ForgeSync "Global Industry 4.0"

Project Sector: Precision High-Tech Manufacturing (Automotive & Aerospace)

1. Project Overview: The Digital Nervous System

The Vision: "**ForgeSync Core**" is a next-generation **On-Premises-First** architecture. Unlike standard IT systems, **manufacturing cannot rely** on a **constant internet connection**. If the **connection** to the **cloud drops**, the **factory cannot stop**.

The Core Problem: The "Siloed" Factory

ForgeSync's 4 Global Mega-Factories (*Detroit, Stuttgart, Shanghai, São Paulo*) are currently "islands."

- **The 1% OEE Problem: Overall Equipment Effectiveness** is stuck at **68%.** Because data isn't synchronized, **managers don't know why machines** are **slowing** down **until the shift ends** (*This means 32% of our time and money is being wasted because machines are breaking down, running too slowly, or making broken parts*).
- **The Value: Moving** from 68% **to 69% OEE** is worth **$45 Million/year** in **saved** materials, reduced energy, and higher output.
- **The Constraint:** All **production-critical logic** (*Machine Control, Safety, Quality Vision*) **must** run **On-Premises** at the Factory Edge to **ensure sub-10ms latency** and **99.99 uptime** during **network outages**.

2. Business Scenario & Operational Environment

The "On-Premises" Hierarchy:

Your **architecture must follow** the **industrial standard** where layers are **separated by function** and **physical location**:

Layer	Location	Function	Requirement
Layer 0-2 (Shop Floor)	On-Premises	PLCs, Sensors, Robotic Arms.	**Ultra-Low Latency:** <10ms response time.
Layer 3 (Factory Edge)	On-Premises	Manufacturing Execution System (MES), Local Data Historian.	**High Autonomy:** Must run for 48 hours without internet.
Layer 4 (Corporate)	Global HQ	ERP Integration, Global OEE Analytics, Long-term AI Training.	**Global Visibility:** Aggregated data for executive decision-making.

The "Forge" (Hardware Details):

1. **The Robotic Arm (The Worker):** A large **mechanical arm**. **If it moves too fast, it vibrates**. If **it rubs against metal**, it screeches. **If** it **works too hard,** it **gets hot**.

2. **The PLC (The Machine's Local Controller):** A rugged, **mini-computer inside** the **machine**. It **executes "Move"** or **"Stop" commands**. Your **software must tell** the **PLC** when to "**STOP" instantly**.

3. The Sensors (The Senses)

A **sensor** is a **tiny device** that **converts** a **physical** "feeling" into a **digital number**. You will **monitor 4 main sensors**:

Sensor Name	What it feels	Digital Data	The "Danger" Sign
Vibration	The "shake" of the motor	**Hertz (Hz)**	○ **12Hz** is a happy hum. ○ **85Hz** means a gear is loose.
Acoustic	High-pitched sound	**Decibels (dB)**	○ **70dB** is normal. ○ **95dB** is a "Grinding" metal sound.
Thermal	Heat	**Celsius (°C)**	○ **50°C** is fine. ○ **>80°C** means the motor is melting.
Cycle Time	Speed of work	**Seconds**	○ **2.1s** is perfect. ○ **2.5s** means the robot is lagging.

Operational Constraints:

1. **Data Sovereignty:** By law, detailed "**Build Logs**" for aerospace parts produced in **Shanghai** or **Stuttgart** must **stay** on the **factory's physical servers for 10 years**. **Only "Summarized Health Stats"** can **leave** the **building**.

2. **The Firehose (Data Load):** 4 Factories x 12 Lines x 250 Sensors.
   - High-Velocity (Vibration/Acoustic): **100 reports per second** (100 Hz).
   - Low-Velocity (Thermal/Speed): **1 report per second** (1 Hz).

3. **Safety Interlock:** If the **centralized system sends a "Stop" command**, it must **reach** the machine in **under 5ms**.

4. **Hardware:** **Each factory** has its **own dedicated server room** with **high-availability clusters**.

5. **Latency Constraint (<5ms):** If a **machine** is **"Grinding"** you **cannot send** that **data** to the **Cloud** and **wait** for an **answer**. You **must process** it **locally** in **under 5 milliseconds** to **save** the **robot**.

6. **Autonomy Constraint (100% Uptime):** Even if the **factory loses internet**, the robots and your **software must keep working**.

3. The Assignment: 12 Detailed Tasks

Section 1: Strategic Mapping

- **Assignment 1: Business Vision to Technical Vision.**
- **Assignment 2: Functional & Non-Functional Requirements.**

Section 2: Architectural Selection

- **Assignment 3: Select Paradigm.**
- **Assignment 4: Select Model.**
- **Assignment 5: Select Architecture Style.**
- **Assignment 6: Select Architecture Pattern.**

Section 3: Technical Design & Flow

- **Assignment 7: High-Level Design (HLD).**
- **Assignment 8: Low-Level Design (LLD).**
- **Assignment 9: Component & Service Selection.**
- **Assignment 10: Create 3 ADRs (Architectural Decision Records).**

Section 4: Visualizing the Flow

- **Assignment 11: Create System Flow.**
- **Assignment 12: Final Architecture Picture.**