Types of FPGAs for Spacecraft or Space Missions

FPGAs (Field Programmable Gate Arrays) used in spacecraft and space missions must meet stringent requirements to withstand extreme temperatures, space radiation, and harsh operational conditions. Below are the key characteristics and types of FPGAs suitable for space missions:

Necessary Characteristics for Space-Grade FPGAs

1. **Radiation Resistance:**
    - FPGAs must be protected against **Radiation-Induced Single Event Upsets (SEUs)** and **Single Event Latch-ups (SELs)**.
    - This is achieved using technologies like **antifuse**, **hardening by design (HBD)**, or redundancy techniques such as **TMR (Triple Modular Redundancy)**.
2. **Wide Thermal Range:**
    - Operating range: **-55 °C to +125 °C** (or even broader in some cases).
    - Metallic or ceramic packages are used to improve thermal resistance and heat dissipation.
3. **High Reliability:**
    - Must comply with standards such as **MIL-STD-883** and **NASA EEE-INST-002**.
    - Testing includes thermal cycling, vibration resistance, and shock durability.
4. **Low Power Consumption:**
    - Energy is limited in space, so power consumption must be minimized.
5. **Robust Packaging:**
    - Typically, **hermetic ceramic packaging** is used to protect against the harsh space environment.

Types of FPGAs for Space Applications

1. **Antifuse-Based FPGAs:**
    - Example: **Microsemi RTAX/RTSX**.
    - Radiation-resistant, non-volatile, and highly reliable.
    - Limited in reconfiguration capability (one-time programmable).
2. **SRAM-Based FPGAs with Radiation Protection:**
    - Example: **Xilinx Virtex Q Pro (Rad-Hard)**.
    - Reconfigurable in-flight but require radiation protection through **ECC (Error Correcting Code)** or redundancy (TMR).
3. **Flash-Based FPGAs:**
    - Example: **Microsemi RTG4**.
    - Reconfigurable, radiation-resistant, and low power consumption.

- Offer a middle ground between SRAM and antifuse FPGAs.

Examples of Space-Grade FPGAs

1. **Microchip (formerly Microsemi) RTG4:**
   - Specifically designed for space applications.
   - Radiation tolerance up to 100 krad (TID) with SEU mitigation.
2. **Xilinx Kintex UltraScale Space-Grade:**
   - High processing capability and support for complex applications like image processing or communication.
3. **NanoXplore NG-MEDIUM and NG-LARGE:**
   - European manufacturer meeting ESA standards for space missions.
4. **BAE Systems RAD750 FPGA:**
   - Used in critical control systems for several NASA space missions.

Factors to Consider for a Specific Mission

1. **Mission Environment:**
   - Low Earth Orbit (LEO), Medium Earth Orbit (MEO), Geostationary Orbit (GEO), or interplanetary missions.
   - Higher radiation levels the farther from Earth's magnetosphere.
2. **Specific Applications:**
   - **Attitude and Orbit Control (AOCS):** Low-latency FPGAs.
   - **Image Processing:** High-performance FPGAs with DSP capability.
   - **Communications:** FPGAs for custom protocols.
3. **Required Certifications:**
   - Compliance with standards from ESA, NASA, or national space agencies.

Conclusion

For space missions, FPGAs like **Microsemi RTG4**, **Xilinx Virtex Q Pro**, or **NanoXplore NG-MEDIUM** are viable options due to their radiation resistance and ability to operate in extreme temperatures. The choice will depend on the mission, budget, and specific design requirements.