**Project Overview

We need to build an AI system to **consolidate and analyze data from multiple lab instruments** studying exosomes (extracellular vesicles). The system should identify anomalies and patterns across different data types but **NOT interpret** the results—just flag them for researchers.

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## Input Data Sources

### 1. Flow Cytometry Data (FCS files)

- `.fcs` files containing scatter plot data
- Parameters: FSC (Forward Scatter), SSC (Side Scatter), and multiple fluorescence channels (FL1-FL6)
- Each event = one particle
- Need to parse using FlowCytometry libraries

### 2. Nanoparticle Tracking Analysis (Text files)

- The `text file discussed.txt` contains ZetaView output
- Size distribution data (particle size in nm, concentration, volume, area)
- Metadata: temperature, pH, conductivity, experimental conditions

### 3. Electron Microscope Images (TEM data)

- Image files showing exosomes
- Need computer vision to:
  - Detect scale bars
  - Measure particle sizes
  - Filter background noise
  - Identify viable exosomes

### 4. Western Blot Data (future integration - early 2025)

- Not yet provided, but needs to be architected for

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## Architecture Components

### 1. Data Ingestion Layer

**Sub-components:**

- **FCS File Parser**: Use `fcsparser` or `FlowCytometryTools` (Python)
- **Text File Parser**: Custom parser for ZetaView format
- **Image Processor**: OpenCV/PIL for TEM images
- **Metadata Extractor**: Parse experimental conditions from all sources

### 2. Data Preprocessing Layer

**Sub-components:**

- **Data Normalization**: Standardize units across different instruments
- **Quality Control Module**:
  - Check temperature compliance
  - Validate particle drift

  - Filter invalid readings
- **Size Binning Engine**: Group particles by size ranges (40-80nm, 80-100nm, 100-120nm) based on customer-provided thresholds

### 3. Computer Vision Module (for TEM)

**Sub-components:**

- **Scale Detection**: Identify and measure scale bars
- **Particle Segmentation**: Separate exosomes from background
- **Size Measurement**: Calculate particle diameters
- **Noise Filtering**: Remove artifacts

### 4. Multi-Modal Data Fusion Layer

**Sub-components:**

- **Sample ID Matcher**: Link data from same sample across instruments
- **Feature Extraction**:
  - From FCS: scatter intensities, fluorescence profiles
  - From NTA: size distributions, concentrations
  - From TEM: morphology, size validation
- **Data Alignment**: Temporal and spatial correlation

### 5. Anomaly Detection Engine

**Sub-components:**

- **Scatter Plot Analyzer**:
  - Auto-select optimal X/Y axis combinations
  - Detect population shifts between readings
  - Identify outlier clusters
- **Statistical Comparison Module**:
  - Compare repeat measurements
  - Flag significant deviations
  - Cross-validate size data (NTA vs TEM)
- **Pattern Recognition**: Use ML (clustering, PCA) to find unusual patterns

### 6. Visualization & Reporting Layer

**Sub-components:**

- **Interactive Plot Generator**: Create scatter plots with highlighted anomalies
- **Comparison Dashboard**: Side-by-side views of multiple readings
- **Alert System**: Flag specific anomalies with timestamps
- **Export Module**: Generate reports in PDF/Excel

### 7. AI/ML Core

**Sub-components:**

- **Unsupervised Learning**:
  - K-means/DBSCAN for clustering
  - Autoencoders for anomaly detection
- **Semi-supervised Learning**: Use customer feedback to refine models
- **Feature Importance**: Identify which parameters matter most

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## Recommended Tech Stack

### Languages & Frameworks

- **Python 3.9+** (as discussed in transcript)
- **Pandas/NumPy**: Data manipulation
- **Scikit-learn**: ML algorithms
- **PyTorch/TensorFlow**: Deep learning (if needed)

### Specialized Libraries

- **fcsparser** or **FlowKit**: FCS file handling
- **OpenCV**: Image processing
- **Matplotlib/Plotly**: Visualization
- **scikit-image**: Advanced image analysis

### Storage & Pipeline

- **Database**: PostgreSQL for structured data
- **File Storage**: S3/local for raw files
- **Pipeline**: Apache Airflow or Luigi for workflow orchestration

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## What You Need to Deliver

### Phase 1 (Initial - for Tuesday call)

1. **System Architecture Diagram** showing all components
2. **Data Flow Diagram** from input → processing → output
3. **Technology Stack Recommendations**
4. **Timeline Estimate** (6-8 months feasibility)
5. **Resource Requirements** (1-2 developers needed?)

### Phase 2 (Implementation priorities)

1. FCS file parser + basic scatter plot generation
2. NTA text file parser + size distribution analysis
3. Anomaly detection for scatter plot shifts
4. TEM image analysis (can be later phase)

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## Key Challenges to Address

1. **How will you handle FCS files?** → Use existing Python libraries
2. **What ML approach for anomaly detection?** → Likely clustering + statistical methods
3. **How to correlate data across instruments?** → Sample ID + timestamp matching
4. **Scalability?** → Process multiple samples in batch
5. **User interface?** → Web dashboard (Flask/Django + React?)

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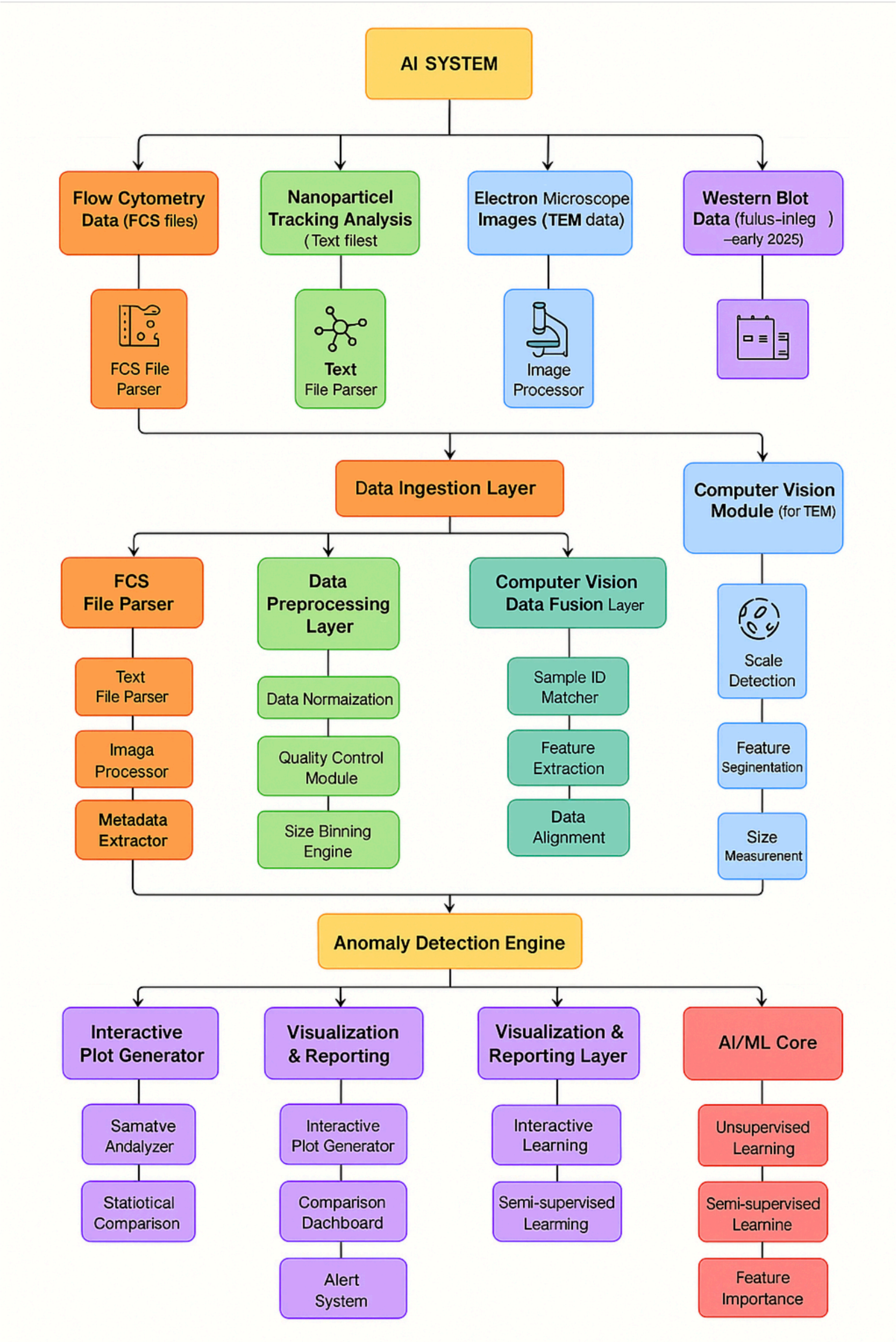
## Questions to Ask the Client (Tuesday)

1. What are the "best view" combinations for scatter plots?
2. What thresholds define anomalies?
3. How many samples/week will they process?
4. Do they need real-time processing or batch?

5. What format for output reports?
6. Any existing tools they currently use?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Nanoparticel Tracking Analysis (Text filest
Electron Microscope Images (TEM data)
Western Blot Data (fulus-inleg ) –early 2025)
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Text File Parser
Image Processor
Data Ingestion Layer
Computer Vision Module (for TEM)
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Data Preprocessing Layer
Computer Vision Data Fusion Layer
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AI/ML Core
Samatve Andalyzer
Statiotical Comparison
Interactive Plot Generator
Comparison Dachboard
Alert System
Interactive Learning
Semi-supervised Learming
Unsupervised Learning
Semi-supervised Learnine
Feature Importance

30 to 100 is one set and 100 to 200 is another set