Cloud Solutions
Reinvent Vital Sign Monitoring

Project Presentation

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Practical Partner: Prof. Phillip Landgraf (Charité Berlin)

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Agenda

Introducing the Team

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Meet the Team

Maximilian Bornstädt

Cloud Architect

Designs and implements cloud infrastructure and services for the project

Varsha Balaji

Data Scientist

Develops and applies machine learning models to analyse and interpret data for the project

Nibedita Sahoo

Software Engineer

Writes software code, creates the project's user interface, and ensures a positive user experience

Project Charter

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Project Goals

Specific

- Prototype to enhance vital sign monitoring in surgeries using cloud service.
- Promote the use of interoperability standards in medical devices.
- Identify the specific features and use cases to be unlocked

Measurable

- Conceptualization of a functional model
- Conceptualization of a serverless and cloud–native AWS infrastructure
- Development progress for the prototype
- Stakeholder feedback

Achievable

- Utilize existing AWS services
- Leverage the expertise of the project team members
- Collaborate with healthcare professionals

Relevant

- Alignment with course requirements
- Advancement in medical technology
- Promotion of interoperability for medical devices

Time Bound

- Develop a clear timeline for the project with specific milestones and deadlines.
- Regularly monitor progress and adjust the timeline as needed.

Project Charter

Project Scope

- Backlog of user stories
- Prioritize user stories
- Conceptualize a functional model
- Develop a Cloud-based MVP prototype

Stakeholders

- Project team
- Project supervisor SRH (Prof. Tamm)
- Project supervisor Charité (Prof. Landgraf)
- Healthcare professionals for protype validation

Key success factors / KPIs

- Number of user stories implemented
- Time to complete the MVP prototype
- Level of interoperability
- Usability and effectiveness of the developed features
- User satisfaction

Deliverables

- Backlog of user stories
- Prioritized user stories
- Functional model
- Cloud-based MVP prototype
- Project documentation

Project Charter

Identified risks

- Incomplete or unclear user stories
- Difficulty in prioritizing user stories
- Technical challenges
- Delays in the development process
- Insufficient stakeholder feedback

Mitigation strategy

- Clear communication with stakeholders
- Regularly review project progress
- Leverage existing resources, solutions, and best practices
- Assign project roles and responsibilities

Quality assurance and testing

- Test the prototype
- Ensure the prototype complies with the interoperability standards (OpenSDC, FHIR)
- Verify that the MVP prototype

Project Closure

- Present the MVP prototype to project supervisors and stakeholders
- Gather final feedback and lessons learned
- Document project outcomes and archive project materials

Describing the Use Case

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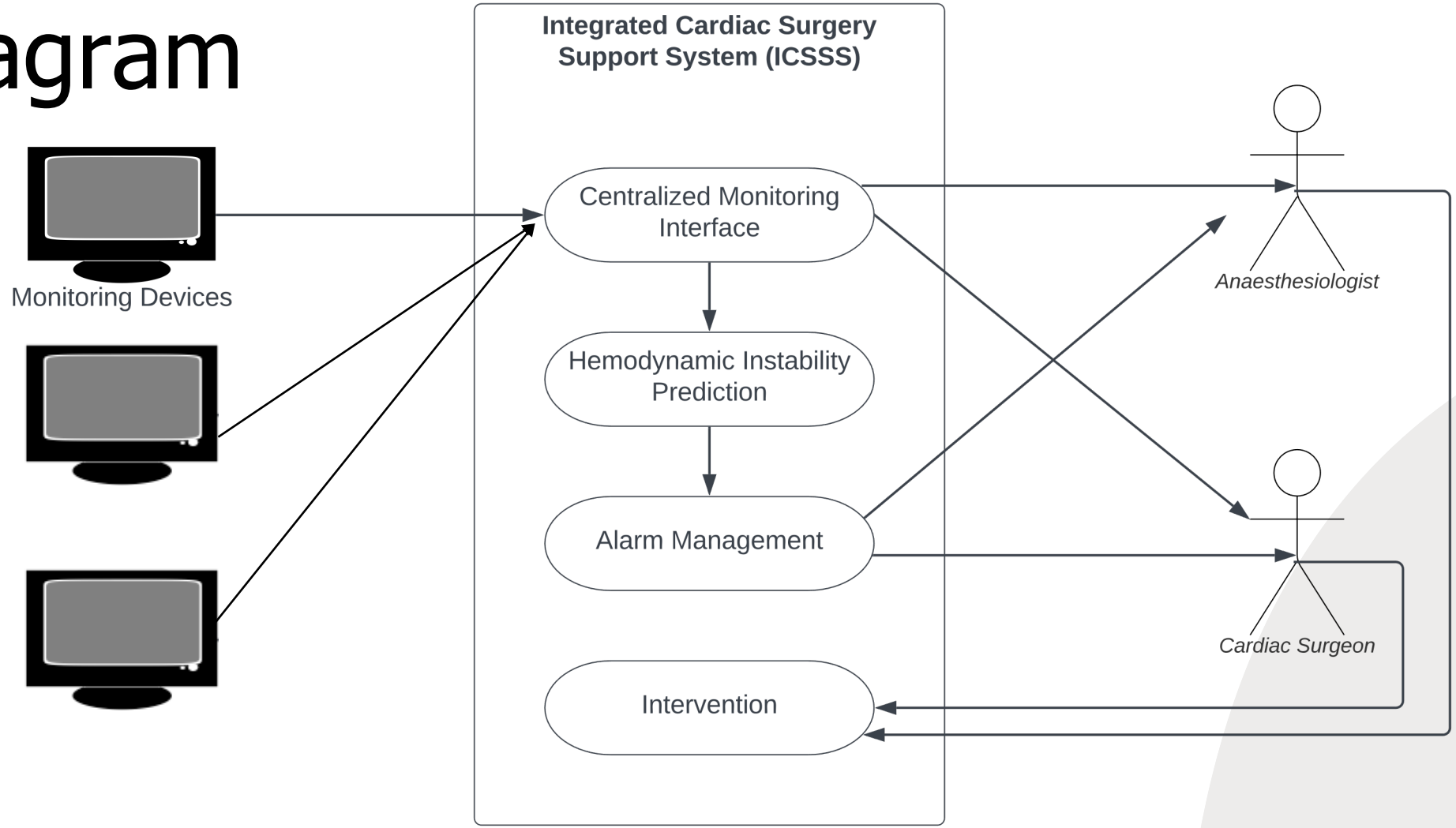
User Stories

As a cardiac surgeon, I need a system that combines real-time data from multiple monitoring devices to have a comprehensive view of my patient's vital signs during surgery.

As a cardiac surgeon, I need a system that predicts hemodynamic instability during surgery based on real-time data, so I can proactively address potential complications.

As a cardiac surgeon, I want an intelligent alarm system that accurately identifies true alarms, filters out false alarms, and provides timely alerts so that I can intervene quickly and provide necessary care.

Use Case Diagram



Solution Concept

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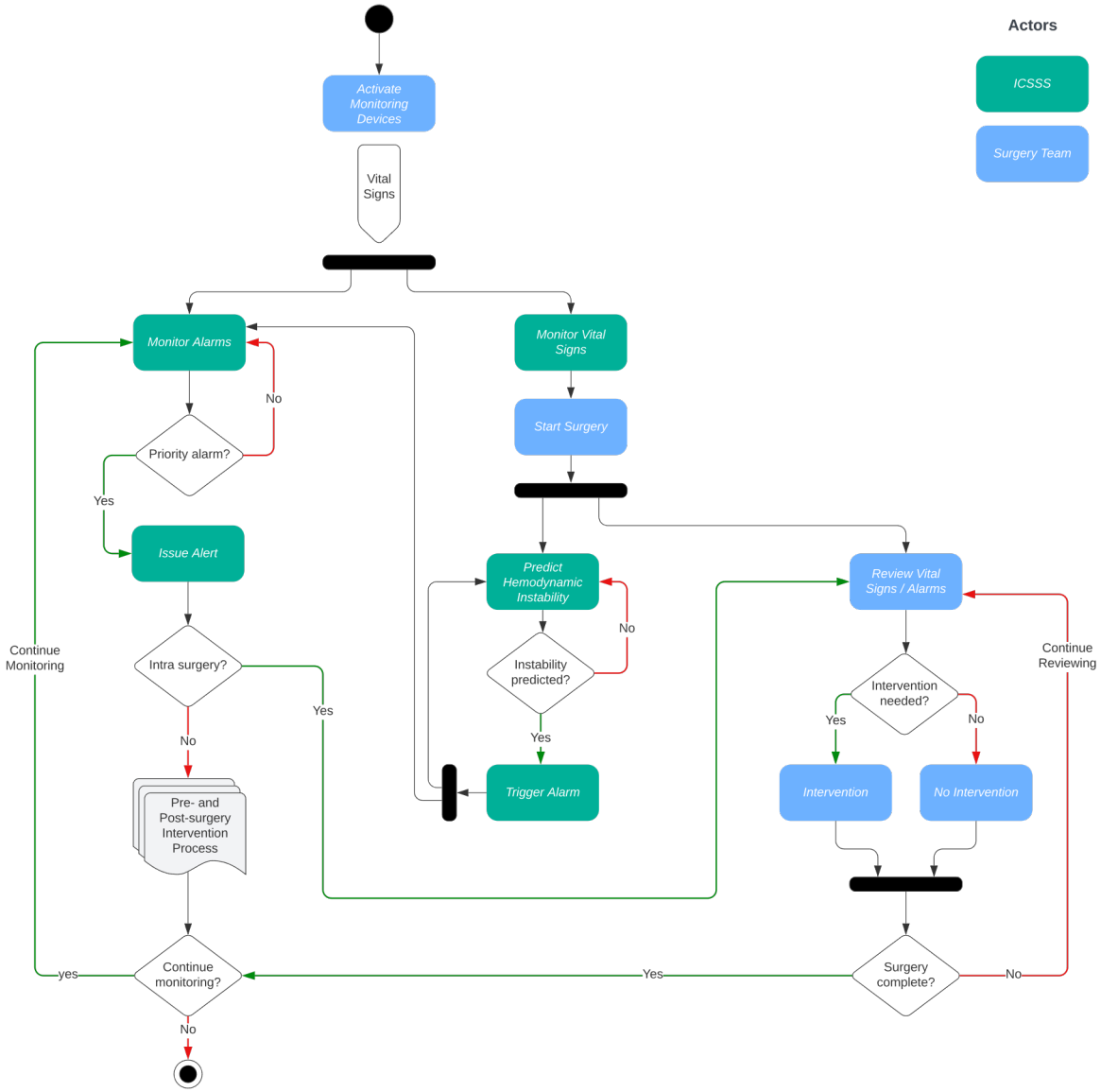
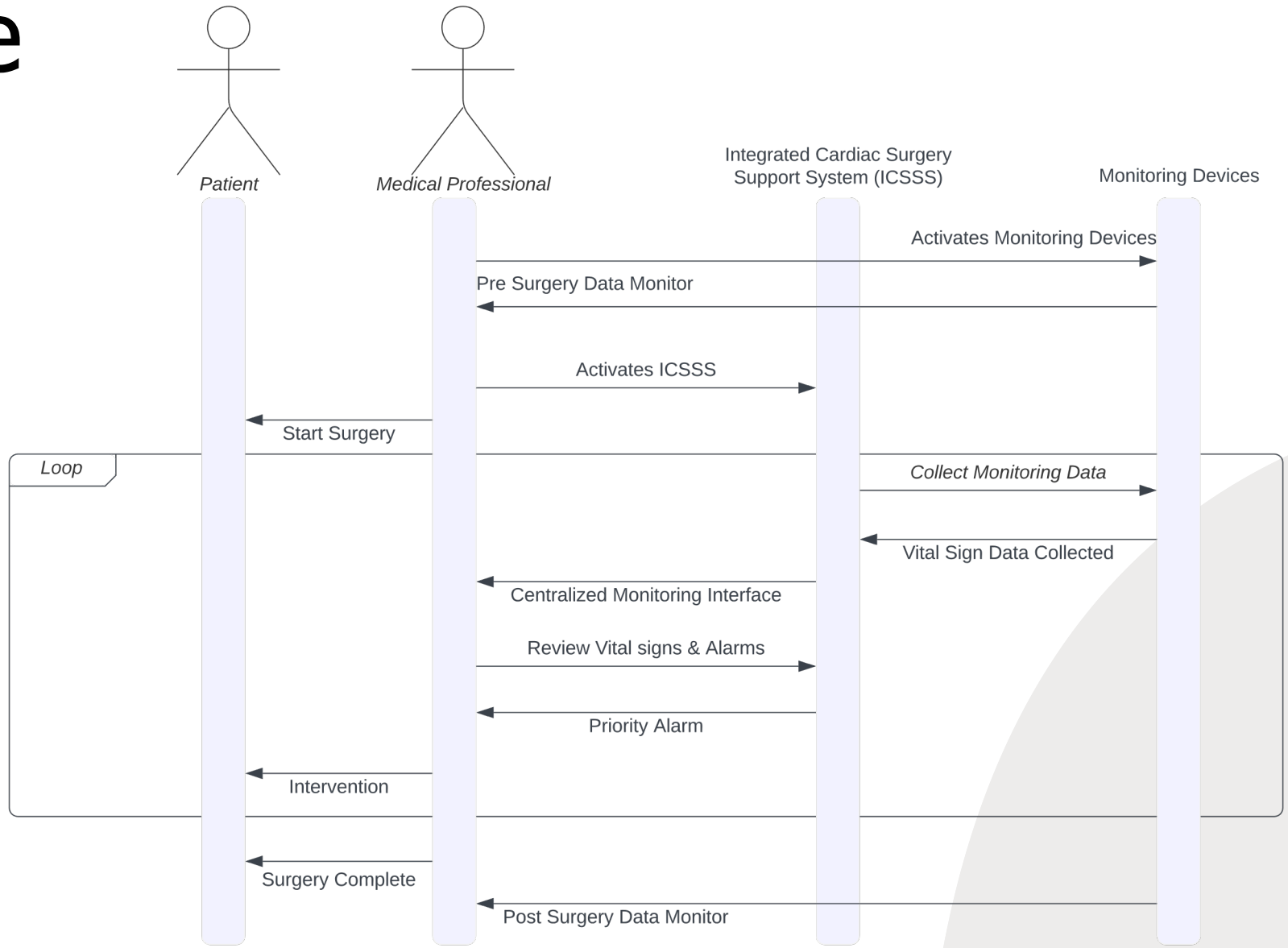
Activity Flow



Sequence Diagram



Cloud Provider Selection

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Cloud Provider Overview

Microsoft Azure

- Emphasis on hybrid cloud solutions and easy on-premises integration
- Third-party tools and services offer customization options
- Azure API for FHIR is compliant with healthcare data regulations like HIPAA and GDPR
- Azure integrates with Azure Machine Learning, Azure Cognitive Services, and Power BI for advanced analytics and machine learning applications

Google Cloud Provider (GCP)

- Google Cloud offers Healthcare API supporting FHIR, HL7v2, and DICOM for data interoperability with compliance and security
- Containerization is a top priority, with Google Kubernetes Engine (GKE) and Cloud Run for efficient deployment and scaling
- Integration with Google Cloud services, including BigQuery, AI Platform, and Data Studio, enables advanced analysis

Amazon Web Service(AWS

- AWS prioritizes security and compliance, with features like AWS Shield and AWS Config
- AWS HealthLake uses FHIR as its primary data format, promoting data interoperability with secure and compliant data storage
- AWS HealthLake integrates with other AWS services, including Amazon SageMaker for advanced analytics and machine learning capabilities

Comparing Providers for Suitability

Cloud provider	Pros	Cons
	• Seamless integration with other Microsoft products • A strong focus on security and compliance, and a wide range of tools and services	• Azure may have potentially higher costs compared to other cloud providers • Azure has limited global data center presence in some regions
	• Strength in machine learning and artificial intelligence • Competitive pricing and a pay-as-you-go model, and integration with other Google services and APIs	• Limited global data center presence in certain regions • Learning curve for unfamiliar users
	• An extensive global infrastructure, a wide range of services and tools, and a strong reputation for reliability, security, and scalability	• Complex pricing model that can lead to unpredictable costs

Conclusion

- Microsoft Azure, Google Cloud, and AWS offer **unique strengths** in healthcare-focused solutions, security, and advanced analytics capabilities.
- AWS is the preferred cloud provider for the ICSSS prototype due to its **robust and scalable infrastructure** with an extensive global presence.
- The **familiarity** among the team members, and strong reputation for **reliability, security, and scalability**.
- **AWS HealthLake** is designed for storing, transforming, and analyzing health data at scale and is compliant with regulatory standards such as HIPAA and GDPR.
- AWS's **seamless integration** with other AWS services provides a comprehensive suite of tools that cater to the project's unique requirements.

Cloud Architecture

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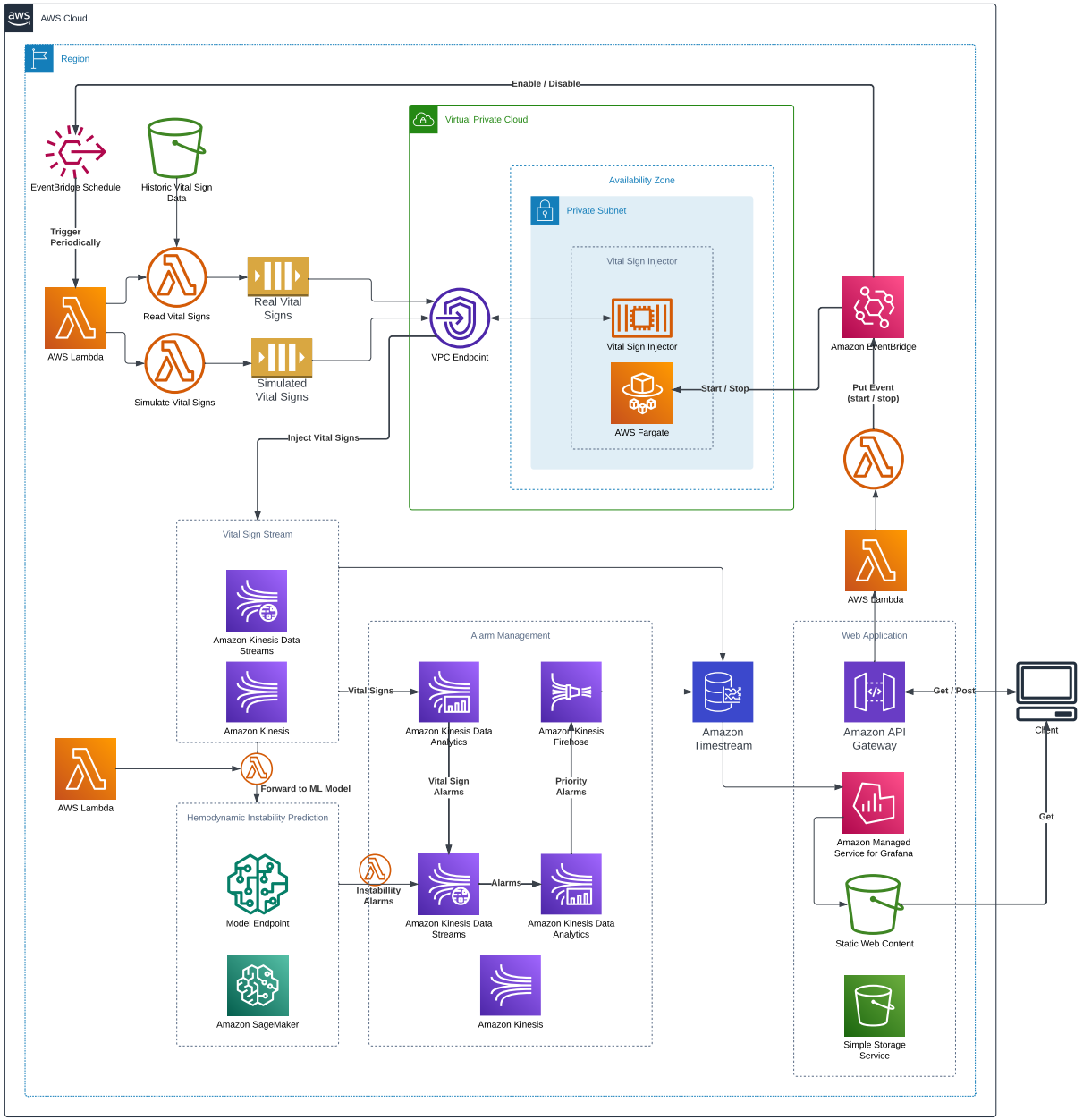
Cloud Architecture

MACH Architecture

- Data layer
- Compute/Analytics layer
- Visualisation layer



Progress Status

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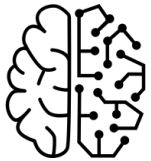
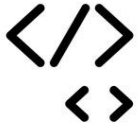
Progress Status

Historic **vital sign data collected and pre-processed**

Grafana functions as the application's **web interface**



Machine learning model for hemodynamic instability prediction is build (deployment WIP)



The **alarm management system** is currently simulated

All **cloud resources** of the current prototype are deployed in the cloud

Resources

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Resources

1. Scientific Papers
   a) Generalized Prediction of Hemodynamic Shock in Intensive Care Units
   b) Early prediction of hemodynamic interventions in the intensive care unit using machine learning
   c) Intraoperative hypotension and its prediction
   d) External validation of a machine learning model to predict hemodynamic instability in intensive care unit

2. Case Studies, Whitepapers, and Best Practices
   a) AWS Well-Architected Framework
   b) Overview of Amazon Web Services
   c) Gold Coast University Hospital Optimizes ICU Efficiency Through Datarwe Solutions Running on AWS and Intel
   d) Machine Learning Best Practices in Healthcare and Life Sciences

Resources

3. Learning Resources and Communities
    a) AWS Skillbuilder
    b) AWS Documentation
    c) Resources to navigate your AWS Cloud learning journey
    d) Perform biomedical informatics without a database using MIMIC-III data and Amazon on Athena
    e) FHIR is transforming interoperability in healthcare
4. News and Events
    a) DMEA Berlin 2023
    b) AWS Summit Berlin 2023
    c) AWS Events and Webinars
5. Other references
    a) Microsoft Azure
    b) Google Cloud

Prototype

Dashboard in normal state

Prototype

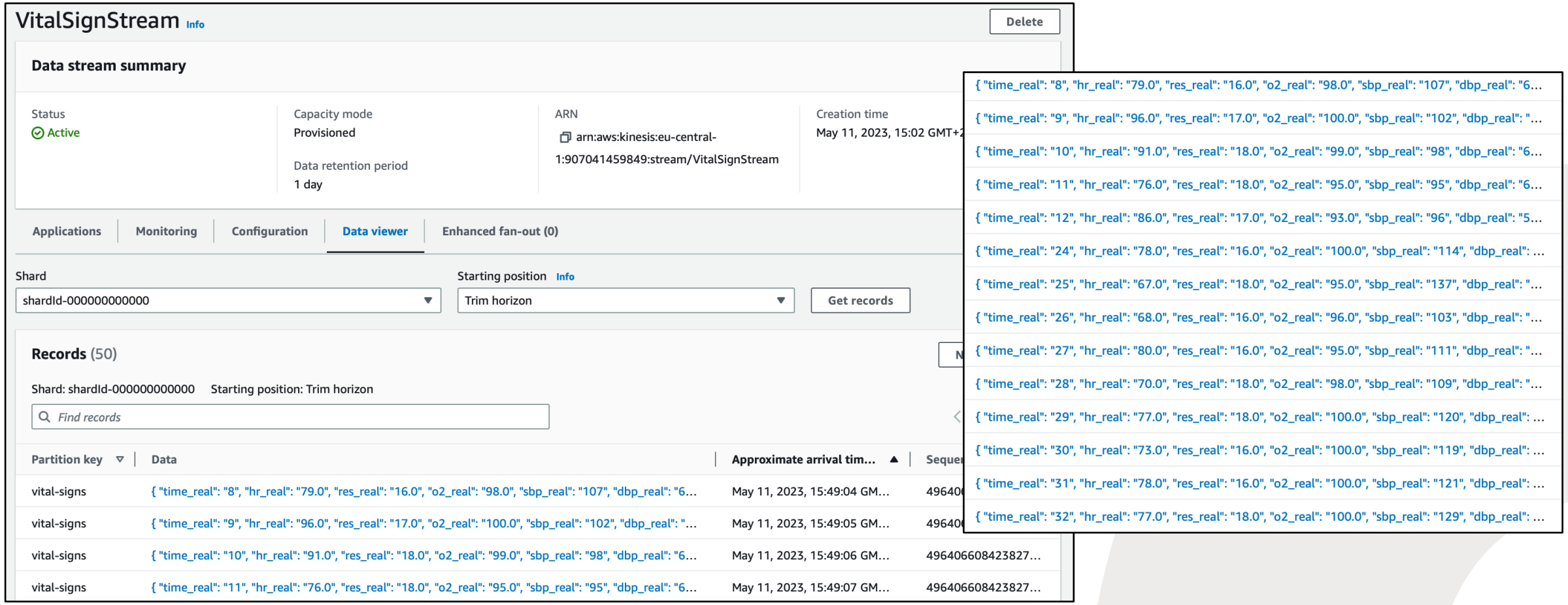
Dashboard with instability alarm

Prototype

Dashboard with instable patient state

Prototype

Kinesis Data Stream with real-life vital sign data



Prototype

DL and ML model with negative prediction state

```
====================================
  o2sat  sbp dbp heartrate resprate
0    60   90  49       215        9
1    70  142  50        49        8
2   189  100  79       190       10
3    35  143  72       244       26
4    44   72  59        55        7
1/1 [==============================] - 0s 40ms/step
[[44 72 59 55  6]]
1/1 [==============================] - 0s 31ms/step
[[71 71 57 71  8]]
1/1 [==============================] - 0s 25ms/step
[[76 71 57 80  8]]
1/1 [==============================] - 0s 25ms/step
[[79 71 57 83  8]]
1/1 [==============================] - 0s 25ms/step
[[80 71 57 84  8]]
Rolling average of the predicted values:
   o2sat  sbp  dbp  heartrate  resprate  predicted_instability
0    137  109   60        197        13                      0
```

Prototype

DL and ML model with positive prediction state

```
====================================
  o2sat  sbp  dbp heartrate resprate
0   145   75   59       137       22
1   158   47   42        78       20
2    50   78  102       152       30
3   100   70   87       149       18
4   108  147  115        62       33
1/1 [==============================] - 0s 70ms/step
[[108 147 115  62  33]]
1/1 [==============================] - 0s 35ms/step
[[147 165 124  72  38]]
1/1 [==============================] - 0s 42ms/step
[[157 168 125  77  40]]
1/1 [==============================] - 0s 36ms/step
[[157 168 126  77  40]]
1/1 [==============================] - 0s 40ms/step
[[157 168 126  77  40]]
Rolling average of the predicted values:
   o2sat  sbp  dbp  heartrate  resprate  predicted_instability
0    120   83   85        125        24                      1
====================================
Instability predicted
====================================
```

Thank you for your attention!