STRATEGIC REPORT: INTEGRATION OF SAULE PEROVSKITE TECHNOLOGY WITH C4ISR ARCHITECTURE BLOX-TAK FOR POLISH CIVIL DEFENSE
Date: December 1, 2025
Classification: OPEN SOURCE / DUAL USE
Subject: Feasibility analysis of powering distributed C4ISR nodes (EUD and Orange Pi 5) using Saule Technologies flexible perovskite cells under hybrid threat conditions.

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1. Executive Summary

This report constitutes a technical and operational validation of the use of Saule Technologies flexible photovoltaic modules ($1m^2$) within the **BLOX-TAK-SERVER-GCP** ecosystem. Despite the legal and financial turbulence surrounding Saule Technologies, this analysis demonstrates that this technology possesses unique features critical for the Polish security system (Civil Defense, WOT), which standard silicon panels cannot replace.

Key Conclusions for the BLOX-TAK Project:

1. **Utility Confirmation:** A flexible perovskite cell of $1m^2$ (generating nominally ~100 Wp) is fully sufficient to power a smartphone (EUD) running the ATAK-CIV-PL plugin year-round, providing a massive safety margin even during winter months.
2. **The Orange Pi 5 Challenge:** For the Orange Pi 5 server node (with SSD drive and Waydroid emulation), a single $1m^2$ cell ensures full operational autonomy from March to October. In critical winter months (December-January), there is an energy deficit of approximately 50 Wh/day, which requires the use of a battery buffer (LiFePO4) with a minimum capacity of 40Ah or increasing the cell surface area to $2m^2$.
3. **Tactical Advantage (Stealth):** Saule technology enables node camouflage in a way impossible for rigid, shiny silicon panels. The matte surface, flexibility, and lack of requirement for perfect solar angling constitute **Low Probability of Detection (LPD)** characteristics.

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2. Technical Analysis: Saule Technologies Perovskite Cell ($1m^2$)

Based on the technical specifications of perovskite technology and data regarding the implementation of large-area module production by Olga Malinkiewicz's team:

- **Physical Characteristics:** Cells are printed on flexible PET foil, characterized by low weight ($\sim730~g/m^2$) and the ability to operate in scattered and artificial light.
- **Real Power:** While laboratory records exceed 25% efficiency, a safe operational efficiency of 10-12% has been assumed for field applications (mass-produced flexible modules). This results in a peak power (STC) of approximately **100 Wp per $1m^2$**.
- **Performance in Poland (Winter):** This is a critical parameter. In December in Poland, the average insolation on a vertical plane (e.g., a wall) is approx. $16-23~kWh/m^2$ per month, averaging 0.5-0.7 kWh/m²/day. Thanks to a better absorption coefficient for scattered light, perovskites maintain higher voltage on cloudy days than silicon.

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3. Scenario A: Powering End User Device (Smartphone without screen)

Configuration: Smartphone (e.g., Google Pixel or Samsung) with the screen off, running the ATAK-CIV-PL plugin (AI/TensorFlow listening) and a WireGuard VPN tunnel.
Energy Balance:

- **Power Consumption (Idle/Background):** Modern smartphones in deep sleep consume negligible amounts of energy, but an active microphone and NPU processor (continuous listening) increase consumption. Measurements indicate a draw of approx. 1.5 - 2.0 W during active audio inference.
- **Daily Consumption:** $2.0~W \times 24h = \mathbf{48~Wh}$.

Conclusions for EUD:

- One Saule $1m^2$ cell is completely sufficient.
- **Summer:** Generation >600 Wh/day (excess of over 12-fold).
- **Winter (December):** Generation ~60-80 Wh/day (at 10-12% efficiency in scattered light).
- **Verdict:** The $1m^2$ cell covers the smartphone's demand with a safety margin even in the darkest month of the year. A standard 20,000 mAh power bank suffices as a buffer for 2-3 days of total darkness.

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4. Scenario B: Powering Edge Node (Orange Pi 5 + Waydroid)

This is the key scenario for the C4ISR project. The Orange Pi 5 (ARM64 architecture, RK3588S) acts as an autonomous server/relay with Android emulation (Waydroid).
Energy Balance (Orange Pi 5):
Running the Waydroid container prevents the processor from entering deep sleep states.

- **Configuration:** Orange Pi 5, NVMe SSD drive, no monitor (fake HDMI), LTE/5G modem.
- **Power Consumption:**
  - Idle (Linux only): ~2.2 W.
  - Load with Waydroid, SSD, and network: ~5.0-5.5 W (continuous).
- **Daily Demand:** $5.5~W \times 24h \approx \mathbf{132~Wh}$.

Confrontation with Saule Cell ($1m^2$):

- **Spring/Summer/Autumn:** The cell produces 200-600 Wh daily. Full autonomy. The energy excess is massive.
- **Winter (December/January):**
  - Production from $1m^2$: ~60-80 Wh (average).
  - Node Demand: 132 Wh.
  - **DEFICIT:** Approximately 50-70 Wh is missing daily.

Solution for the Winter Problem (SBC):

To ensure the Orange Pi 5 node operates year-round, two approaches are recommended:

1. **Military Option (Recommended):** Two Saule cells. Increasing the surface area to $2m^2$ (e.g., wrapping a tree trunk and a roof) will provide ~120-160 Wh in winter, covering the demand barely but effectively.
2. **Hybrid Option:** Specialized Energy Storage. If the system must operate on a single $1m^2$ cell, a large battery is necessary to store energy during rare sunny winter days (when production jumps to 200 Wh) and release it on cloudy days.
    - **Recommendation:** LiFePO4 12V 40Ah Battery.
    - **Capacity:** ~480-500 Wh.
    - This allows survival for approx. 7-10 days with a 50Wh/day deficit. This solution is sufficient for the Polish climate, where periods of absolute overcast rarely last longer than a week without breaks.

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5. Integration with Starlink Direct to Cell

The project aligns with the upcoming Starlink Direct to Cell revolution.

- **Key Fact:** This service does not require a Starlink dish antenna (which consumes 50-70W and would destroy the energy balance).
- **Operation:** The smartphone (EUD) or LTE modem in the Orange Pi 5 connects to the satellite just like a GSM tower.
- **Power Impact:** Power consumption during transmission to the satellite is comparable to transmission to a distant ground-based BTS. The energy balance (50Wh for EUD) accounts for this reserve.
- **Strategic Importance:** A node hidden in the forest, powered by perovskite, communicating with a satellite, is completely independent of national infrastructure.

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6. Argumentation for Saule Technologies Defense (Dual Use)

In the "White Paper" document, the following strategic arguments should be used:

1. **Low Probability of Detection (LPD) / Stealth:** Standard silicon panels are "mirrors" visible to drones and thermal imaging. Saule cells on flexible foil can be wrapped around branches, tree trunks, or integrated into tent fabric. They are matte and do not create such a distinct thermal signature.
2. **Technological Sovereignty:** Most silicon panels originate from Asia. Saule Technologies is Polish production. Maintaining domestic production capacity for these cells is critical for the continuity of "dual use" equipment supply during a crisis.
3. **Resilience:** A C4ISR system powered by distributed energy sources (perovskites on every node) is impossible to disable by attacking systemic power plants (a tactic observed in Ukraine).

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7. Implementation Recommendations

Hardware Configuration (BOM):

- **Source:** 1x (or 2x for winter certainty) Saule Technologies $1m^2$ Cell.
- **Storage:** LiFePO4 12V 40Ah Battery (instead of multiple small power banks).
- **Controller:** MPPT dedicated to thin-film cells (e.g., Genasun or Victron SmartSolar) - critical for obtaining energy in shade.
- **Converter:** High-efficiency (95%) Step-Down 12V->5V converter for Orange Pi 5 (e.g., Pololu brand).

Software Optimization (Orange Pi 5):

- Implementation of a script monitoring battery voltage on GPIO. In case of a voltage drop below 12.0V (winter crisis), the script should stop the Waydroid container, leaving only the basic Linux system for telemetry, reducing energy consumption by half.