### CASE AEROSPACE ENGINEERING - SPACECRAFT POWER SYSTEM

The European Space Agency (ESA), impressed by the technical skills of Information Technology students, has tasked you with writing software for a spacecraft's power system. The spacecraft, intended for a mission to Jupiter's moons, requires a sophisticated energy system. Due to mission-critical deadlines, the software must be ready within three hours.

The spacecraft's power system consists of a solar array, a battery module, and a thermal control unit. The solar array is equipped with one or more solar panels, each with an efficiency percentage that starts at 100%. The panels generate power using a generatePower method. This method returns the generated power in kW based on incident solar radiation (I, measured in W/m²) and time (t, measured in seconds).

Two types of solar panels are used, each with distinct properties. Table 1 describes the properties of each type. Note that in Java, sqrt {x} is Math.sqrt(x).

**Table 1: Solar Panel Properties**

| **SOLAR PANEL TYPE** | **PROPERTIES** |
| --- | --- |
| **MONO-CRYSTALLINE** | Efficiency decreases by 0.05% per second of operation. Generated power is 0.95 \* (I \* t \* 0.8). If the temperature exceeds 120°C, the generated power is reduced by 20%. |
| **POLY-CRYSTALLINE** | Efficiency decreases by 0.0001 \* I \* t + 0.0005%. Generated power is (I \* 0.6) \* t \* 0.85. At temperatures below -50°C, no power is generated. |

The power system also includes a battery module. The battery stores energy using a storeEnergy method, which accepts the generated power (kW) as input and tracks the total stored energy (kWh). The battery has a maximum capacity of 1000 kWh. If the capacity exceeds this value, energy is wasted.

In addition, there is a thermal control unit. This unit regulates the operating temperature of the solar panels using a regulateTemperature method. The temperature adjustment depends on the excess power input to the system. The new temperature is calculated as:

current temperature - excess power \* 0.2

• **Dynamic Solar Radiation**: The solar radiation fluctuates between 200 W/m² and 1500 W/m² every second. Use ScheduledExecutorService to update this value dynamically.

• **Temperature Changes**: The ambient temperature also fluctuates between -100°C and 150°C in real time. Use ScheduledExecutorService to simulate these changes at regular intervals.

• **Efficiency Updates**: Solar panel efficiency must update every second, reflecting operational degradation and environmental factors. Use CompletableFuture to handle the computation asynchronously.

Finally, the spacecraft's power system brings everything together: the solar array generates power, the battery stores it, and the thermal control unit regulates the temperature. The system includes a run method with parameters for solar radiation, time, and ambient temperature. This method orchestrates the power system, calculating power generation, energy storage, and temperature regulation. It returns the remaining battery capacity

### ASSIGNMENT 1

Build the software based on the above text and class diagram (Appendix 1). Ensure that each component of the spacecraft's power system is represented as a class. Use CompletableFuture and ScheduledExecutorService to simulate real-time changes in solar radiation, temperature, and system operations.

### ASSIGNMENT 2

Spacecraft systems must be robust to handle critical failures.  
a) Create a PowerSystemFailureException.  
b) Throw the exception in the following cases:

* **Mono-Crystalline Panel**: The time exceeds 60 seconds, solar radiation exceeds 1500 W/m², or the efficiency percentage falls below 0.1%.
* **Poly-Crystalline Panel**: The temperature falls below -80°C, or the efficiency percentage falls below 0.05%.

### ASSIGNMENT 3

Create a system monitoring framework.  
a) Implement a getStatus method in all power system components. This method returns one of the following: Stable, Needs Attention, or Unstable. Follow the rules below:

| **COMPONENT** | **NEEDS ATTENTION** | **UNSTABLE** |
| --- | --- | --- |
| **Solar Array** | If one panel's efficiency is ≤ 20%. | - |
| **Battery Module** | If capacity is > 900 kWh. | If capacity is ≥ 1000 kWh. |
| **Thermal Control** | If temperature is between -10°C and 0°C. | If temperature < -10°C or > 150°C. |

b) **Create a ControlCenter class** to monitor the power system's components.

c) **Add a method isPowerSystemStable** in the control center that returns false if any component's status is not Stable. Otherwise, return true.

**d) Integrate the control center into the spacecraft power system. Use ScheduledExecutorService** to update and check the system status periodically.

### ASSIGNMENT 4

Write unit tests for the Poly-Crystalline solar panel to verify the correctness of power generation, efficiency degradation, and failure scenarios. Include test cases for dynamic updates triggered by the ScheduledExecutorService.