Example Applications in Aerospace: Integrating FRET, WEST, and R2U2

1. FRET and WEST Integration

Application: Validation of a satellite's fault recovery procedure.

- **Scenario:** A satellite must initiate a recovery sequence within 10 seconds after detecting a critical fault.
- **Process:**
  - **Using FRET:** The requirement, "The satellite shall start the recovery sequence within 10 seconds after fault detection," is formalized into an MLTL formula.
  - **Using WEST:** This formula is validated in WEST to ensure correctness under mission-time constraints. WEST generates regular expressions to simulate fault recovery scenarios and verify compliance.
- **Outcome:** Ensures pre-deployment validation of fault recovery procedures, reducing the risk of in-orbit failures.

2. FRET and R2U2 Integration

Application: Real-time monitoring of an unmanned aerial vehicle's (UAV) response to a low-battery signal.

- **Scenario:** The UAV must return to its base within 5 minutes of detecting a low-battery condition.
- **Process:**
  - **Using FRET:** The requirement is formalized into an MLTL formula: "If the battery level falls below 20%, the UAV shall return to the base within 5 minutes."
  - **Using R2U2:** This formula is deployed as a runtime monitor to continuously track the UAV's battery level and flight path.
- **Outcome:** R2U2 detects anomalies, such as deviations from the expected return behavior, allowing operators to intervene in real-time.

3. WEST and R2U2 Integration

Application: Monitoring spacecraft thermal system behavior during re-entry.

- **Scenario:** A spacecraft must keep its internal temperature within a specific range (e.g., 20–25°C) during re-entry.
- **Process:**
  - **Using WEST:** Thermal management requirements are validated against MLTL formulas in WEST, ensuring the constraints hold across all expected re-entry scenarios.

    - **Using R2U2:** The validated formulas are deployed as runtime monitors. R2U2 observes temperature sensors and raises alerts if deviations occur.
- **Outcome:** Continuous runtime monitoring guarantees compliance with thermal constraints, reducing the risk of system failures during critical re-entry phases.

4. FRET, WEST, and R2U2 Combined Integration

Application: Comprehensive validation and monitoring of a rover's mission to collect and analyze Martian soil samples.

- **Scenario:** The rover must collect samples within a specific time frame while avoiding hazardous terrain and maintaining communication with Earth.
- **Process:**
    1. **Using FRET:** Requirements such as "The rover shall transmit a status update every 15 minutes" and "The rover shall avoid hazardous zones identified within a 10-meter radius" are formalized into MLTL formulas.
    2. **Using WEST:** These formulas are validated in WEST to ensure they meet mission constraints, generating regular expressions for further use.
    3. **Using R2U2:** Validated formulas are deployed for real-time monitoring. For instance, R2U2 tracks proximity sensors for hazardous zones and communication intervals with mission control.
- **Outcome:** The integrated workflow ensures end-to-end traceability, pre-deployment validation, and runtime compliance monitoring, minimizing mission risks.

Summary

Each integration leverages the unique strengths of FRET, WEST, and R2U2 to address specific aerospace challenges. Combining the tools ensures comprehensive coverage of system requirements, pre-deployment validation, and runtime monitoring. By applying these integrations in domain-specific contexts, such as UAVs, satellites, and rovers, reliability, safety, and mission success rates are significantly enhanced.