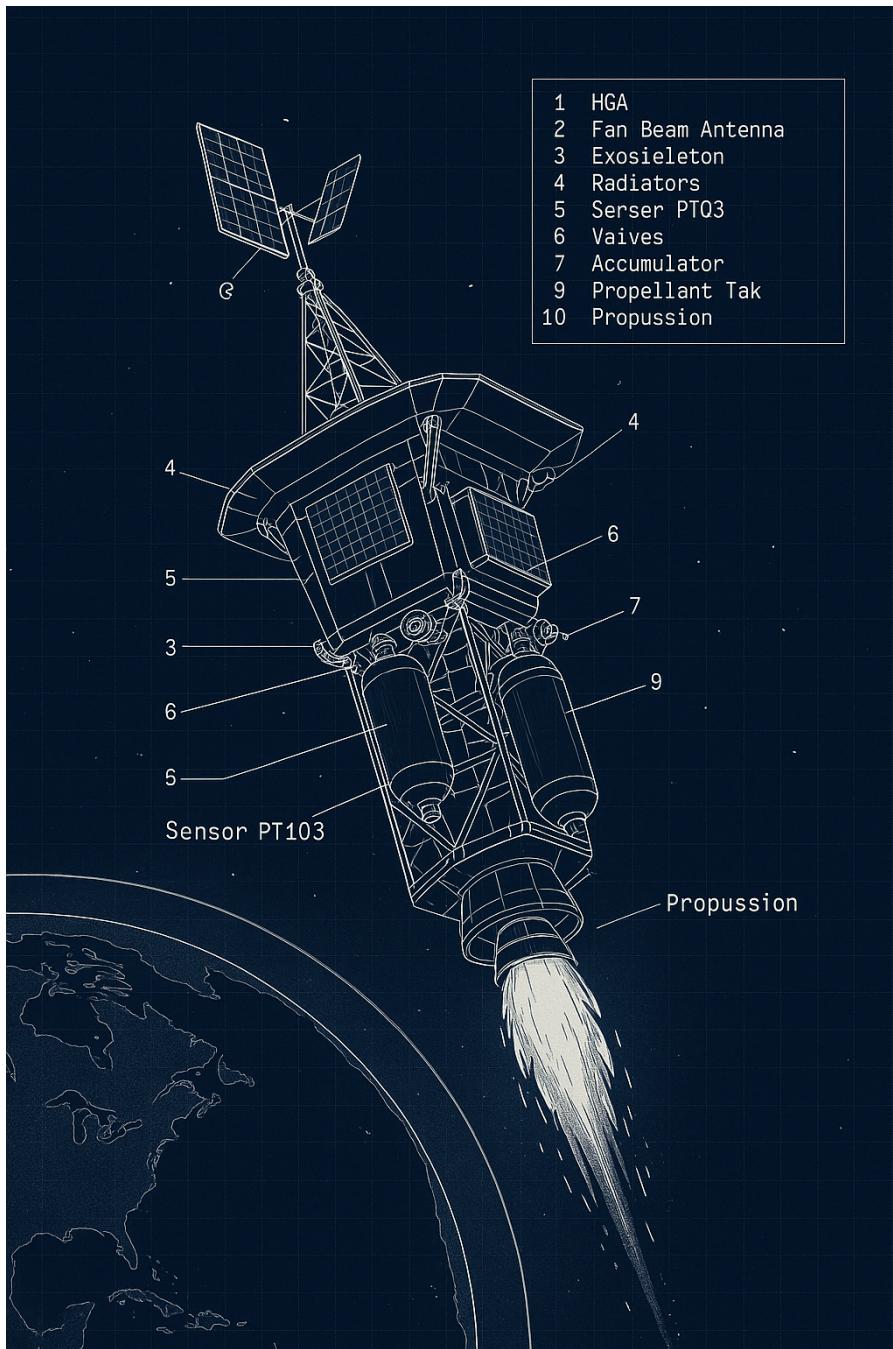


Design main concepts:

- High-temperature and radiation space exploration,
- AI research, and Data or resource mining in extreme environments (such as solar orbit, Lagrange, asteroids, etc.).



The SACS was comprehensively calibrated over the operating temperature range (referenced at the pump CV) as a function of input power during the integrated thermal vacuum test (ITVT) in March 2017.

The SACS thermal model developed for the ITVT was correlated against the test data and was used and adjusted during the observatory thermal vacuum test in early 2018. Prior to wetting CSPR2 and CSPR3, the SACS heat load based on the measured pump check valve (CV) temperature, 70°C, was estimated to be 1900 W using the correlated (flight) SACS thermal model.

Impact damage resistance and glass transition temperature (Tg):

CAI (Compression After Impact) defines a structure's tolerance to damage.

Tg: Maximum service temperature before the material softens.

Application: Material selection for fuselages or sun shields.

Three days later, the umbra test was performed, where the heat load from the recently wetted CSPR2/CSPR3 was reduced to zero due to the umbra attitude, and the heat load to the SACS came exclusively through the SAs.

Correcting for the decrease in solar distance, the 1900 W predicted on 14 September 2018 (0.90 AU) became 2033 W (0.87 AU). After approximately 3 hours in umbra attitude, the measured steady-state temperature was ~33°C. This lined up very well with the model prediction for the 2033-W power input and four active radiators.

In flight, there is no way to independently or directly measure SACS input power, so it must be estimated based on temperature using the flight model

MATERIALS-DESIGN-METRICS-PLASMA-BLACK_HOLE_METRICS — Shown are the pump CV and accumulator temperatures (°C) as well as the system total pressure (psia) and delta-P (psid). When inside of 0.70 AU (Umbra Attitude) the solar array flap angle is adjusted as a function of solar distance to keep the SACS operating temperature between 60 °C and 65 °C.

To date, the system has performed as designed.

26–30 August 2019, Newport News, VA — 30th Annual Thermal & Fluids Analysis Workshop

Spacecraft TCS Overview: The spacecraft (excluding the SACS) is a passive thermal design that utilizes louvers, multilayer insulation (MLI), and heaters along with waste electronics heat dissipation to maintain the core bus temperature between +10°C and +50°C.

The internally mounted SACS and propulsion components (the propellant tank and the accumulator, pressure transducers, latching valves, and fill and drain valves) are thermally coupled to the bus and rely on the bus bulk temperature to keep their respective temperatures above freezing (both hydrazine and water freeze at nearly the same temperature) during cold spacecraft conditions.

Two 20-blade and three 10-blade louvers are utilized to help minimize bus heater power and maintain the bulk bus temperature above 10°C.

The battery is thermally isolated from the bus and uses a seven-blade louver and software-controlled heaters to maintain its nominal temperature between 0°C and 15°C.

The majority of the high-powered radio frequency (RF) components are located on or near the $-Z$ aft deck and utilize two of the 10-blade louvers to reduce bus heat leak when the RF system is powered off.

Instrument TCS Overview: The body-mounted instruments are thermally isolated from the bus and, with the exception of Solar Probe Analyzer (SPAN)-B, are located with the louvers on the “cold side” of the spacecraft ($+X$).

The truss structure assembly-mounted instruments, the four Electromagnetic Fields Investigation instrument suite (FIELDS) antennas, and the Solar Probe Cup (SPC) are completely isolated from the bus and are the only instruments designed to withstand the full solar constant when at minimum perihelion. The FIELDS magnetometers are located on a 3.4-m boom and also are thermally isolated from the bus.

During aphelion operation (outside of 0.70 AU), the spacecraft is tilted so as not to exceed 45° from $+Z$ toward $-X$ to allow for X-band (fan beam) and KA-band (HGA) communications.

Inside of 0.82 AU, this angle can be adjusted anywhere between umbra pointing and 45° to allow for proper HGA pointing toward Earth and also to relax the thermal input into the SACS, the externally mounted bus components, and the bus as long as the thermal attitude does not interfere with HGA-KA-band operations.

During this period, the externally mounted components on the $-X$ side of the spacecraft experienced near-mission-maximum temperatures (0.70 AU/ 45° tilt), and some of the internally mounted components experienced mission-maximum temperatures as well.

These conditions are dependent on sun angle and will most likely repeat several more times as the spacecraft adjusts its attitude to allow proper HGA pointing for KA-band downlink.

So far in the mission, the spacecraft has experienced one of its two hot cases: during O-2 when near 0.70

AU and in aphelion-variable attitude while tilted 37° (1 March 2019) for KA-band downlink using the high-gain antenna (HGA).

In the second and more severe hot case, predicted for the mission minimum perihelion (9.86 RS), the external components will stay relatively cold and the temperature gradient inside of the spacecraft will be from top to bottom ($+Z$ to $-Z$) instead of from side to side ($-X$ to $+X$), so the internal components that were warm during this hot case will be a bit cooler during the perihelion hot case and vice versa.

COMPONENTS

1. Radiators
2. Louvers
3. Propellant and accumulator tanks
4. Antennas (HGA and fan beam)
5. Solar panels
6. Instruments such as SPC, SPAN-B, FIELDS

Shown are the CSPR temperatures as measured by the 32 temperature PT103 temperature sensors (eight per radiator) during the two activation events. The thermal “spike” at the beginning of each CSPR activation represents the orientation illustrated. The SACS was comprehensively calibrated over the operating temperature range (referenced at the pump CV) as a function of input power during the integrated thermal vacuum test (ITVT) in March 2017. The SACS thermal model developed for the ITVT was correlated against the test data and was used and adjusted during observatory thermal vacuum test in early 2018.

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MATERIALS-DESIGN--METRICS-PLASMA-BLACK_HOLE_METRICS

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PYTHON

JET ENGINE COMPONENTS

- | | |
|-----------------------|--|
| 1. Diffuser | - Slows down airflow and increases pressure. |
| 2. Compressor | - Increases air pressure via energy transfer from turbine. |
| 3. Combustion Chamber | - Location of air-fuel combustion. |
| 4. Turbine | - Converts thermal energy to mechanical energy. |
| 5. Nozzle | - Accelerates exhaust gases for thrust. |

SPACECRAFT COMPONENTS

- | | |
|-------------------|---------------------------------|
| 1. Jet Engines | - Provide thrust. |
| 2. Fuel System | - Stores/supplies fuel. |
| 3. Control System | - Regulates engines/operations. |

PLASMA & BLACK HOLE METRICS

- | | |
|-------------------|-------------------------------|
| 1. Frolov Metrics | - Spacetime near black holes. |
| 2. Schwarzschild | - Spherical black holes. |
| 3. Kerr | - Rotating black holes. |

TURBINE & NOZZLE DESIGN

- | | |
|-----------------------|----------------------------------|
| 1. Turbine CAD Design | - Precision modeling in CAD. |
| 2. Nozzle CAD Design | - CAD-based nozzle optimization. |

PROPULSION MATERIALS

- | | |
|----------------------|-------------------------|
| 1. Fuel & Oxidizers | - Generate thrust. |
| 2. Plasma Propulsion | - Plasma-based systems. |

BLACK HOLE RESEARCH

- | | |
|----------------------------|--|
| 1. Spacetime Symmetries | |
| 2. Plasma Tensor Converter | - Analyzes plasma-black hole interactions. |
-

MATERIALS & SYSTEMS: SOLAR PARKER PROBE (SPP)

- Launch Mass: 685 kg
- Dimensions:
 - Height: 3 m
 - TPS Diameter: 2.3 m
 - Bus Diameter: 1 m
- C-C Thermal Protection System
- Bus: Hexagonal prism
- Solar Arrays:
 - Active, water-cooled
 - Output: ~364 W at closest approach
 - Area: 1.54 m²; Radiator: 4.0 m²
- Comms: 0.6 m HGA, 34W Ka-band, DL rate 163 kbps @ 1 AU

THERMAL CONTROL SYSTEM (SACS)

- Heat dissipation: 6400 W at 9.86 Rs
- Liquid Cooling Loop (Redundant Pump/Electronics)
- Temp Ranges:
 - Operative: +20°C to +150°C
 - Survival: +10°C to +190°C (wet), -80°C to -130°C (dry)
- Activation:
 - Prelaunch: Accumulator heated to 40-50°C
 - Radiators 2 & 3 active at 0.89 AU (Day 41)

Key Components:

- Accumulator (non-redundant)

- Pump Electronics (block redundant)
- Platens, Radiators, Valves
- Thermal Simulation & Testing (C1/C2 configs)

THERMAL TESTING

- C-1 Hot B6 (No TPS): Max 125°C, MLI fin in place
 - C-2 Hot C6 (TPS at 300°C): Confirms TPS heat load
 - C-1 Cold A2/B2: Validates minimum load at 1.02 AU
 - Critical Cases: R23, Eclipse, Post-launch warm-up
 - Data gathered to calibrate thermal model across mission phases
-

CALCULATIONS: COMPRESSOR STAGES

Centrifugal Compressor:

INLET:

$C_1 = 150 \text{ m/s}$; $W_1 = 250 \text{ m/s}$; $U_1 = 200 \text{ m/s}$

OUTLET:

$C_2 = 390 \text{ m/s}$; $W_2 = 150 \text{ m/s}$; $U_2 = 350 \text{ m/s}$

β_2 = Flow angle; $\beta_2' = \beta_2 + 5^\circ$

(a) Impeller Type:

Based on velocity triangle, calculate β_2 .
 If $\beta_2 < 90^\circ$ → Forward-curved
 $\beta_2 = 90^\circ$ → Radial
 $\beta_2 > 90^\circ$ → Backward-curved

(b) Slip Factor (σ):

Use empirical models (Stodola, Wiesner) or:
 $\sigma = 1 - (C_{\theta 2} / U_2)$

(c) Stage Temperature Rise (ΔT_0):

$$\Delta T_0 = (U_2 * C_{\theta 2} - U_1 * C_{\theta 1}) / c_p$$

Turboprop Dual Compressor System:

Given:

- $T_{01} = 288 \text{ K}$; $P_{01} = 101 \text{ kPa}$
- $\pi_1 = 3$; $\sigma_1 = 0.94$; $\eta_1 = 0.86$; $\psi_1 = 1.04$
- $D_{1t} = 0.5 \text{ m}$; $D_2 = 0.8 \text{ m}$
- $\xi_{\text{inlet}} = 0.65$; $M_{1\text{rel}} = 1.0$

1. Mass Flow Rate (\dot{m}):

$$\dot{m} = \rho * A * C_1 = (P_{01} / RT_{01}) * A * C_1$$

2. Inlet Velocity (C_1):

$$C_1 = \sqrt{2 * c_p * \Delta T_{01}}$$

3. Rotational Speed (N) :

$$U_1 = \pi * D_1 * N \rightarrow N = U_1 / (\pi * D_1)$$

4. Compressor Power:

$$P = \dot{m} * c_p * \Delta T_0$$

AXIAL COMPRESSOR RELATIONS:

$$\begin{aligned}\tan(\alpha_1) &= [(1 - \Lambda) - \psi/2] / \varphi \\ \tan(\alpha_2) &= [(1 - \Lambda) + \psi/2] / \varphi \\ \tan(\beta_1) &= (\Lambda + \psi/2) / \varphi \\ \tan(\beta_2) &= (\Lambda - \psi/2) / \varphi\end{aligned}$$

Temperature Rise Comparisons:

Axial:

$$(C_1/U)^2 = [(1 - \Lambda - \psi/2)^2 + \varphi^2]$$

Centrifugal:

$$\Delta T_{0_axial} / \Delta T_{0_centrifugal} = (U_m/U_2)^2$$

$$\text{If } U_m = U_2 \Rightarrow \Delta T_{0_axial} / \Delta T_{0_centrifugal} = r_m / r_2$$

DEGREE OF REACTION (Λ):

$$\Lambda = 1 - (\varphi^2 * A^2 * \sec^2 \alpha_2 * \sec^2 \alpha_1) / (AB * \tan \alpha_2 * \tan \alpha_1)$$

APPLICATION: RADIATION-RESISTANT MATERIALS (SPP)

- Primary Shielding Material: Carbon-Carbon composite (C-C)
- Heat Shield (TPS): Ablative, layered for radiation protection
- Cooling Fluids: Water-based system with high latent heat
- High-temp MLI: Multi-Layer Insulation with aluminum/Mylar
- Key Design Constraint: Heat flux + radiation near perihelion (9.86 Rs)
- Redundant Sensors/Control logic for thermal monitoring

1. Fiber surface treatment (sizing and finishing):
2. Function: Improves adhesion between fiber and resin matrix (this provides structural strength and thermal stability).
3. Application: Crucial for structural panels, thermal protection components, and deployable antennas.
4. Importance: Allows the manufacture of lightweight, strong structures for harsh space environments.
5. Use advanced fiber and resin composites to:

6. Insulate critical areas (tanks, AI cores, sensors).
7. Reduce weight and improve thermal/mechanical resistance.
8. Impact damage resistance and glass transition temperature (Tg):
9. CAI (Compression After Impact) defines a structure's tolerance to damage.

10. Tg: Maximum service temperature before the material softens.
11. Application: Material selection for fuselages or sun shields.

Choose resins such as CYCOM 823 RTM or equivalent to achieve:

Extremely high resistance to micrometeorite impacts or structural loads.

Stability at extreme temperatures ($>300^{\circ}\text{C}$). Structural composite composition:

Type A1 + A2 + B2-2 fiber = C (final composite).

- Injection molding (RTM) to achieve uniform impregnation and a solid structure.
- Insulation panels.
- Antenna or sensor arms. Structural cladding for AI or space mining areas.

Fiber Type	Application	Key Property
E-glass	Electrical and thermal insulation	High dielectric strength
M-glass	Lightweight structures	High elastic modulus
High-silica	Thermal shielding	High temperature resistance ($>900^{\circ}\text{C}$)
Hollow fibers	AI containers, EMI interference	Low conductivity, ultra-light weight

Objective: EMI shielding (EN data protection). External thermal protection (sun shield type). AI-powered space mining: deployable structures and collection containers.

1. Design in modules such as:
2. Laser source
3. Optical module (beam splitter, lenses)
4. Optical fiber (hollow fiber, M-glass, etc.)
5. Detector (photodiode, CCD)
6. Control electronics (RTOS, microcontroller)
7. Coatings and protection (glass, anti-reflective coatings, etc.)

a) Optical errors(REVIEW)

Intensity loss (due to misalignment or poor coupling)

Thermal noise (simulating extreme temperatures)

Dispersion and attenuation (in defective fibers)

b) Electronic errors: RTOS failure ()

IDEA

No.	Technical Component	Function	Material / Details
--	--	--	--
1	**Front Heat Shield**	Protection against extreme solar radiation	Carbon-Carbon + ceramic coating
2	**Adjustable Solar Panels**	Electrical Power	Monocrystalline silicon with thermal reflective film
3	**Propellant Tanks**	Fuel storage (hydrazine, xenon)	Titanium, protected by high-silica fiberglass
4	**Ion Propulsion System or Hall Effect Thruster**	Orbital correction, navigation	Tungsten alloys, electromagnetic acceleration system
5	**AI System for Data Mining**	Collection, analysis, and prioritization of cosmic signals	Rad-hard CPU with optional quantum FPGA
6	**Plasma and magnetic field sensors**	Study of solar and deep-space particles	Insulating ceramic casing, encapsulated sensors
7	**Structural exoskeleton**	Protection and mechanical support	M-Glass + carbon fibers embedded in an epoxy matrix
8	**Cooling system**	Heat distribution and dissipation	Closed coolant circuit + heat pipes
9	**Communication system**	Link with ground stations and other spacecraft	High-gain, dielectric-coated antennas
10	**Redundant flight computer**	Trajectory, propulsion, and data control	Microcontrollers with RTOS (e.g., FreeRTOS, QNX)
11	**Cameras and spectrometers**	Image capture and spectral analysis	Radiation shielding with E-glass and fused silica lenses

a) Heat shield

Simulate ablation failure under temperature spikes

Evaluate carbon-carbon conductivity with matplotlib + numpy

b) Solar panels

Simulate efficiency drop due to prolonged exposure

Dynamic shading models or temperature vs. voltage (IV curves)

c) Propulsion

Simulate thrust loss due to valve failure or magnetic drift

Validate response to navigation pulse

d) Onboard AI

Maximum workload, bottlenecks, data packet losses

e) Thermal errors

Use heat maps to determine if the cooling system fails during a close-to-sun trajectory

f) Sensor system

Simulate false readings due to cosmic radiation noise

Sensitivity testing with different solar radiation levels

Concepts: The most solid and effective approach at this advanced design stage is:

A thorough study of each real material (titanium, carbon-carbon, E-glass, etc.), understanding:

- Their thermal behavior curves.
- Fatigue and strain limits.
- How they behave under thermal stress, radiation, or vibration.
- Formulate key technical questions, such as:
- How does titanium respond to 300°C in a vacuum?
- At what threshold does carbon-carbon lose mass by ablation?

How does solar radiation affect the microstructure of fiberglass?

Use Python or other languages (such as MATLAB) as an auxiliary tool, not as a replacement for real-world testing:

To model heat transfer equations.

To predict theoretical behavior.

But never to validate final mechanical or thermal properties.

Radiation resistance design:

```
def evaluate_material(material_name, temp_limit, radiation_limit):
    materials = {
        "C-C Composite": {"temp_limit": 3000, "radiation": "high"},
        "MLI Aluminum/Mylar": {"temp_limit": 500, "radiation": "low"}
```

```

"medium"} ,
}
mat = materials.get(material_name)
if not mat:
    return "Material not found"

return (
    temp_limit <= mat["temp_limit"]
    and radiation_limit in ["low", mat["radiation"]]
)

```

Thermal control

```

from calculations.compressor_stage import temp_rise
from thermal_control.system_config import thermal_ranges

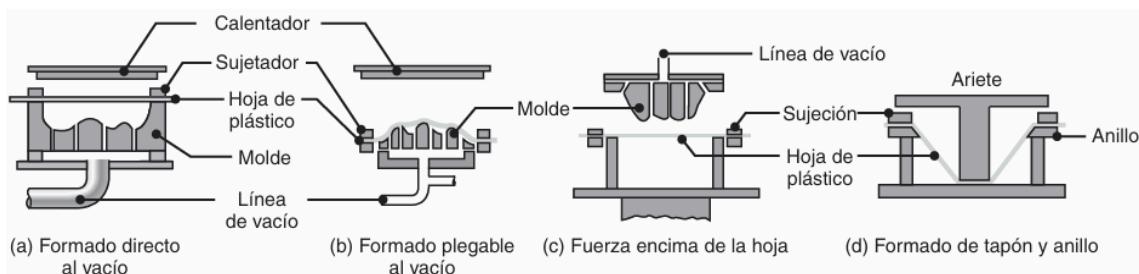
def main():
    print("== Solar Parker Probe Simulation ==")
    ΔT₀ = temp_rise(U₂=350, C_theta₂=150, U₁=200, C_theta₁=250)
    print(f"ΔT₀ (Stage Temp Rise): {ΔT₀:.2f} K")

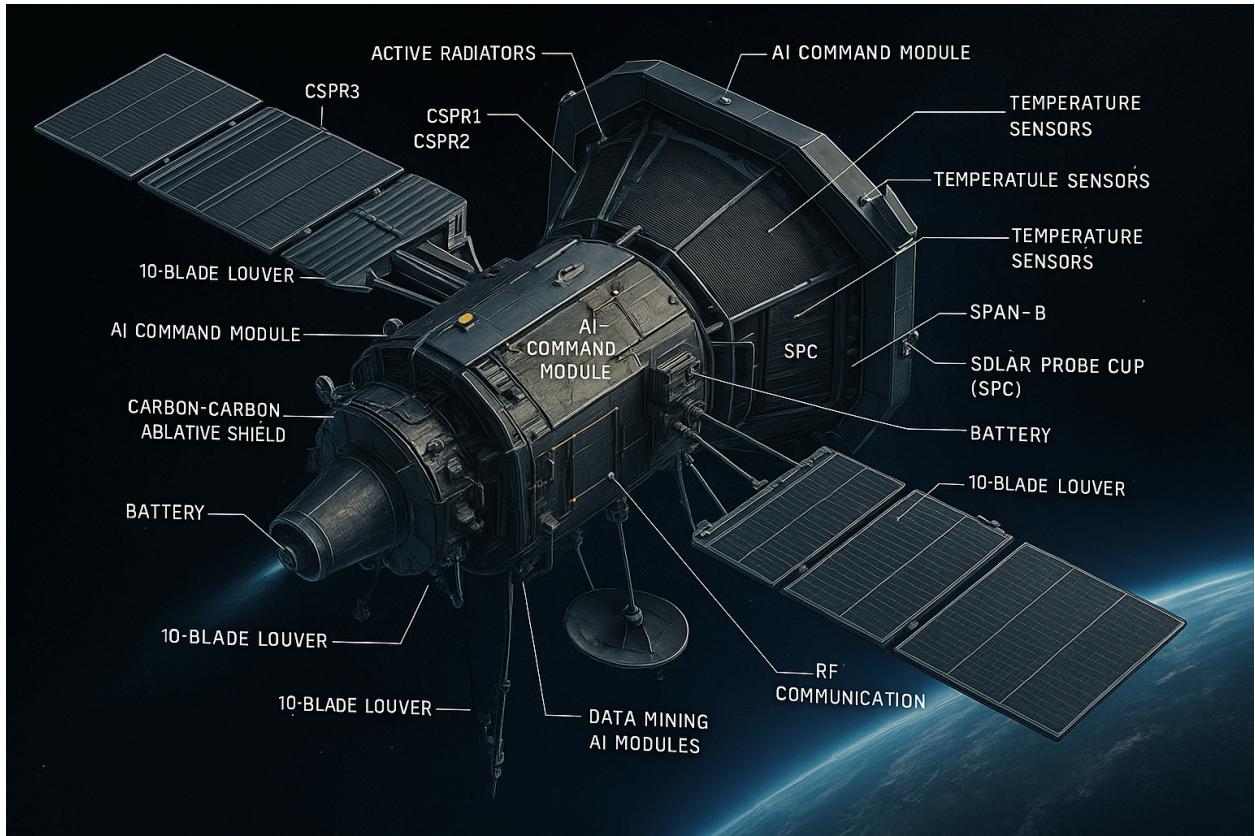
    print(f"Thermal Operational Range: {thermal_ranges['operative']} °C")

if __name__ == "__main__":
    main()

```

The internal components of the space shuttle shown in the image are inspired by real-life systems like those of the Parker Solar Probe, but adapted to a more futuristic spacecraft for space research and AI data mining. Below are the main internal components depicted (or implied) in the technical design:





Thermal Control System (TCS): CSPR radiators (8 per panel) with PT103 sensors. SACS (Solar Array Cooling System): correlated thermal model with estimated power input (1900–2033W). Louvers (thermal ventilation grilles) in solar shadow for passive dissipation.

2. Power Unit: Solar panels (SAs) with adjustable flaps depending on solar distance (between 0.70–0.90 AU). Thermally insulated batteries, operating between 0°C and 15°C with dedicated software and louver.

3. Propulsion and Fuel System: Propellant tanks thermally coupled to the bus. Check valves (CV), fill and drain valves. Pressure accumulators with transducers.

4. Bus Exostructure: MLI (Multilayer Insulation). Geometry optimized for aphelion/umbra. Truss-type structure for antennas and instruments.

5. AI Core / Data Mining Center: Dedicated module for real-time scientific data processing using AI. Includes radiation-tolerant quantum computing units, protected with carbon-carbon.

6. Communication System: X-band and KA-band antennas (HGA). Dynamic orientation between 0°–45° depending on solar distance to cool and maintain link with Earth.

7. Scientific Instruments and Sensors: FIELDS Suite (EM sensors). Solar Probe Cup (SPC). Magnetometers on a 3.4 m boom, thermally isolated.

8. Construction Materials: Carbon-carbon fiber structure (high thermal resistance). Internal components coated with radiation-resistant insulating materials (ceramic polymers).

Surface Treatment of Fibers (Sizing and Finishing): Function: Improves adhesion between fiber and resin matrix, providing structural strength and thermal stability. **Application:** Crucial for structural panels, thermal protection components, and deployable antennas. **Importance:** Enables the manufacturing of lightweight and durable structures for hostile space environments.

In your design, this translates into using advanced fiber + resin composites for:

- Insulating critical areas (tanks, AI cores, sensors).
- Reducing weight while improving thermal/mechanical resistance.

2. Impact Damage Resistance and Glass Transition Temperature (Tg): CAI (Compression After Impact): Defines a structure's tolerance to damage. **Tg:** Maximum service temperature before the material softens. **Application:** Selection of materials for fuselages or solar shields.

For the Parker Solar Probe or your spacecraft, this means choosing resins like CYCOM 823 RTM or equivalents to achieve:

- High resistance to micrometeorite impacts or structural loads.
- Stability at extreme temperatures ($>300^{\circ}\text{C}$).

3. Structural Composite Composition: Composition type A1 + A2 + fiber B2-2 = C (final composite). RTM injection (Resin Transfer Molding) to achieve uniform impregnation and a solid structure.

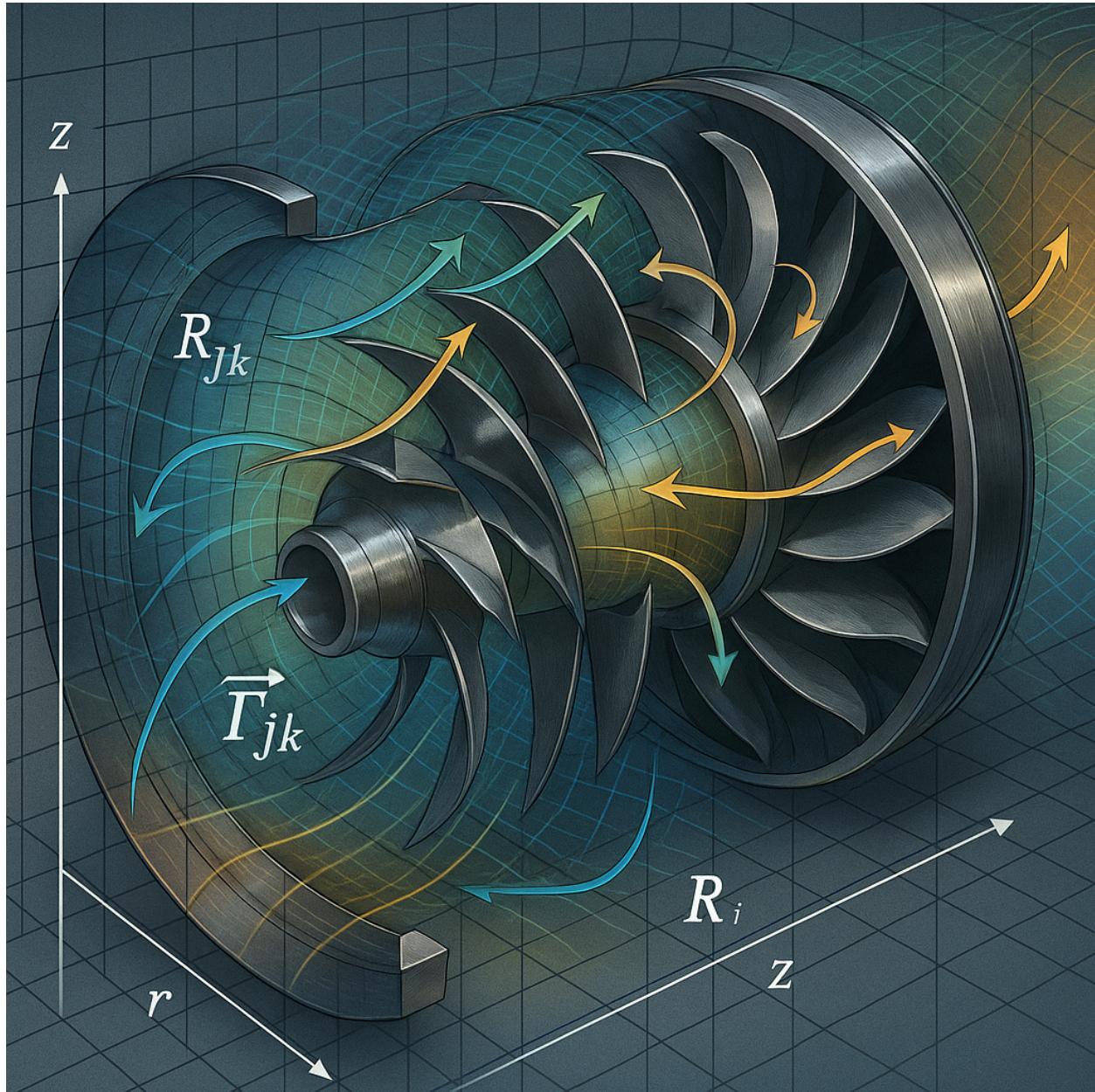
This is how the following components are built:

- Insulating panels.
- Antenna or sensor arms.
- Structural coatings for AI or space mining areas.

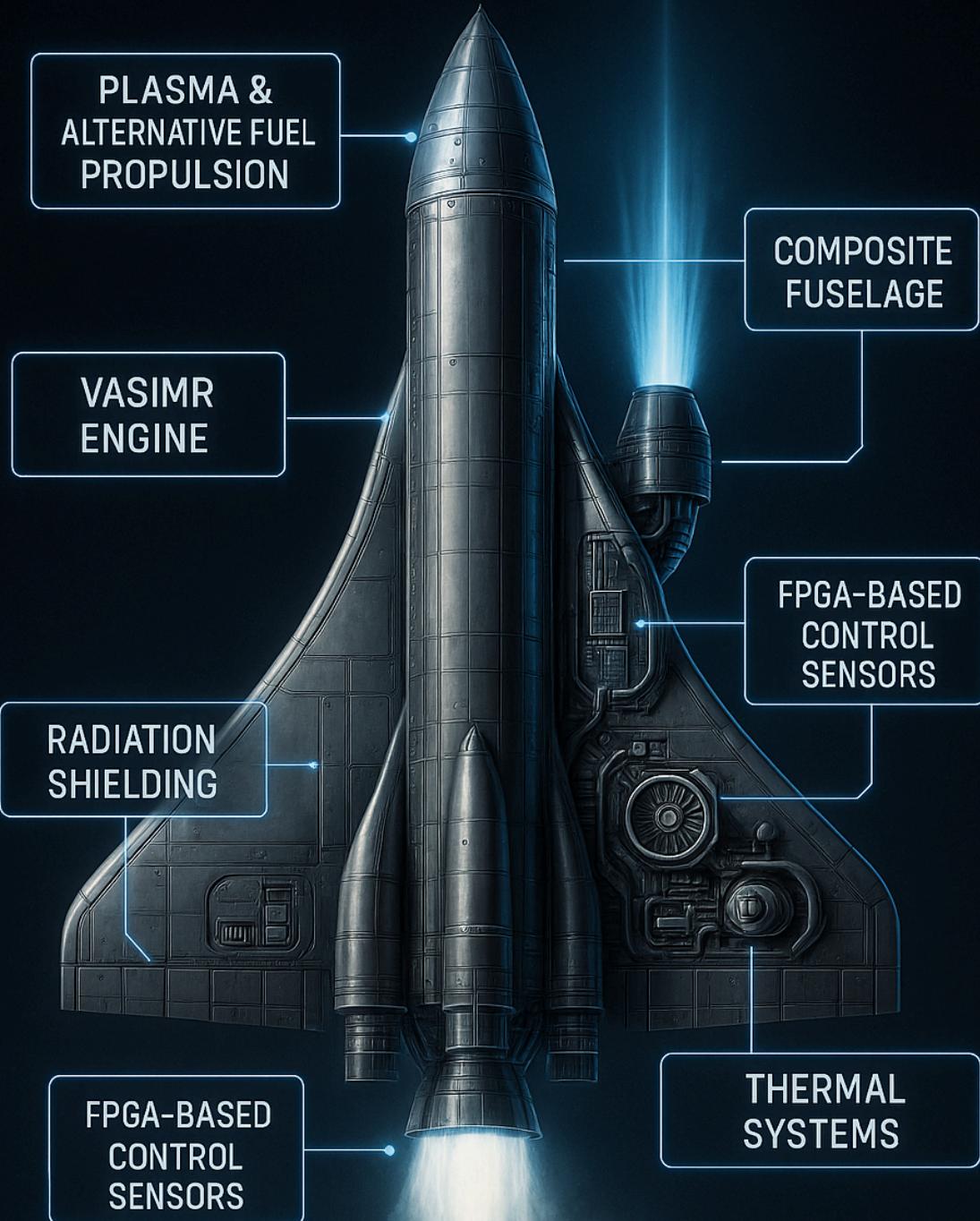
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Fiber Type	Application	Key Property
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Hollow fibers	AI containers, EMI interference	Low conductivity, ultra-lightweight

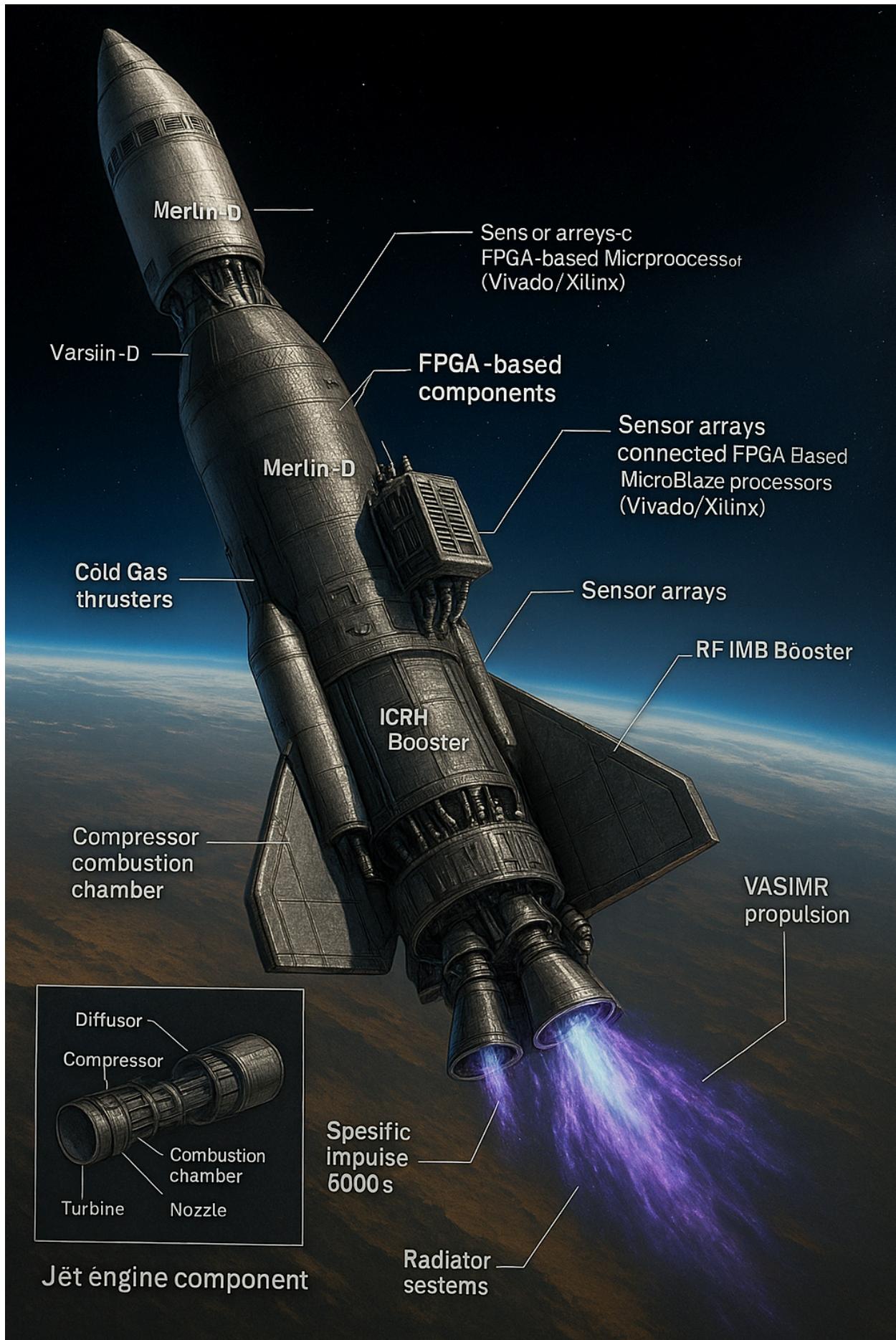
EMI shielding (AI data protection).External thermal protection (solar shield type).Space mining with AI: deployable structures and collection containers.



FUTURISTIC SPACECRAFT



DESIGNED FOR OPERATION IN WEAK ATMOSPHERES
AND HIGH-RADIATION SPACE ENVIRONMENTS



Central Idea: Expanding into Space for Manufacturing, Resource Collection, and Propulsion

1. Manufacturing spacecraft or systems in space Advantages:

- Avoids the immense energy required to escape Earth's gravity.
- Enables the construction of larger or modular structures.
- Utilizes in-situ resources (ISRU - In-Situ Resource Utilization).

Where to do it:

- Lunar orbit or Lagrange points L1-L5.
- Metallic asteroids (such as Psyche).
- Orbital stations with automated factories (based on metallic and ceramic 3D printing).

Technologies involved:

- 3D printing in microgravity.
- Autonomous assembly robots.
- Laser sintering of lunar regolith.

2. Collecting fuel in space Realistic or theoretical options:

- Lunar helium-3: ideal for fusion, very scarce on Earth.
- Hydrogen from interstellar clouds: for fusion or as propellant in nuclear thermal engines.

Planetary atmospheres:

- Methane on Titan.
- Carbon dioxide on Mars or Venus (convertible to methane via the Sabatier process).
- Cold plasma dust in magnetic belts (such as Jupiter's).

Capture systems:

- Magnetic sails to collect plasma.
- Cryogenic chambers to condense light gases.
- Automated robotic mining on meteorites.

3. Hybrid propulsion using collected resources Combining various systems depending on the environment:

- Ion engine with solar plasma.
- Pulsed fusion with helium-3 or collected deuterium.
- Laser-assisted propulsion from orbital stations.
- Solar thermal engine for intra-solar system travel.