosity was added by injection at low temperature until fibers were fully immersed and impregnated and then heated to achieve further chemical reaction. During the chemical reaction, resin parts A2 and A1 adhered to fiber fabric B2−2 were dissolved and infused to form a uniform phase, increasing the immersing effect. The final dried fabric was fully impregnated with resin.

Material example: Epoxy resin composites(RTM) Service temperature 75°C,3266ES CAI 300MPa Performance Equivalent to or higher than that of CYCOM 823 RTM.

Fiber Reinforcement:

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 TiO_2, ZrO_2 or Al_2O_3 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.

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.

M-Glass Fibers M-glass fibers, also referred to as high-modulus glass fibers, generally have a higher modulus than common glass fibers. Their specific modulus is much higher than that of steel because their density is about two-thirds lower. Improving the modulus of glass fibers allows their use in structural composites, which results in better performance. For SiO_2–Al_2O_3–MgO glass fibers, oxides such as BeO, Y_2O_3, ZrO_2, TiO_2 and CeO_2 are usually incorporated to increase their Young's modulus. However, highly toxic BeO and expensive Y_2O_3 have not been industrially used even though they are particularly effective in increasing moduli. Chinese type "M2" glass fibers with a Young's modulus of about 95 GPa have been produced, and they contain CeO_2, TiO_2 and ZrO_2.

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.

a new type of glass fiber, hollow glass fibers have features such as lightness, high stiffness, low dielectric constants and low thermal conductivity. Their main technical indexes are hollow percentage and hollow degree. The hollow percentage refers to the ratio of the number of hollow filaments versus the total number of filaments and is expressed as a percentage; the hollow degree refers to the ratio of the inner diameter versus the outer diameter of the hollow fibers, often expressed as a K value.

Hollow fibers are generally prepared from E-glass. Their tensile strength increases when the K value increases from zero to 0.8 and decreases when the K value increases more than this. For general industrially produced hollow glass fibers, K = 0.5 -- 0.7. They are characterized by low thermal conductivity and low dielectric constant, as listed in Table 2.7. Composites made from hollow glass fibers can be used in the aviation industry and in underwater facilities such as radomes, deep water containers and high pressure containers. Additionally, hollow glass fibers with metal coatings of zinc or aluminum can be used as electronic-interference materials. Because of their excellent lightness, reliability, capacity and response time, they can float in air over long periods and proliferate over a large area while having good interference effects. These antistatic and electromagnetic shielding fields.

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.

Carbon Fibers Fibrous carbons include continuous carbon (graphite) fibers, carbon whiskers and the recently developed carbon nanotubes, and these are new types of nonmetallic materials [3]. Among them, carbon fibers are a kind of polycrystalline fiber with incompletely crystallized graphite arranged along the fiber axial [6].

Carbon fibers are manufactured from carbon precursors followed by spinning into fiber form (spinning step), cross-linking using proper agents (stabilization step), and heating up to 1200–3000 °C under inert gas to remove non-carbon elements (carbonation step) [6–21]. As the most successful commercialized carbon products in the last 40 years, carbon fibers have developed into one of the most important modern industrial materials. They are mainly used as reinforcements for polymer matrices, ceramic matrixes and carbon matrix composites. At present, most countries regard high-performance carbon fibers as important engineering materials for the twenty-first century [6, 7]. Based on their mechanical properties, carbon fibers can be classified into the following categories: high-tenacity type (HT), ultra-high-tenacity type (UHT), high-modulus type (HM) and ultra-high-modulus type (UHM). Their corresponding mechanical property ranges are listed in Table 2.8. Based on the type of carbon precursor, carbon fibers can be classified as poly acrylonitrile (PAN)-based carbon fibers, pitch-based carbon fibers and rayon (viscose filament)-based carbon fibers, whose typical species and major mechanical properties are listed in Tables 2.9, 2.10 and 2.11. From the above tables, the most representative manufacturer is the Toray Company, whose high-performance carbon fibers are second to none in terms of production and performance. Additionally, their fiber varieties tend to be serialized [8–12]. As functional reinforcements, in addition to high specific strength and high specific modulus [10], carbon fibers also have excellent properties like high-temperature stability, chemical corrosion resistance, heat impact resistance, electrical conductivity, thermal conductivity, anti-friction properties, anti-radiation properties, damping, shock absorption, noise reduction and availability. Carbon fiber-reinforced composites have been widely used in the aerospace, defense and other military fields, as well as in advanced sporting goods, medical equipment, the auto industry and in other civilian areas. Their fields of application and their characteristics.

```
fiber_type = "PAN-CF"
manufacturer = "Amoco"
brand = "T-50"
diameter_um = 6.5
density_g_cm3 = 1.81
tensile_strength_GPa = 2.90
youngs_modulus_GPa = 300
tensile_strain_pct = 0.7
compressive_strength_GPa = "1.61–4.09"
note = "C"
```

```
fiber_type = "PAN-CF"
manufacturer = "Amoco"
brand = "T-40"
diameter_um = 5.1
density_g_cm3 = 1.81
```

```
tensile_strength_GPa = 5.65
youngs_modulus_GPa = 290
tensile_strain_pct = 1.8
compressive_strength_GPa = "1.88-2.7"
note = "C"
```

```
fiber_type = "PAN-CF"
manufacturer = "Amoco"
brand = "T-650/35"
diameter_um = 6.8
density_g_cm3 = 1.77
tensile_strength_GPa = 4.55
youngs_modulus_GPa = 241
tensile_strain_pct = 1.8
compressive_strength_GPa = 0.8
note = "C"
```

```
fiber_type = "PAN-CF"
manufacturer = "Amoco"
brand = "T-300"
diameter_um = 7.0
density_g_cm3 = 1.76
tensile_strength_GPa = 3.45
youngs_modulus_GPa = 231
tensile_strain_pct = 1.4
compressive_strength_GPa = "2.8-2.88"
note = "C"
```


```
fiber_type = "PAN-CF"
manufacturer = "Amoco"
brand = "T-300"
diameter_um = 7.0
density_g_cm3 = 1.76
tensile_strength_GPa = 3.45
youngs_modulus_GPa = 231
tensile_strain_pct = 1.4
compressive_strength_GPa = "2.8-2.88"
note = "C"
```


```
fiber_type = "PAN-CF"
manufacturer = "Amoco"
```

```
brand = "T-300"
diameter_um = 7.0
density_g_cm3 = 1.76
tensile_strength_GPa = 3.45
youngs_modulus_GPa = 231
tensile_strain_pct = 1.4
compressive_strength_GPa = "2.8-2.88"
note = "C"
```

Carbon fibre properties:

```
fiber_type = "PAN-CF"
manufacturer = "Hercules"
brand = "Magnamite-AS4"
shear_modulus_GPa = 17.0
damping_factor = 1.10

2)
fiber_type = "PAN-CF"
manufacturer = "Toray"
brand = "Torayca-M30"
damping_factor = 1.42
horizontal_compressive_modulus_GPa = 3.2

3)
fiber_type = "PAN-CF"
manufacturer = "Toray"
brand = "Torayca-T40"
shear_modulus_GPa = 14.0
damping_factor = 2.00
horizontal_compressive_modulus_GPa = 17.0
horizontal_fracture_strain_pct = 1.96

4)
fiber_type = "PAN-CF"
manufacturer = "Toray"
brand = "Torayca-T40J"
damping_factor = 3.52
horizontal_compressive_modulus_GPa = 4.0
horizontal_compressive_strength_MPa = 17.5
horizontal_fracture_strain_pct = 1.98

5)
fiber_type = "PAN-CF"
manufacturer = "Toray"
brand = "Torayca-T50"
shear_modulus_GPa = 14.0
damping_factor = 1.50
```

```
horizontal_compressive_modulus_GPa = 15.0
horizontal_fracture_strain_pct = 1.36


6)
fiber_type = "PAN-CF"
manufacturer = "Toray"
brand = "Torayca-T300"
horizontal_compressive_strength_MPa = 556
horizontal_fracture_strain_pct = 26
shear_modulus_GPa = 15.0
damping_factor = 1.30
horizontal_compressive_modulus_GPa = 3.21
```

Pitch-CF Type

```
8)fiber_type = "Pitch-CF"
manufacturer = "Amoco"
brand = "Thornel-P25"
horizontal_compressive_strength_MPa = 600

9)fiber_type = "Pitch-CF"
manufacturer = "Amoco"
brand = "Thornel-P55S"
horizontal_compressive_strength_MPa = 300
shear_modulus_GPa = 6.6
damping_factor = 0.85
horizontal_compressive_modulus_GPa = 7.0

10)fiber_type = "Pitch-CF"
manufacturer = "Amoco"
brand = "Thornel-P75S"
horizontal_compressive_strength_MPa = 200
shear_modulus_GPa = 8.0
damping_factor = 0.85
horizontal_compressive_modulus_GPa = 9.0
damping_factor_2 = 0.88

11)fiber_type = "Pitch-CF"
manufacturer = "Amoco"
brand = "Thornel-P100"
horizontal_compressive_strength_MPa = 130
shear_modulus_GPa = 4.7
damping_factor = 1.00
horizontal_compressive_modulus_GPa = 5.0
damping_factor_2 = 1.04
```

DuPont de Nemours

```
1)fiber_type = "Pitch-CF"
manufacturer = "DuPont de Nemours"
brand = "FiberG-E35"
horizontal_compressive_strength_MPa = 80
shear_modulus_GPa = 8.0
damping_factor = 0.70
horizontal_compressive_modulus_GPa = 8.5
damping_factor_2 = 0.73

2)brand = "FiberG-E75"
shear_modulus_GPa = 5.7
damping_factor = 1.00
horizontal_compressive_modulus_GPa = 6.0
damping_factor_2 = 1.01

3)brand = "FiberG-E105"
shear_modulus_GPa = 5.0
damping_factor = 1.00
horizontal_compressive_modulus_GPa = 5.5
damping_factor_2 = 1.04
```

Mitsubishi / Nippon Steel

```
fiber_type = "Pitch-CF"
manufacturer = "Mitsubishi NipponSteel"
brand = "NT-20"
horizontal_compressive_strength_MPa = 160
horizontal_fracture_strain_pct = 8

brand = "NT-40"
horizontal_compressive_strength_MPa = 94.3
horizontal_fracture_strain_pct = 10

brand = "NT-60"
horizontal_compressive_strength_MPa = 54.9
horizontal_fracture_strain_pct = 5
```

PAN-based carbon fibers are characterized by the following features: ① good weaving capability; ② low density, 1.7–2.1 g/cm3; ③ high modulus, 200–700 GPa; ④ high strength, 2–7 GPa; ⑤ fatigue resistant; ⑥ self-lubricating and wear resistant; ⑦ energy absorbing and impact resistant; ⑧ low coefficient of thermal expansion, 0–1.1 10−6 K−1; ⑨ good thermal conductivity without heat accumulation; ⑩ good electrical conductivity, 15–5 lXm, and non-magnetic; good X-ray penetration and good biological compatibility. Toray is the most comprehensive company in terms of PAN-based carbon fiber production, and their fiberspecificationsandperformancesarelistedinTable 2.14[8]. The performance of carbon fibers increases from T300 to T1000G and from M30S to M60 J.