**1. Tools and Components Used in the Architecture**

**🔹 On-Premise Components (MTA On-Premises)**

* **Ladybug Camera**: Captures tunnel segment images.
* **Internal Users**: Upload image files and LDS dialog metadata.
* **LDS Dialog/Plan Files**: Supplementary data for image processing.
* **Upload Path**: Uses **Azure ExpressRoute** for secure, private upload.

**🔹 Network and Connectivity**

* **Azure ExpressRoute**: Enables private, low-latency, and secure connectivity between on-premises and Azure cloud.
* **ExpressRoute Gateway & Subnet**: Connects Azure VNet with the on-premises environment.
* **Private Endpoints**: Ensures secure access to services like Blob Storage within Azure (no public IP exposure).

**🔹 Azure Virtual Network (VNet) Setup**

* **Virtual Machines (VMs)**:
  + Host **Python scripts and tools** to process image files.
  + Sized for high CPU/RAM (performance-intensive workloads).
* **Subnet**: Logical segmentation within the VNet for VM placement.
* **Availability Zone**: Optional for redundancy and high availability.

**🔹 Storage Solutions**

* **Azure Blob Storage**:
  + Stores raw images and processed output (CSV, OIC, etc.).
  + Firewall-enabled for secure access.
* **Azure File Share (Tunnel View Data)**:
  + Intermediate storage or shared file access between processes.
* **Archive Blob Storage**:
  + Long-term retention (up to 1 year) of processed or raw image data.

**🔹 Additional Tools**

* **Python Tools & Scripts**: For automated batch image processing.
* **ESRI GIS Enterprise**: Consumes or visualizes outputs like processed images or geospatial data.
* **Azure Monitor & Log Analytics**: For basic infrastructure monitoring.

**🔄 2. Data & Processing Flow**

**Step-by-Step Flow**

1. **Data Capture & Upload**
   * Images captured by **Ladybug Camera**.
   * Internal users prepare **LDS and plan files**.
   * Data is **uploaded via Azure ExpressRoute** to the cloud.
2. **Network Transmission**
   * Data flows through **MTA Enterprise Gateway** to **Azure ExpressRoute Gateway**.
   * Lands inside **Azure VNet** using **private endpoints**.
3. **Data Processing (VM Layer)**
   * **Azure VM** runs **Python scripts**.
   * Jobs are executed **weekly** in batches (~30GB/day).
   * VMs are dynamically **provisioned and deprovisioned** using automation (to optimize costs).
4. **Data Storage**
   * Raw and processed data goes to:
     + **Blob Storage** for storage and sharing.
     + **Azure File Share** (optional intermediate step).
     + **Archive Blob** for long-term retention (1 year).
5. **Data Consumption**
   * Tools like **ESRI GIS** or internal apps **access via blob endpoints** (secured by private endpoints).

**💡 3. Why Each Component Is Used**

| **Component** | **Purpose** |
| --- | --- |
| **Ladybug Camera** | Captures high-resolution tunnel images. |
| **Azure ExpressRoute** | Ensures secure, low-latency connection from on-prem to Azure. |
| **Private Endpoints** | Prevents public exposure of Azure services; ensures secure access. |
| **Azure VM (Python)** | Executes Python scripts for image analysis and data processing. |
| **Blob Storage** | Stores large unstructured data (images, CSVs, outputs). |
| **File Share** | Shared filesystem if concurrent access or mounts are needed. |
| **Archive Storage** | Cost-effective storage for infrequently accessed data. |
| **Azure Monitor** | Provides logs and metrics for troubleshooting and performance tracking. |

**📊 4. Operational Considerations**

* **Cost Optimization**:
  + Dynamic provisioning of VMs.
  + Archive tier for old data.
* **Security**:
  + No public exposure of services.
  + Access controls reused where possible.
* **Automation**:
  + Automated scripts to handle VM lifecycle.
* **Scalability**:
  + System designed to scale as image volume grows.

**🗂️ 5. Consolidated Architecture Summary**

| **Aspect** | **Details** |
| --- | --- |
| **Image Volume** | ~900GB/month, ~30GB/day, 1-year retention |
| **Processing Frequency** | Weekly, batch-mode |
| **Tools Used** | Python, Azure VMs, Azure Blob/File/Archive Storage, ExpressRoute |
| **Security** | Private Endpoints, Firewall-enabled storage |
| **Access Pattern** | APIs, portals, direct blob access |
| **Monitoring** | Azure Monitor, Log Analytics |
| **Performance** | High-performance VMs with SSD storage |
| **GIS Integration** | ESRI tools used for geospatial processing/visualization |