AI-powered Surgery: Transforming Healthcare Through Innovation and Collaboration

World Summit AI
10-11 December 2024 | Doha, Qatar

Doha, Qatar – December 10, 2024

Ozanan R. Meireles, MD, FACS

Associate Professor of Surgery, Duke University School of Medicine
Vice Chair for Innovation, Department of Surgery
Surgical Director of Duke AI Health

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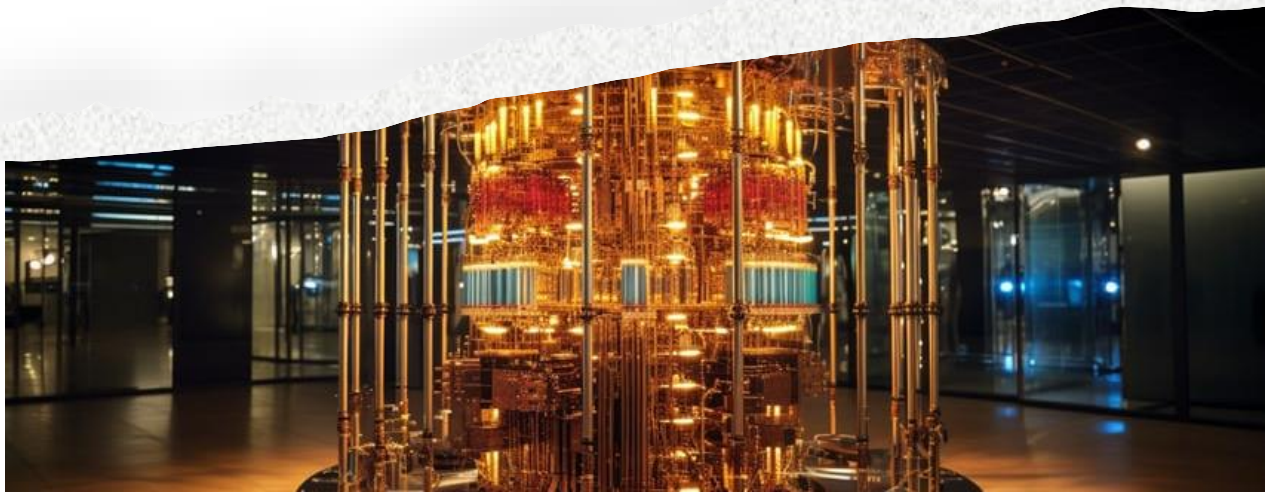
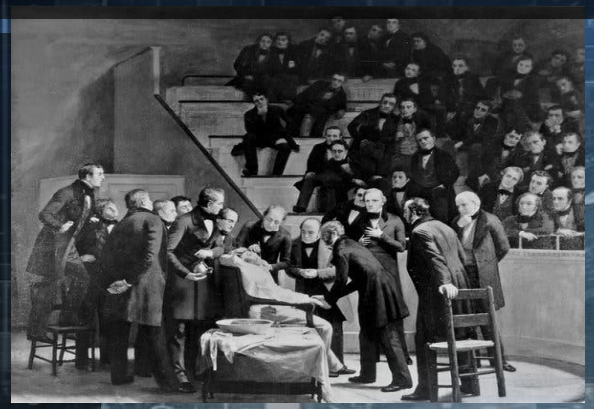
> **Digital Darwinism is also playing out at a national level. It is a game-changer for geopolitics as well as industry.**
>
> — Virginie Maisonneuve, global CIO equity, Allianz Global Investors

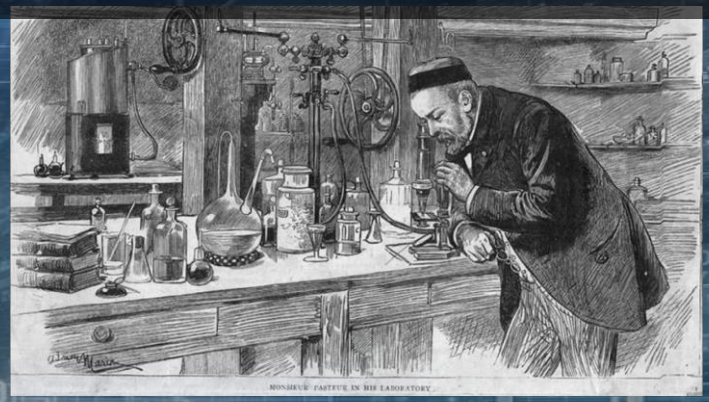
The Era of Technological Disruption



Evolution of the Operating Room

- General Anesthesia – 1840s
- Antiseptic Surgery – 1860s
- Endoscopic Procedures – 1960s
- Cognitive Computing – 2010s
- **Surgical AI – 2016**





Hardware (instruments, Robotics)	Software (Data, Algorithms)	Human Operators	VIDEO
Human (professional preparedness)	Economics (business plan)	Governance	Telecom

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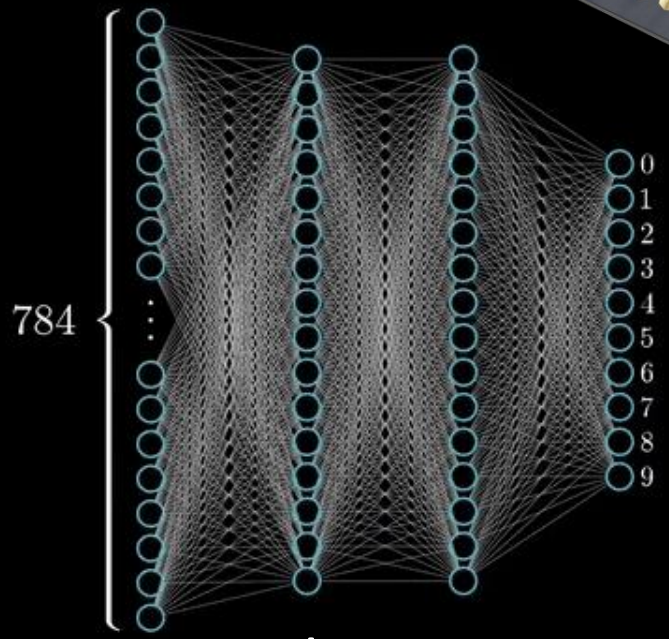
Video DATA

More computing power



More powerful/efficient techniques

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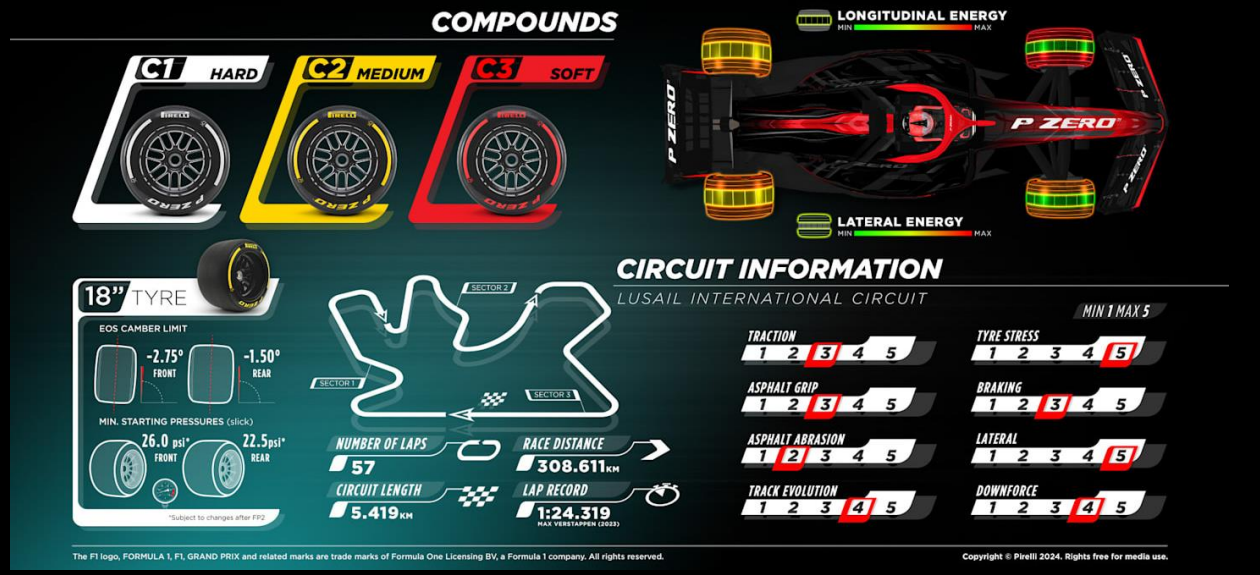
QATAR AIRWAYS
FORMULA 1
QATAR AIRWAYS
QATAR GRAND PRIX
2023
LUSAIL | 06-08 OCTOBER
QATARGP
QATAR AIRWAYS
visit QATAR


Carlos SAINZ
Valtteri BOTTAS
Sergio PEREZ
TOP SPEED
321
308
229
250
0
317
309
141
CURRENT SPEED
CURRENT TYRES
MEDIUM NEW
HARD NEW
START PFM


Global Tyre Partner of Formula 1
FORMULA 1 QATAR AIRWAYS QATAR GRAND PRIX 2024
LUSAIL PREVIEW
QATAR
COMPOUNDS
C1 HARD
C2 MEDIUM
C3 SOFT
LONGITUDINAL ENERGY
LATERAL ENERGY
P ZERO
18" TYRE
EOS CAMBER LIMIT
-2.75° FRONT
-1.50° REAR
MIN. STARTING PRESSURES (slick)
26.0 psi FRONT
22.5psi REAR
*Subject to changes after FP2
SECTOR 1
SECTOR 2
SECTOR 3
CIRCUIT INFORMATION
LUSAIL INTERNATIONAL CIRCUIT
NUMBER OF LAPS
57
RACE DISTANCE
308.611KM
CIRCUIT LENGTH
5.419KM
LAP RECORD
1:24.319
MAX VERSTAPPEN (2023)
MIN 1 MAX 5
TRACTION
ASPHALT GRIP
ASPHALT ABRASION
TRACK EVOLUTION
TYRE STRESS
BRAKING
LATERAL
DOWNFORCE
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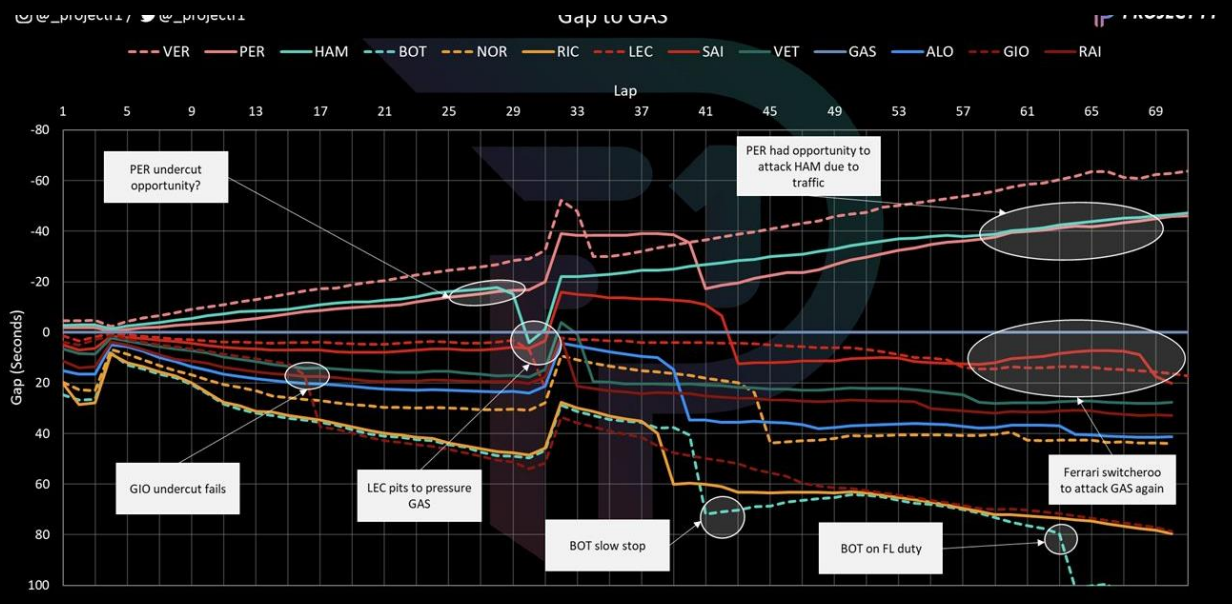
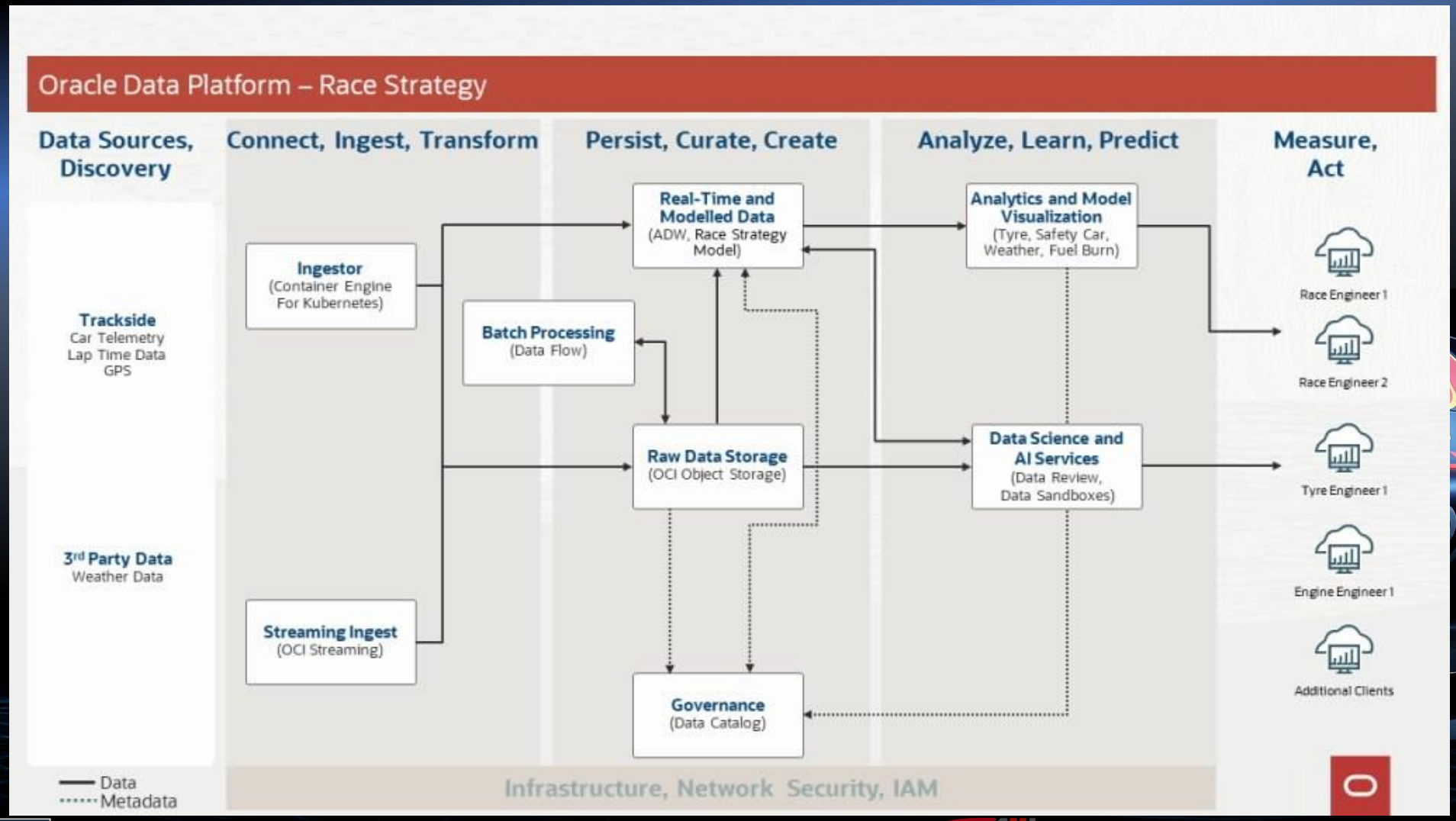
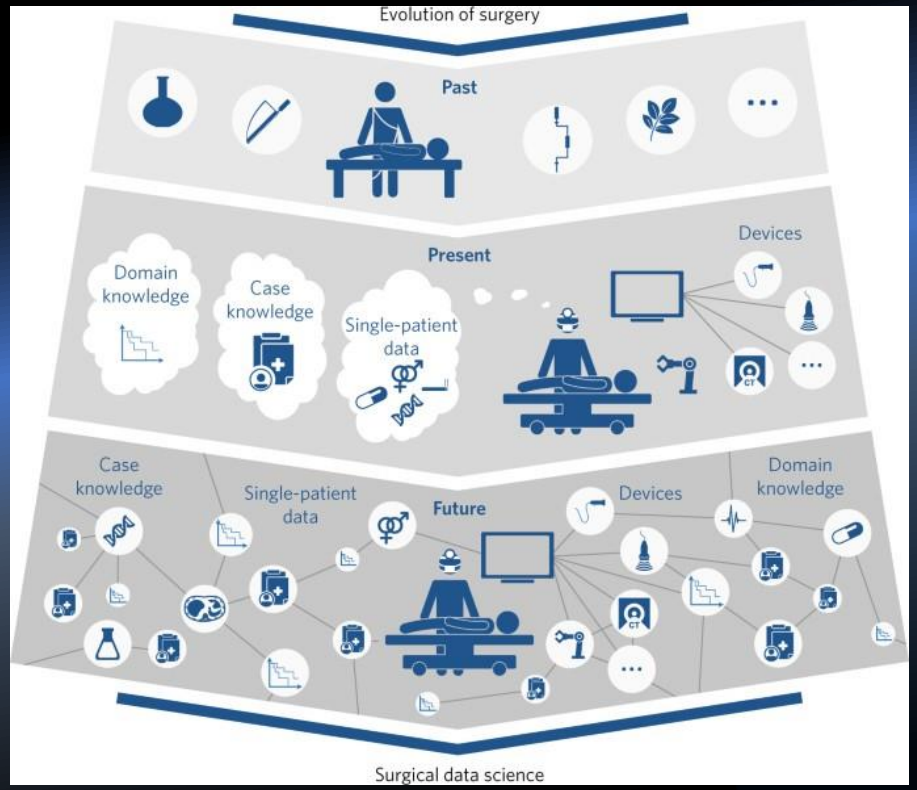
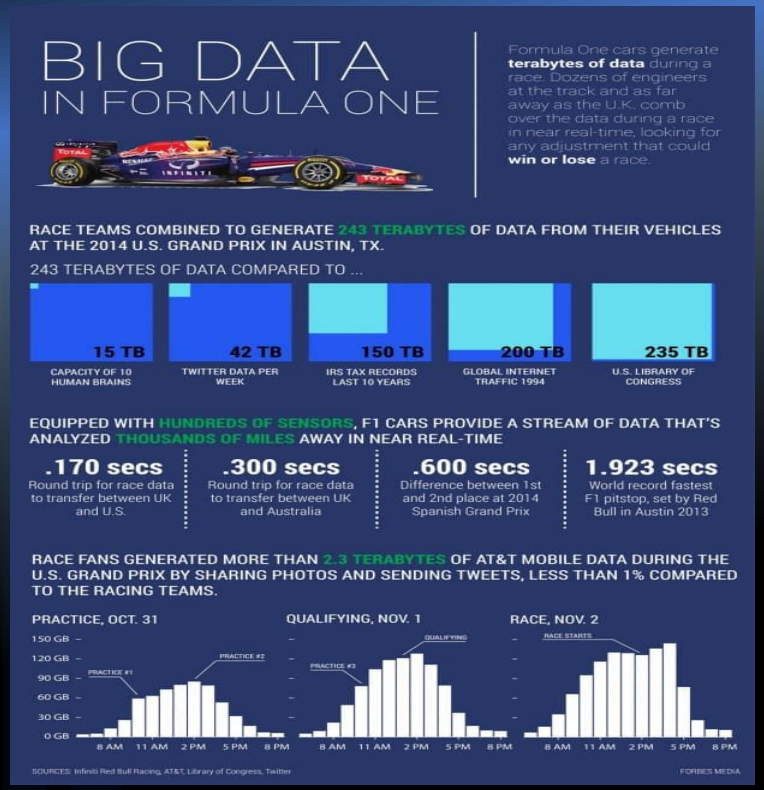

Gap to GAS
VER PER HAM BOT NOR RIC LEC SAI VET GAS ALO GIO RAI
Lap
Gap (Seconds)
PER undercut opportunity?
PER had opportunity to attack HAM due to traffic
GIO undercut fails
LEC pits to pressure GAS
BOT slow stop
BOT on FL duty
Ferrari switcheroo to attack GAS again


Event
Timing
Video/Map
Graphs
Driver
Performance
GPS Analysis
Qualifying
Race
Pit stops
Safety Car
Tyres
Track
Telemetry
Weather
Widgets
Video Window - F1 HOST HD_2018-11-25_16-30-31.ts
Circle Map Viewer
Lap 29/55
01:05:03
Lap Time Distribution (Current Session)
Weather Channel Graph (Current Event,Station 2)
Pit Window
Driver Strategy Graph (HAM)
Minutes into session
LIVE
REVIEW

Error Handling and Recovery







The average hospital generate

137 terabytes per day

F1 teams combined generate

243 terabytes per day

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WHAT IF...?

O.S.

Operative planning:

Surgical Strategy with Error Handling and Recovery System

Potential Current Applications

- Data-driven insights
- Predictive analytics
- Automated scheduling
- Resource allocation
- Quality improvement
- Notification Systems
- Operative Report Generation
- Billing
- Compliance Monitoring
- Resource Prediction, and Allocation

Tele-mentoring

Operative Case Length Prediction

Attention Awareness

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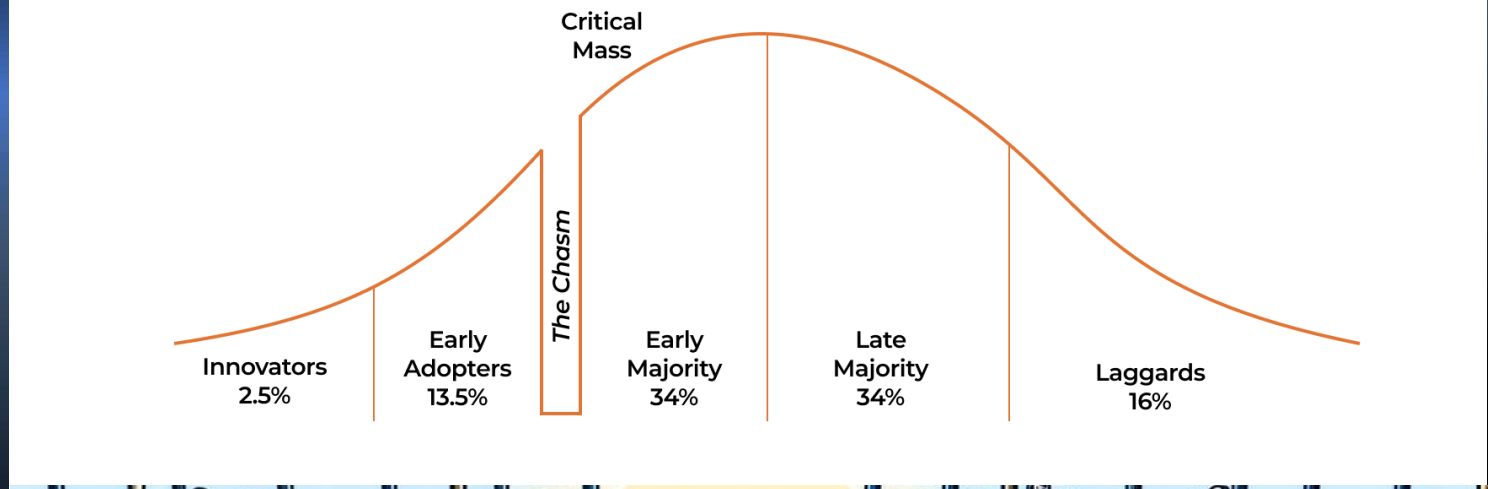
Barriers

- Data Quality And Privacy Concerns
- High Implementation Costs
- Complex Integration
- Cultural Resistance
- Limited AI Interpretability
- Ethical Considerations

Diffusion of Innovation Theory

- Relative Advantage
- Compatibility to Workflow
- Complexity of Use
- Triability of models
- Observability of Results



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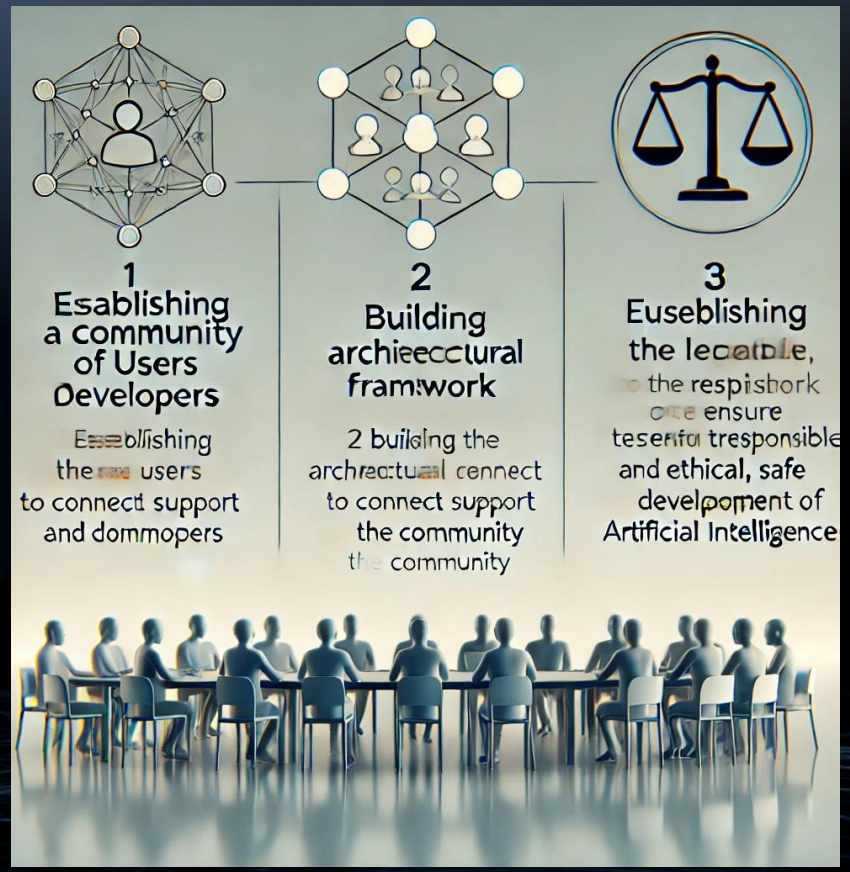
Three Major Pillars of Development

- Establishing a **Community** of users and developers
- Building the **Architectural Framework** to connect and support the community.
- Establishing a **Legal Framework** to ensure trustworthy, responsible, ethical, and safe development of artificial intelligence.



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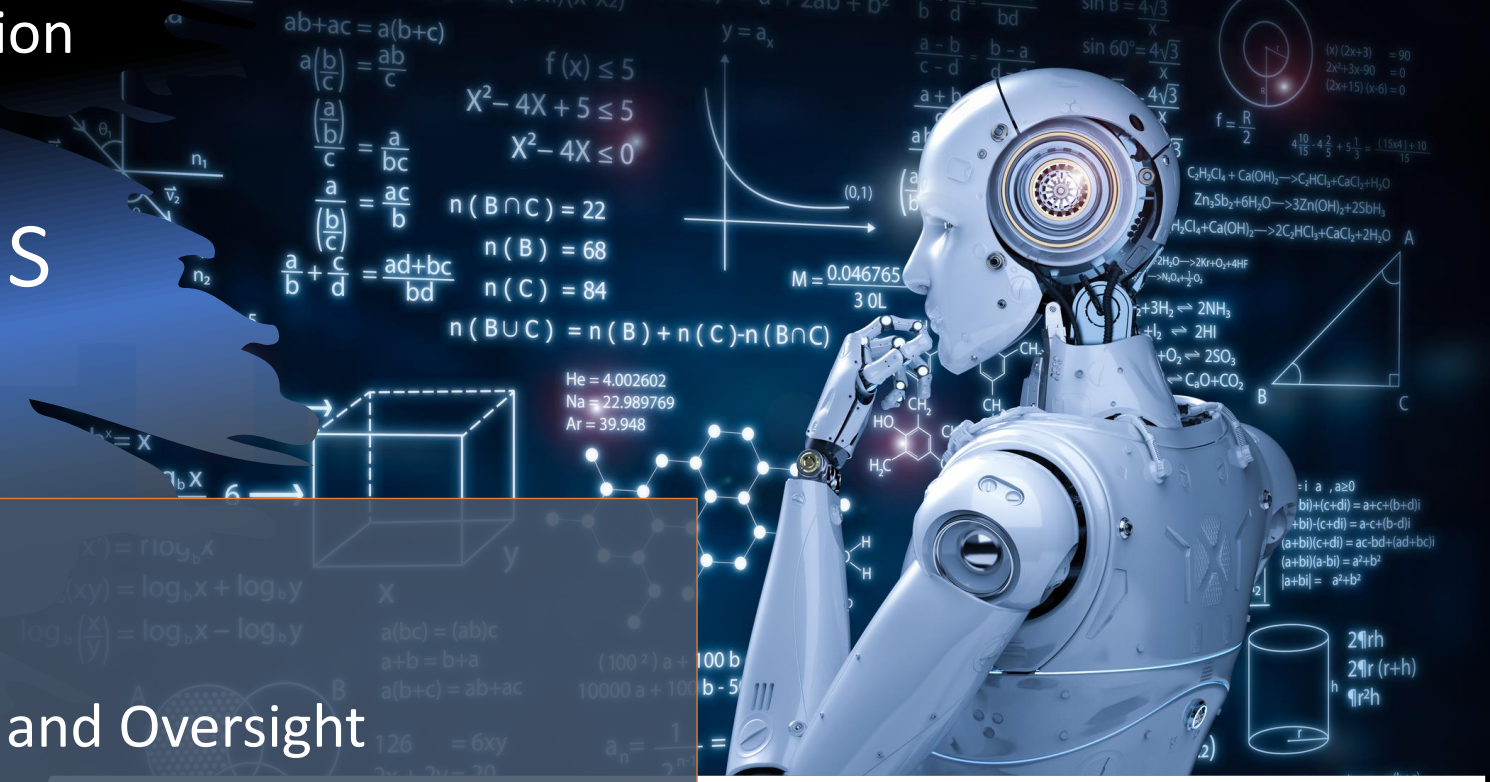
Preparation, Creation, and Implementation

Surgical AI Standards



Foundational work

- Annotation ✅
- Data Structure and Use ✅
- Governance Policies, Regulations, and Oversight

Structural needs

- Video Data Acquisition Framework ✅
- Creation of a Community ✅
- Management through Data Lifecycle

Knowledge creation and dissemination

- Scientific Research ✅
- Education ✅
- Cultural Transformation

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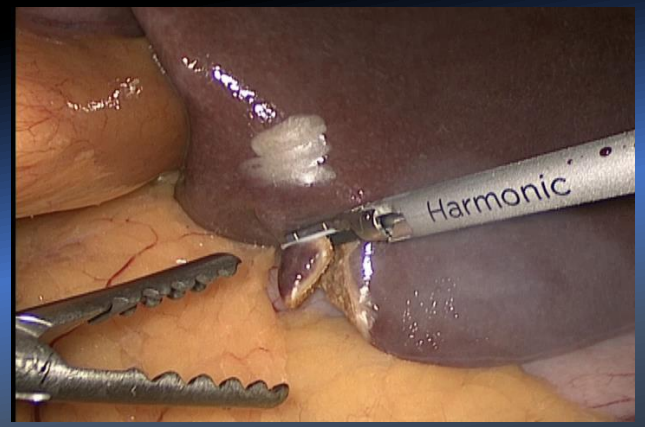
DATA collection



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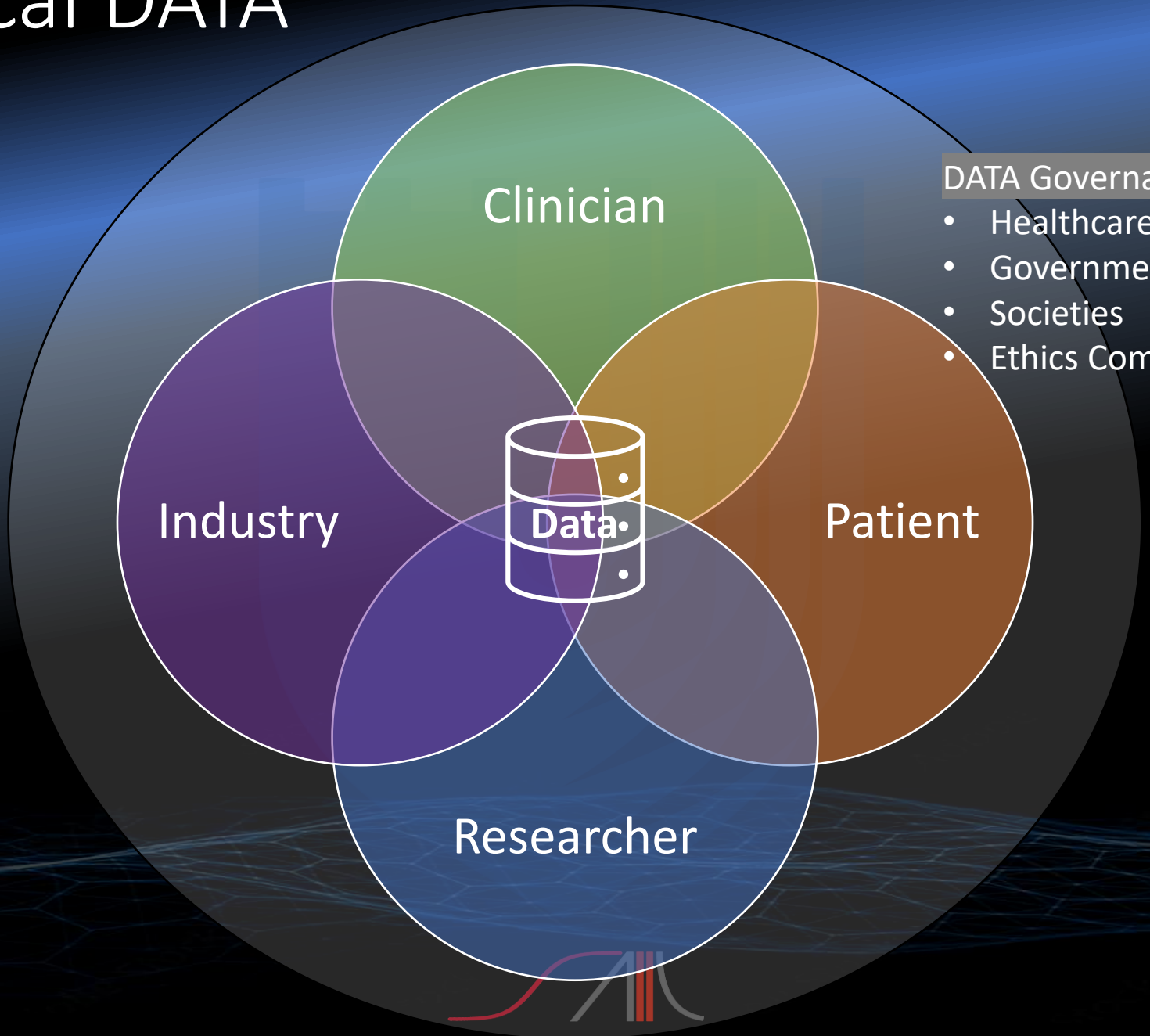
Surgical DATA



DATA Governance, Policies and Oversight

- Healthcare Systems
- Governments
- Societies
- Ethics Committees

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Consensus Recommendations on an Annotation Framework for Surgical Video

Surgical Endoscopy (2021) 35:4918–4929
https://doi.org/10.1007/s00464-021-08578-9

CONSENSUS STATEMENT

SAGES consensus recommendations on an annotation framework for surgical video

Ozanan R. Meireles[1] · Guy Rosman[1,2] · Maria S. Altieri[3] · Lawrence Carin[4] · Gregory Hager[5] · Amin Madani[6] · Nicolas Padoy[7,8] · Carla M. Pugh[9] · Patricia Sylla[10] · Thomas M. Ward[1] · Daniel A. Hashimoto[1] · the SAGES Video Annotation for AI Working Groups

Received: 25 April 2021 / Accepted: 26 May 2021 / Published online: 6 July 2021

Abstract

Background The growing interest in analysis of surgical video through machine learning has led to increased research efforts; however, common methods of annotating video data are lacking. There is a need to establish recommendations on the annotation of surgical video data to enable assessment of algorithms and multi-institutional collaboration.

Methods Four working groups were formed from a pool of participants that included clinicians, engineers, and data scientists. The working groups were focused on four themes: (1) temporal models, (2) actions and tasks, (3) tissue characteristics and general anatomy, and (4) software and data structure. A modified Delphi process was utilized to create a consensus survey based on suggested recommendations from each of the working groups.

Results After three Delphi rounds, consensus was reached on recommendations for annotation within each of these domains. A hierarchy for annotation of temporal events in surgery was established.

Conclusions While additional work remains to achieve accepted standards for video annotation in surgery, the consensus recommendations on a general framework for annotation presented here lay the foundation for standardization. This type of framework is critical to enabling diverse datasets, performance benchmarks, and collaboration.

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Annotation Framework
Hierarchical Structure with Expandable Granularity

Temporal Events

Phase (generic)

Step (procedure- specific)

Task (generic)

Action (generic)

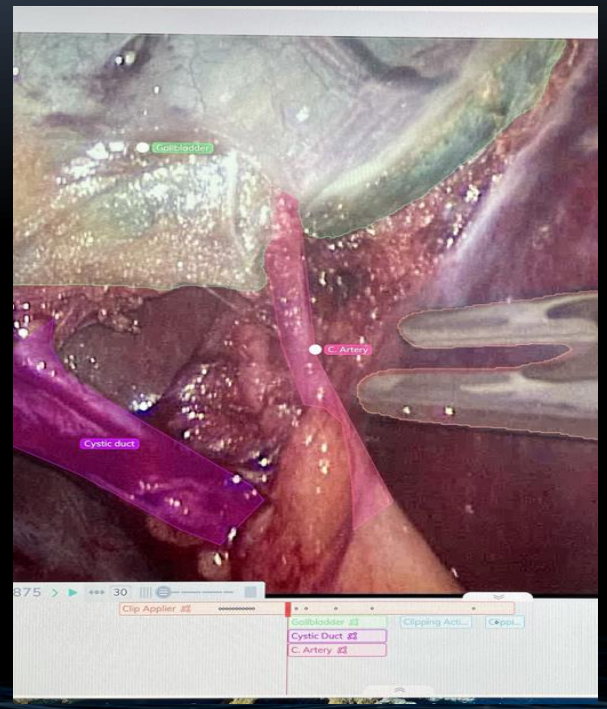
Spatial Events

Anatomic region

Specific anatomy

General anatomy

Tissue characteristics



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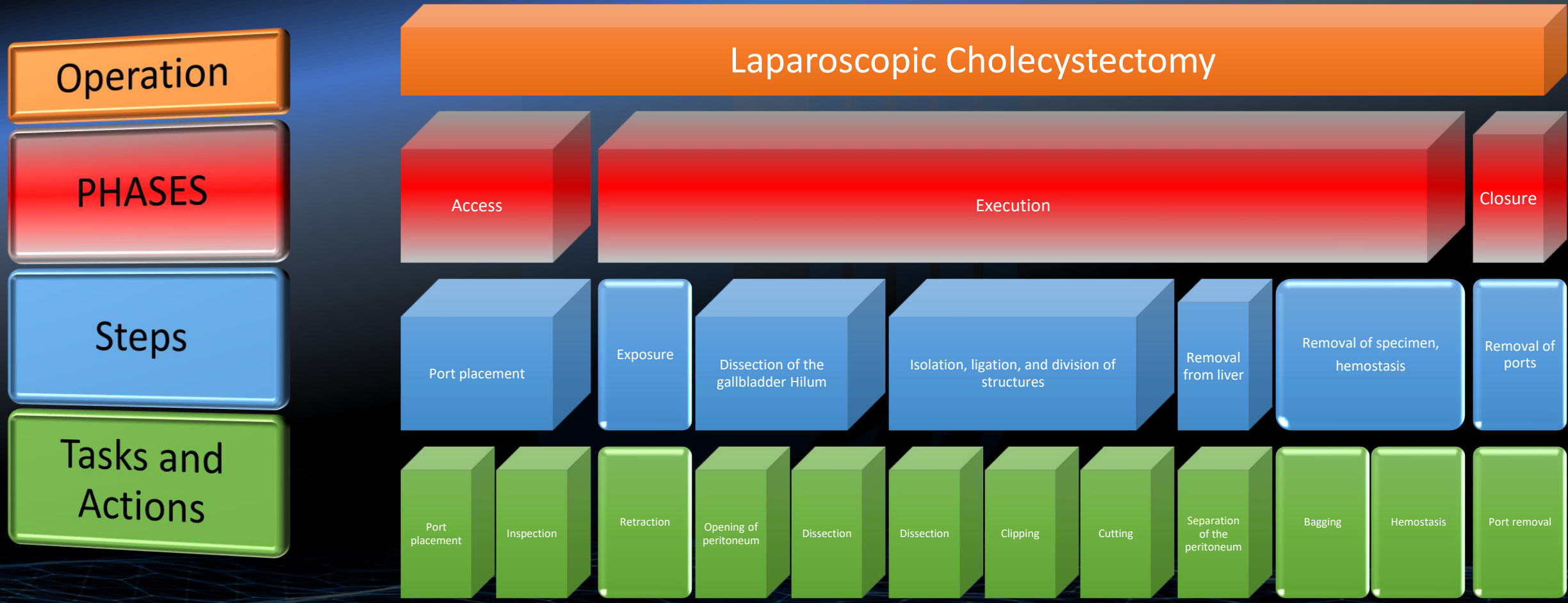
Annotation

Temporal Hierarchy



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Annotation

Spatial Hierarchy

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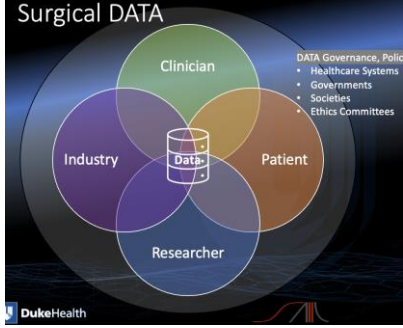
SAGES consensus recommendations on surgical video data use, structure, and exploration (for research in artificial intelligence, clinical quality improvement, and surgical education)



Jennifer A. Eckhoff[1,2] · Guy Rosman[1,3] · Maria S. Altieri[4] · Stefanie Speidel[5] · Danail Stoyanov[6] · Mehran Anvari[7] · Lena Meier-Hein[8] · Keno März[8] · Pierre Jannin[9] · Carla Pugh[10] · Martin Wagner[11] · Elan Witkowski[1] · Paresh Shaw[12] · Amin Madani[13] · Yutong Ban[1,3] · Thomas Ward[1] · Filippo Filicori[14] · Nicolas Padoy[15] · Mark Talamini[16] · Ozanan R. Meireles[1]

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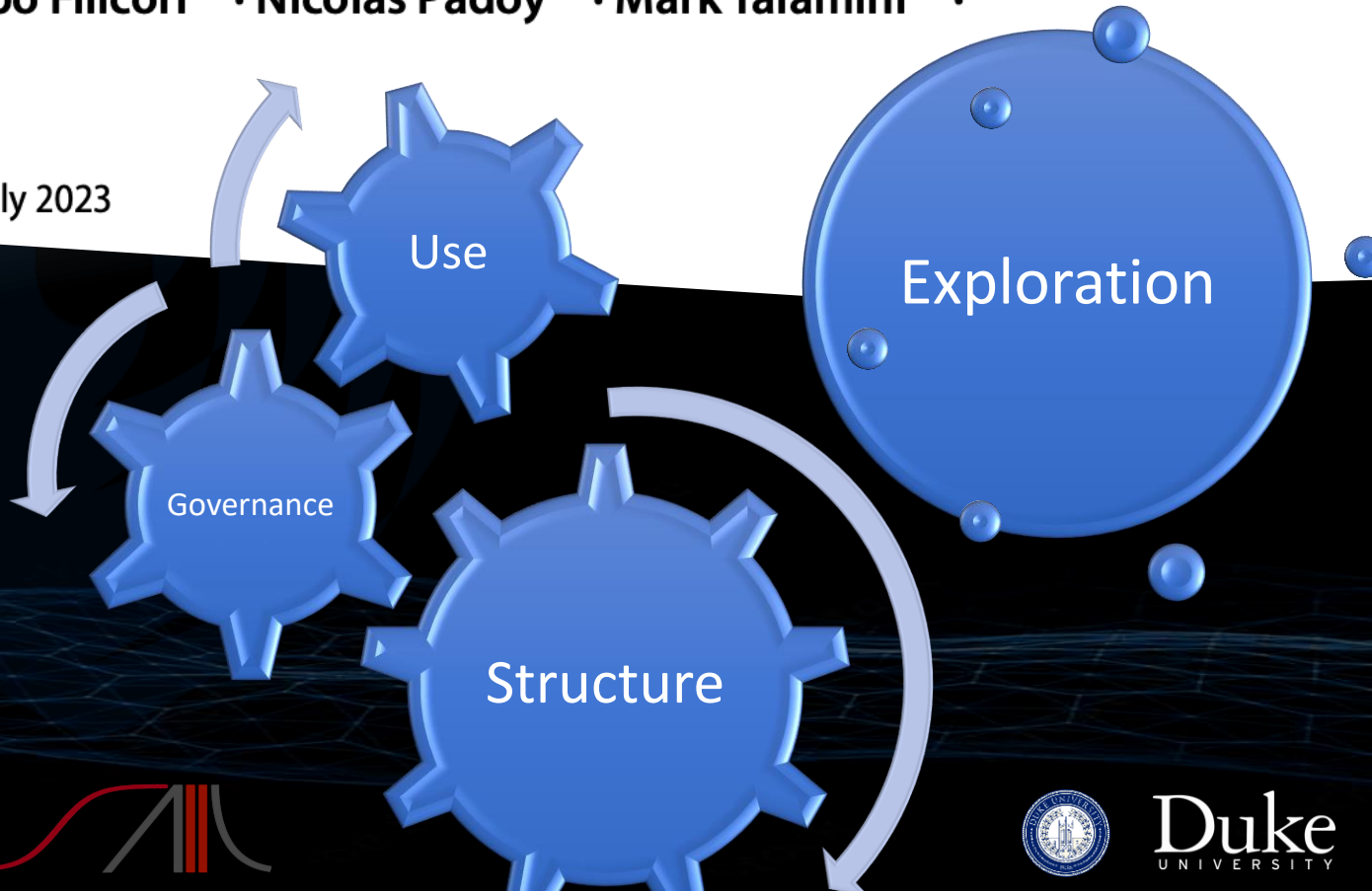

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Use Cases

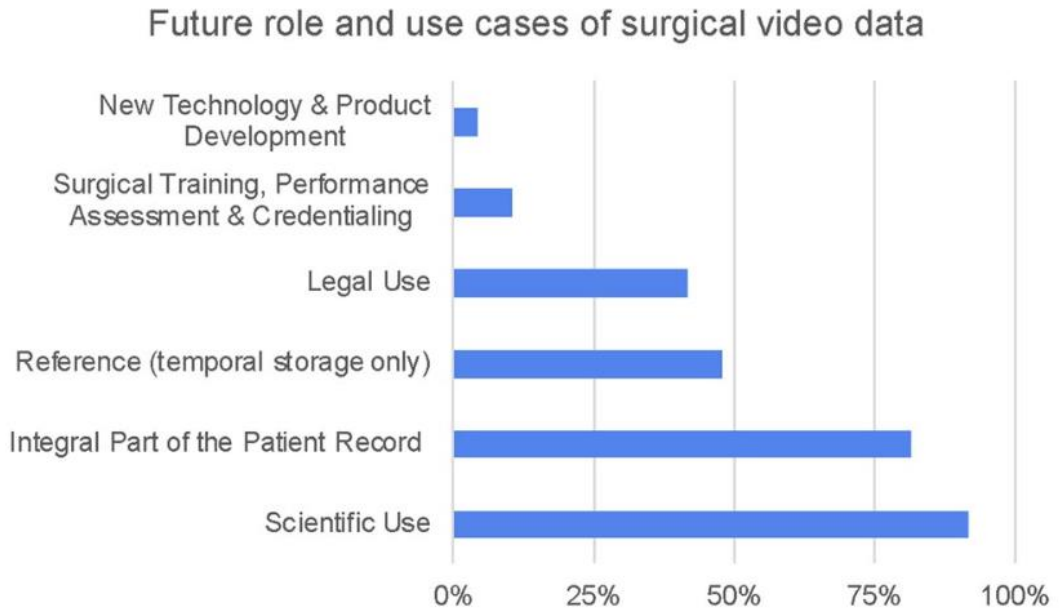
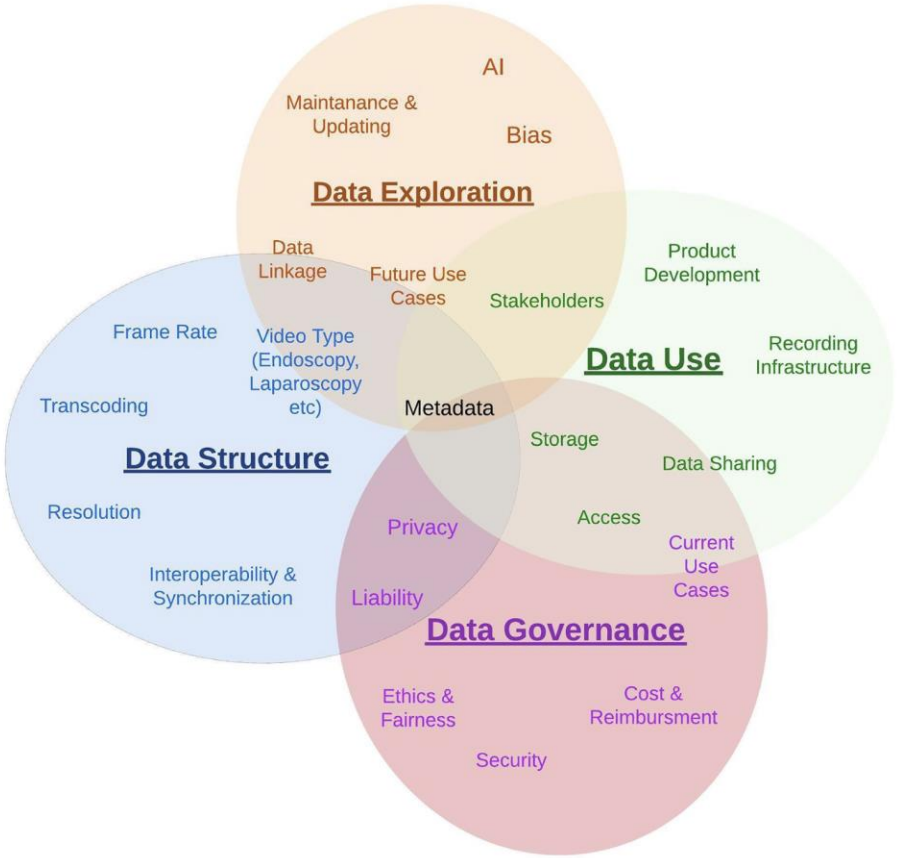


Fig. 7 Results of statement 8—future applications and use cases of surgical video data, identified by survey participants



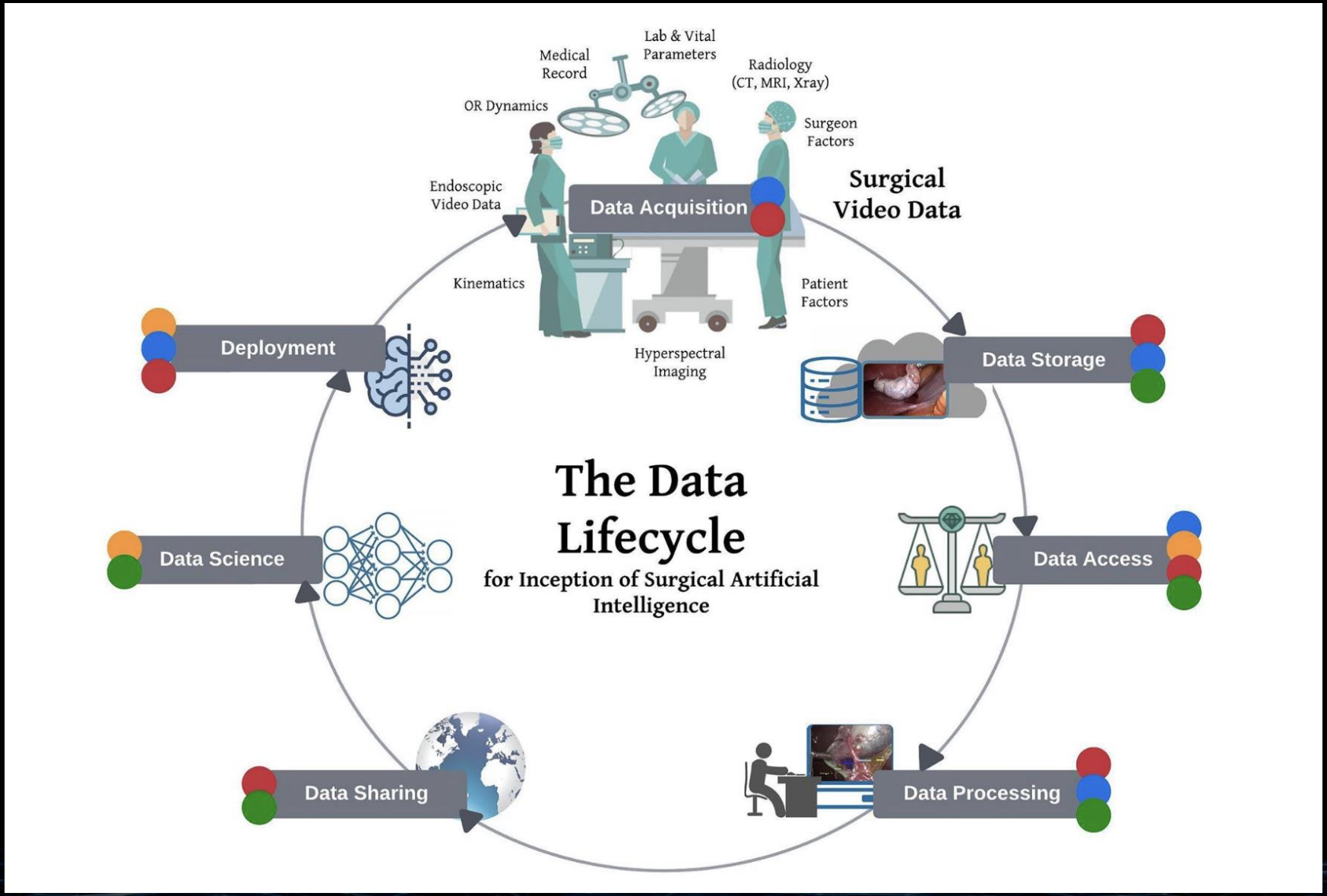


Fig. 1 The Data Lifecycle, highlighting stages of surgical video data en route to the creation of AI. Schematic outline of essential attributes of data architecture and infrastructure influencing current data use and future exploration and considerations for adequate governance

Community

Scientific efforts
Discovery
Validation and Benchmarking

Clinical Trials

Computer Vison Challenges

Multi-institutional collaborations

Academia and Industry partnership

Standards for Publications

Validation Studies

Promote Diversity

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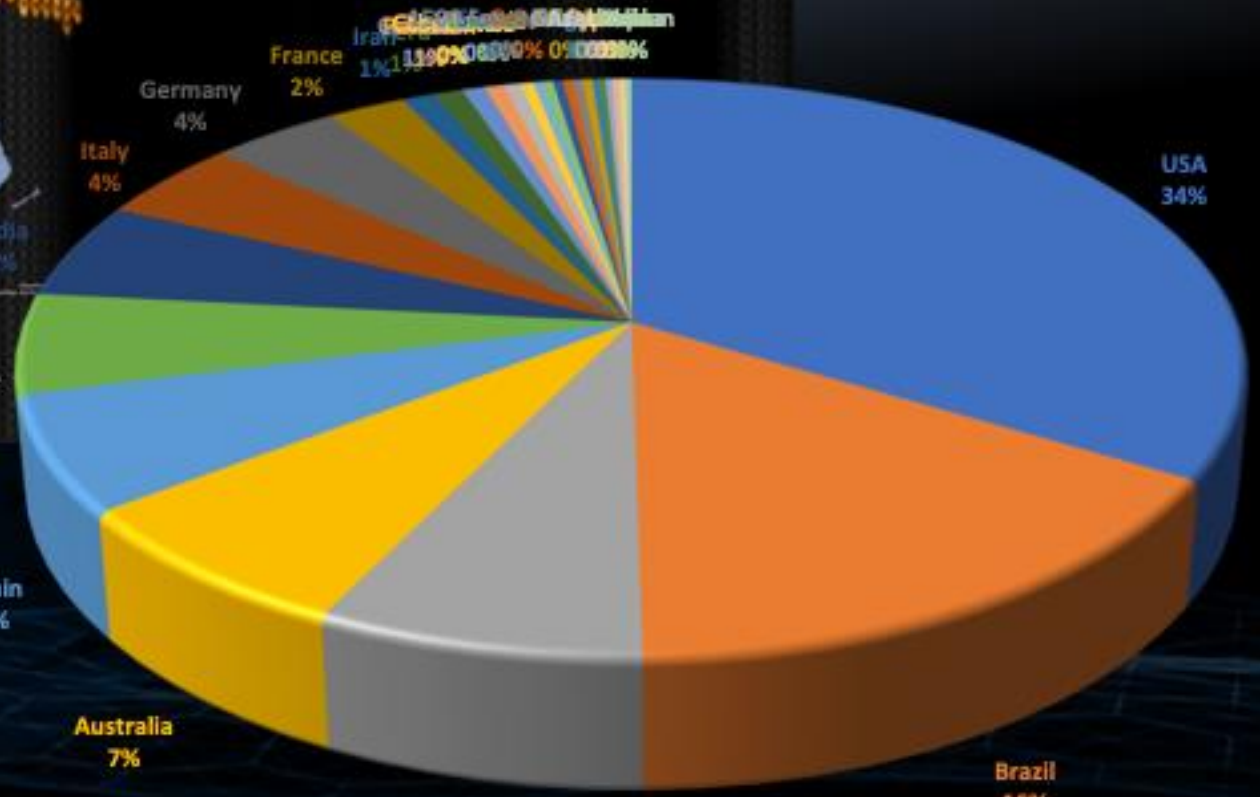
The Critical View of Safety Challenge

A SAGES Initiative



DATA Donors

Accounts: 155
Institutions: 64
29% LMIC

1700 +

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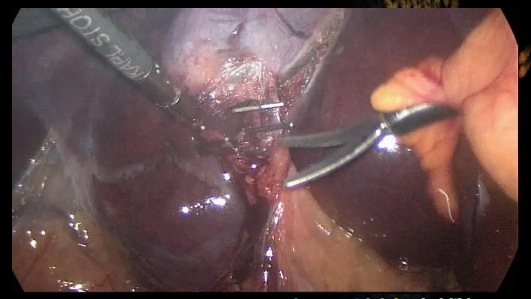
The Critical View of Safety Challenge



A SAGES Initiative

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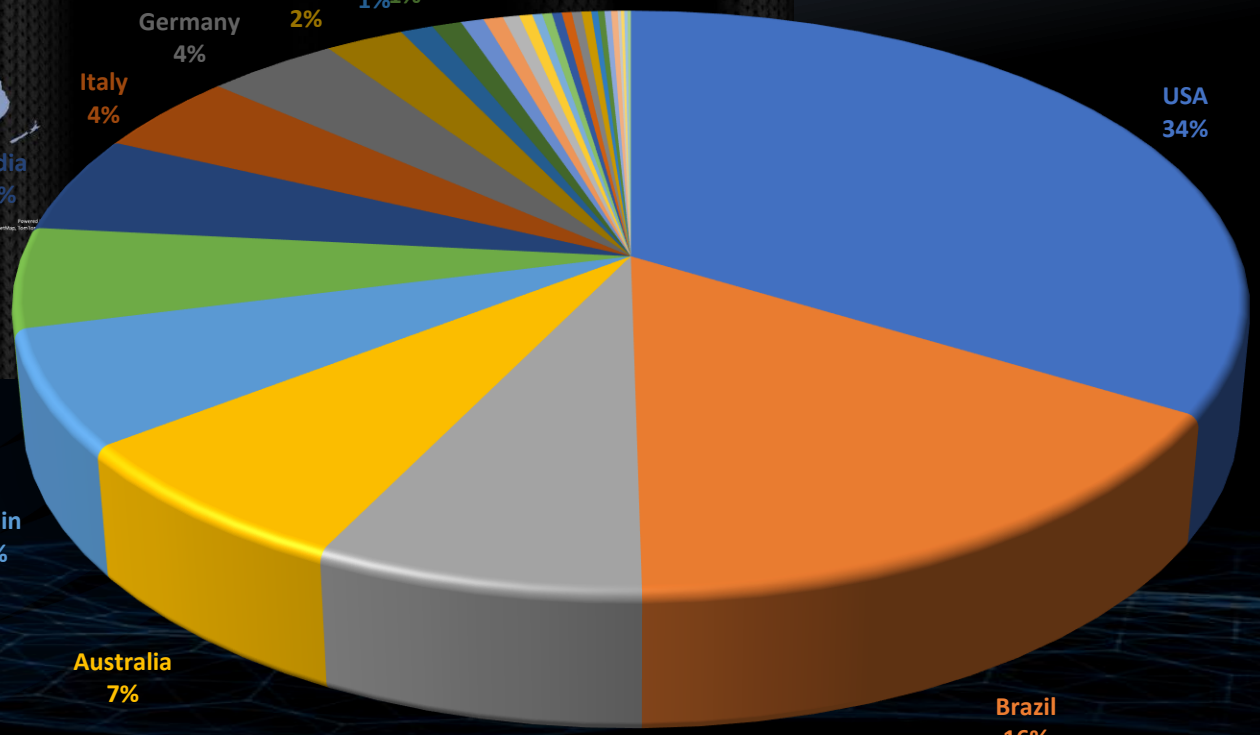

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10.000 Unique Visitors

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Community Effort

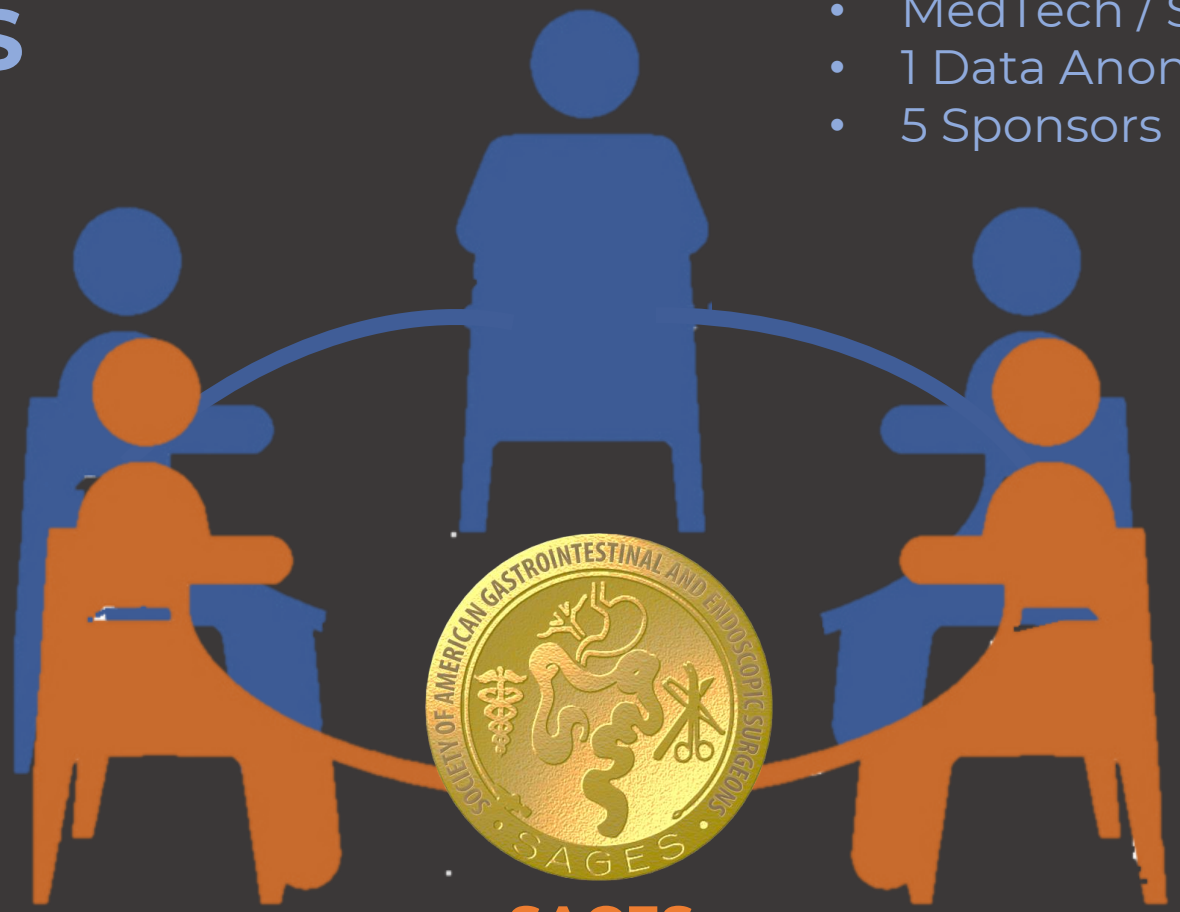
SUPPORTERS

Data Donors

- 55 Surgeons
- 54 Institutions
- 24 Countries

Industry Advisors

- MedTech / Surgical MIS Companies
- 1 Data Anonymization Pipeline
- 5 Sponsors



SAGES

ORGANIZERS

Surgeons

- 6 Clinical Leaders
- 14 Clinical Advisors

Annotators

- 19 Residents & Fellows
- 14 Countries
- 20% Dropout Rate

Computer Scientists

- 7 Technical Leaders
- 8 Technical Advisors

Outreach: Data Characteristics

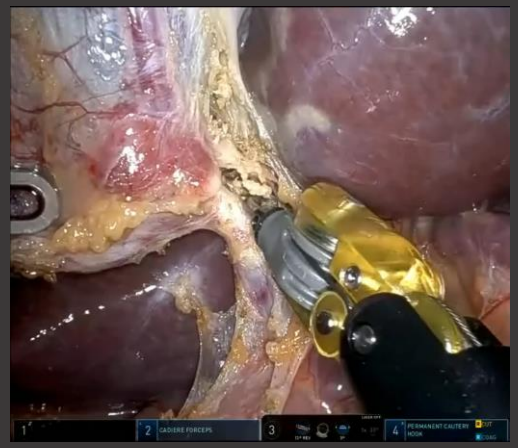
Clinical Diversity (besides origin)

- 9 Recording Devices
- Robotics / Laparoscopic
- ICG +/- IOC

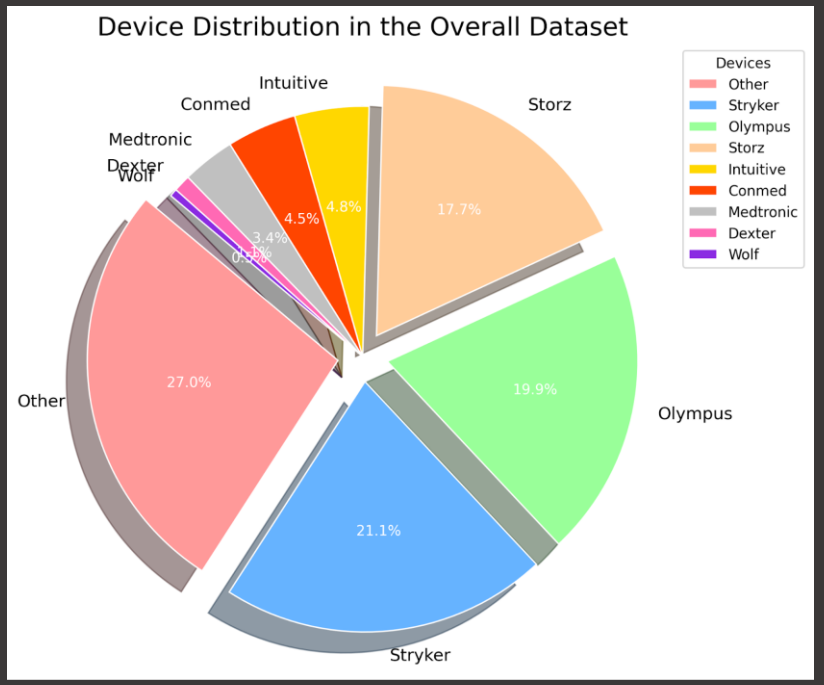
Technical Diversity

- 19 Resolutions
- 4 File Types
- 3 Formats

2D Vision, 854x480 Pixel, Laparoscopic



3D Vision, HD-Resolution, Robotics + ICG



Challenge Goals: Subchallenges

1) CVS Classification

Binary classification of 3 visually distinct criteria

Criterion 1 (C1)

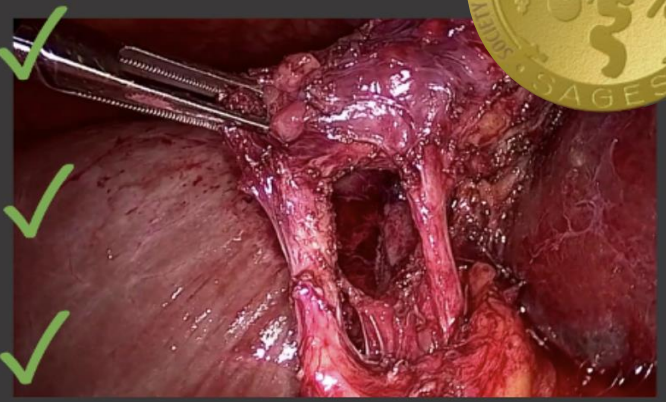
Two and only two tubular structures are seen connected to the gallbladder

Criterion 2 (C2)

The **hepatocystic triangle** is cleared from fat and/or connective tissue so that an unimpeded view is obtained

Criterion 3 (C3)

The lower part of the gallbladder is dissected off the liver bed to expose the lower **1/3 of the cystic plate.**

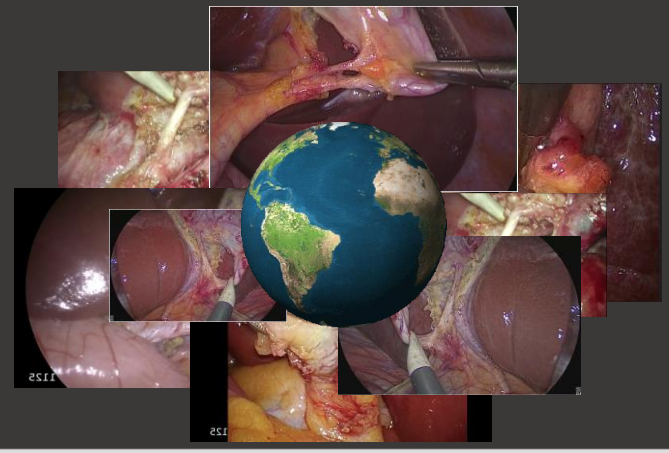


2) Uncertainty Quantification

Accounting for inherent uncertainty in real-world clinical setting

2) Robustness

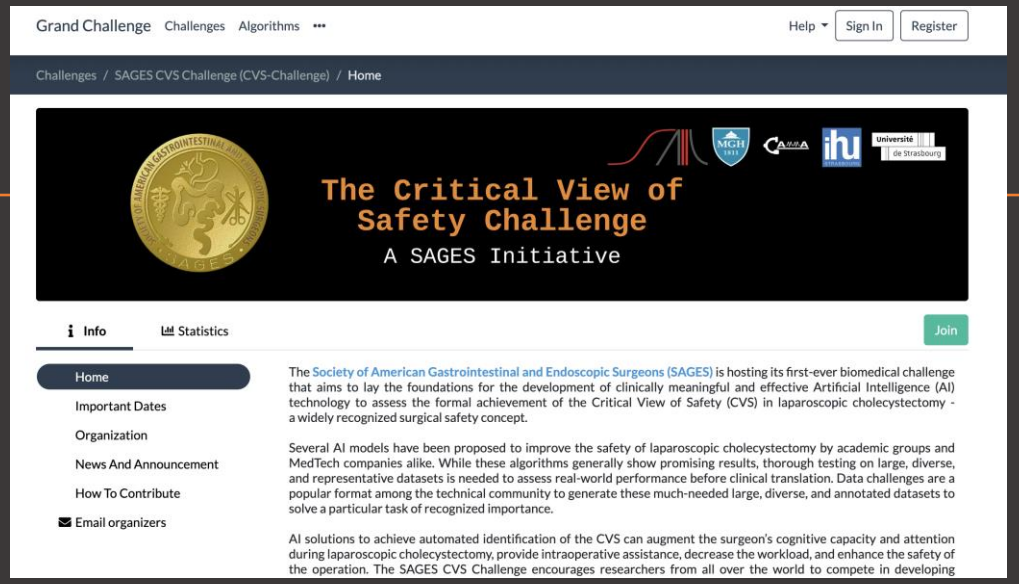
Consistency across distribution shifts linked to clinical & technical diversity



Competitors

36 Teams

16 Countries



Rankings

CVS Classification
Team Farm Stanford University
Theator Inc
SDS-HD German Cancer Research Center
mmll
TUE-VCA
Pandas
FightTumor
Caresyntax
SRV-WEISS
IRCV-URV
Transformers
CVS_HUST
HFUT-MedlA

Uncertainty Quantification
Theator Inc
Pandas Chengdu University China
SDS-HD German Cancer Research Center
SRV-WEISS
Transformers
CVS_HUST
mmll
TUE-VCA
Farm
Caresyntax
IRCV-URV
FightTumor
HFUT-MedlA

SC2 - Ranking
SDS-HD German Cancer Research Center
Theator Inc
Team Farm Stanford University
mmll
TUE-VCA
Pandas
Caresyntax
FightTumor
IRCV-URV
SRV-WEISS
Transformers
HFUT-MedlA
CVS_HUST

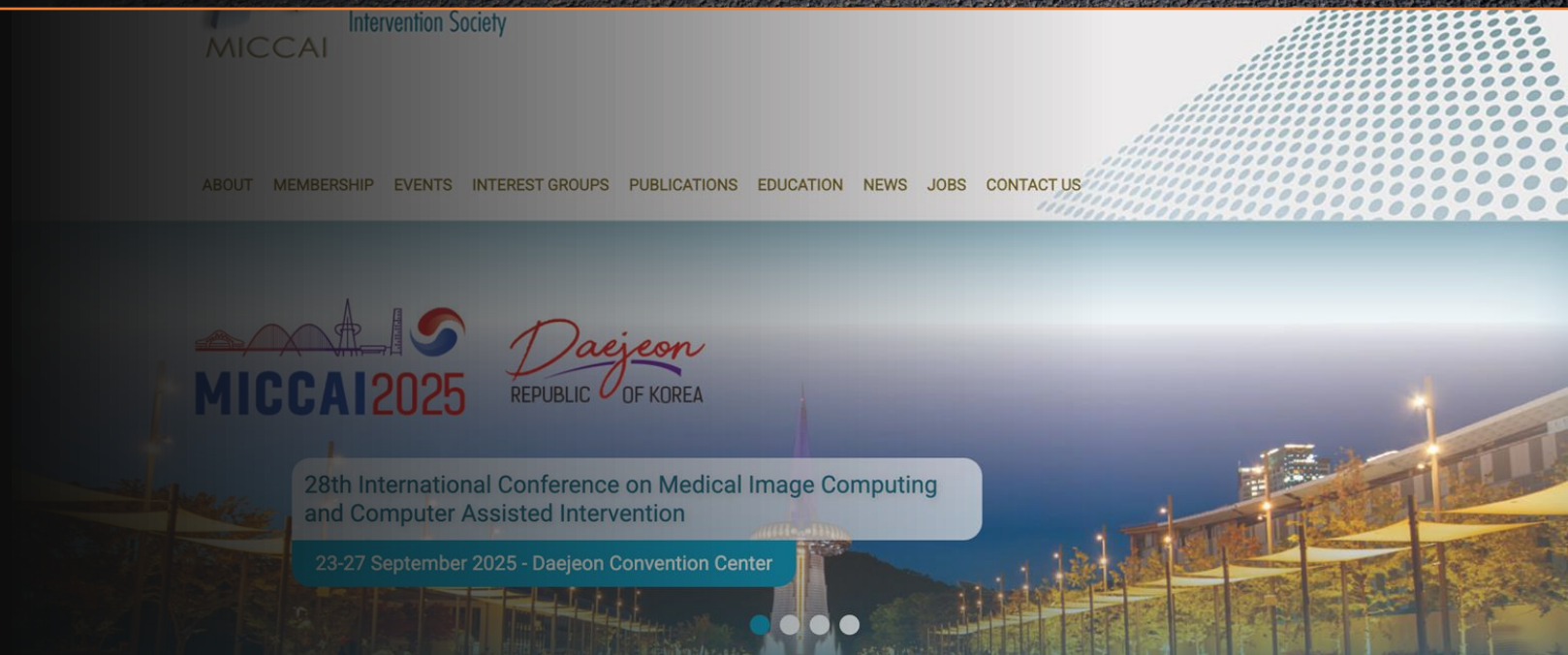
Winners Overall

Winners
Theator Inc
SDS-HD German Cancer Research Center
Team Farm Stanford University

Overall Prize Money: $15.500 + NVIDIA Developer Kit

IGX Origin with RTX 6000 ADA GPU (approx. $20k)

CVS Challenge Part 2



Education and Training

Scientific Meetings

Dedicated Fellowships

e.g. SAIIL

Medical School Curriculum

Publications

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Education and Training

Education and Training

- Scientific Meetings
- Dedicated Fellowships e.g. SAIIL
- Medical School Curriculum
- Publications

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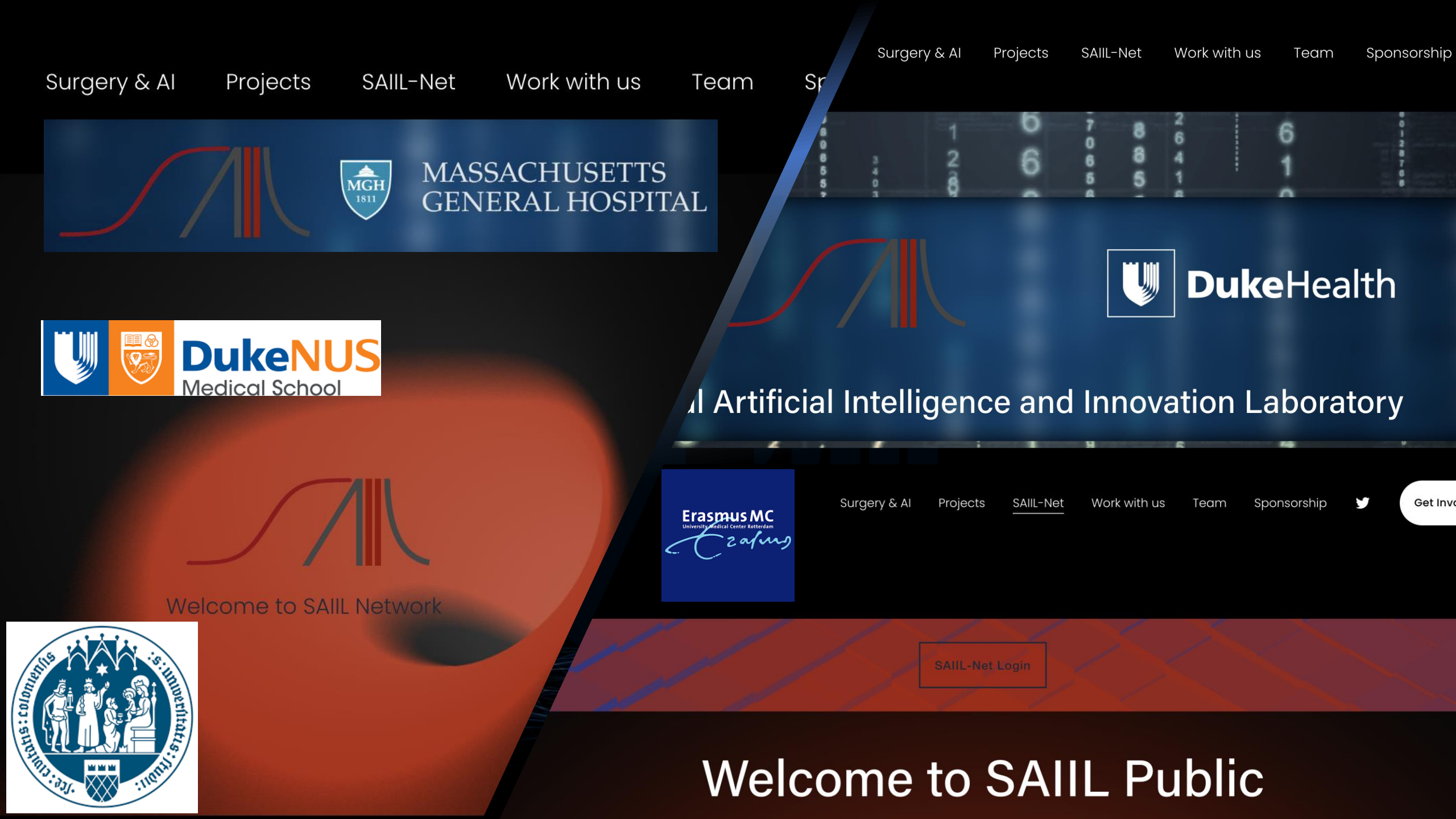

Surgery & AI
Projects
SAIIL-Net
Work with us
Team
Sponsorship
MASSACHUSETTS GENERAL HOSPITAL
MGH 1811
DukeNUS Medical School
DukeHealth
Artificial Intelligence and Innovation Laboratory
Erasmus MC
University Medical Center Rotterdam
Get Inv
Welcome to SAIIL Network
SAIIL-Net Login
Welcome to SAIIL Public

Surgical AI Governance Stakeholders

Regulations, Policies and Oversight

Data governance is a principled approach to managing data during its life cycle, from acquisition to use to disposal.

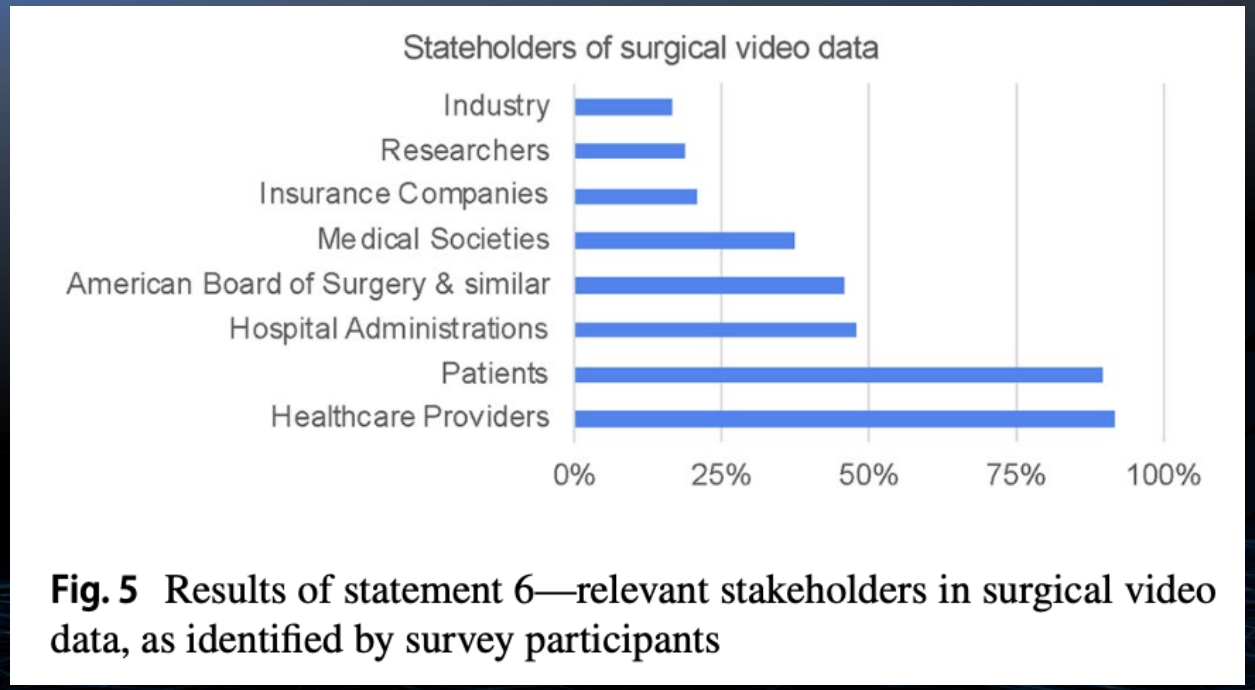
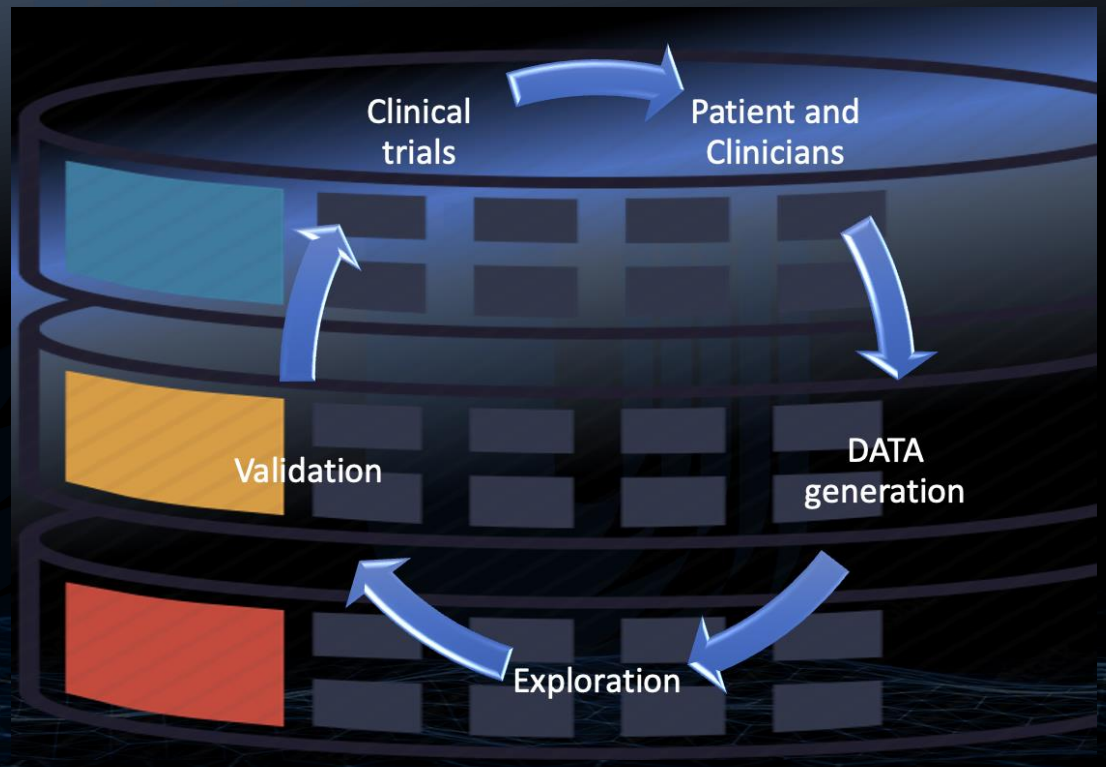


Fig. 5 Results of statement 6—relevant stakeholders in surgical video data, as identified by survey participants



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Legal Framework

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Office for Civil Rights

pdpc PERSONAL DATA PROTECTION COMMISSION SINGAPORE

CHAI

GDPR

TRAIN - SAIIL

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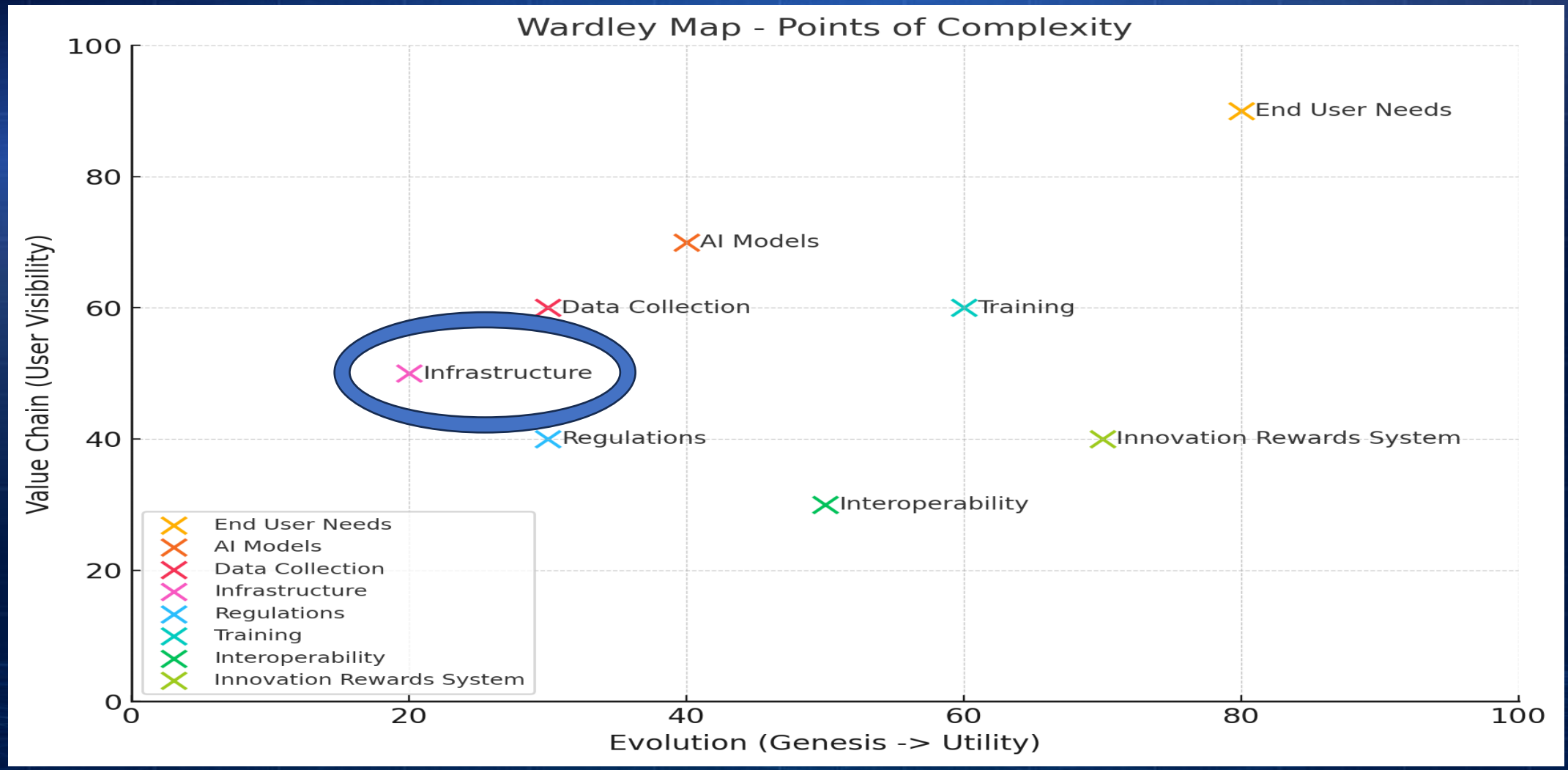
Blueprint

Wardley Map involves mapping components of a system or process based on their value chain and their stage of evolution.



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Building the Surgical Operating System (S.OS)

- **Ethical and Trustworthy Data Generation, Model Development, and Validation**
- **Addressing the Critical Need for Benchmarking and Ethical Considerations**

- **Data Privacy**
- **AI Model Development**
- **Validation**
- **Governance**

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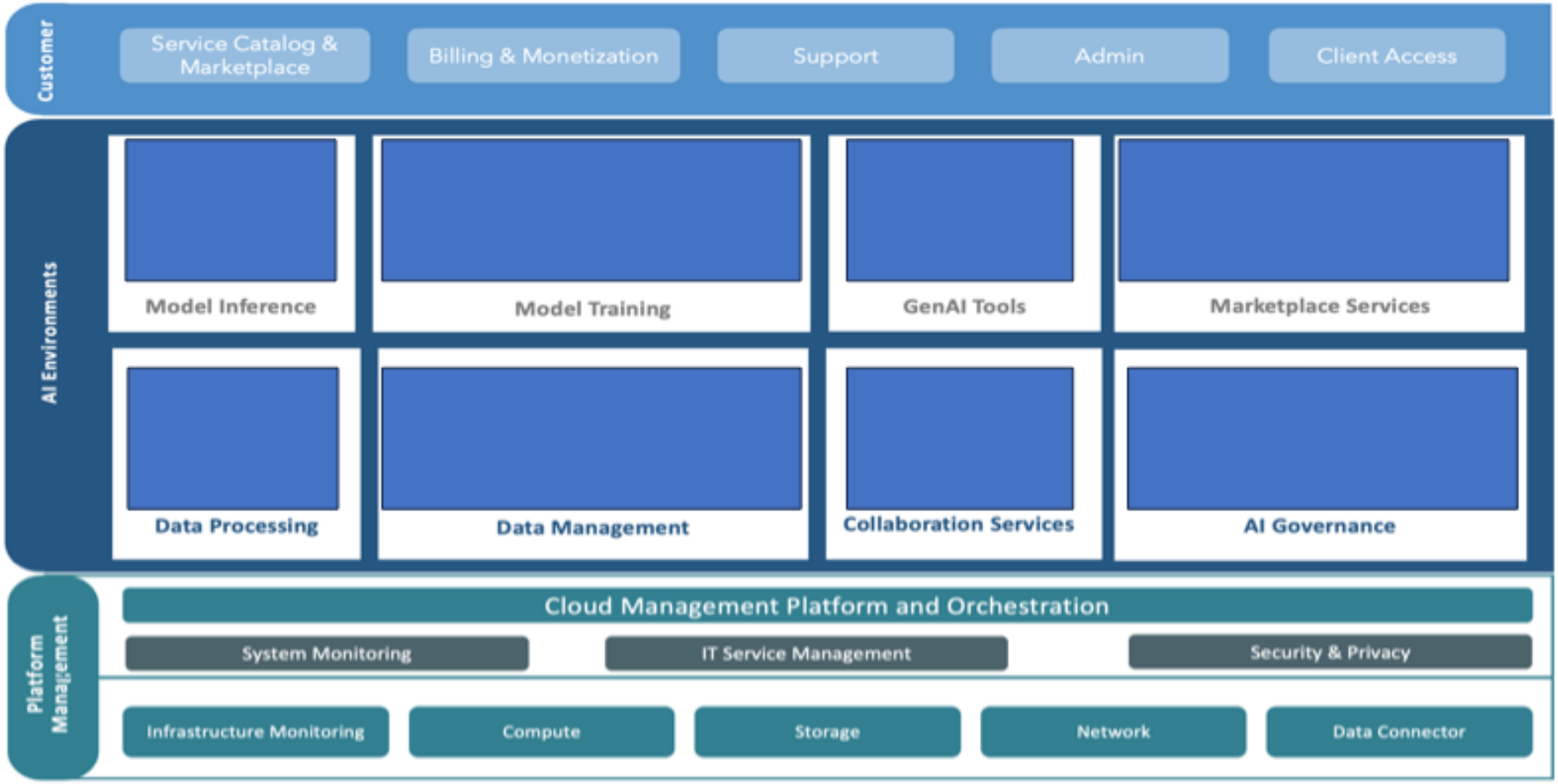
High-level Overview of SAIIL SOS Platform



Stakeholders

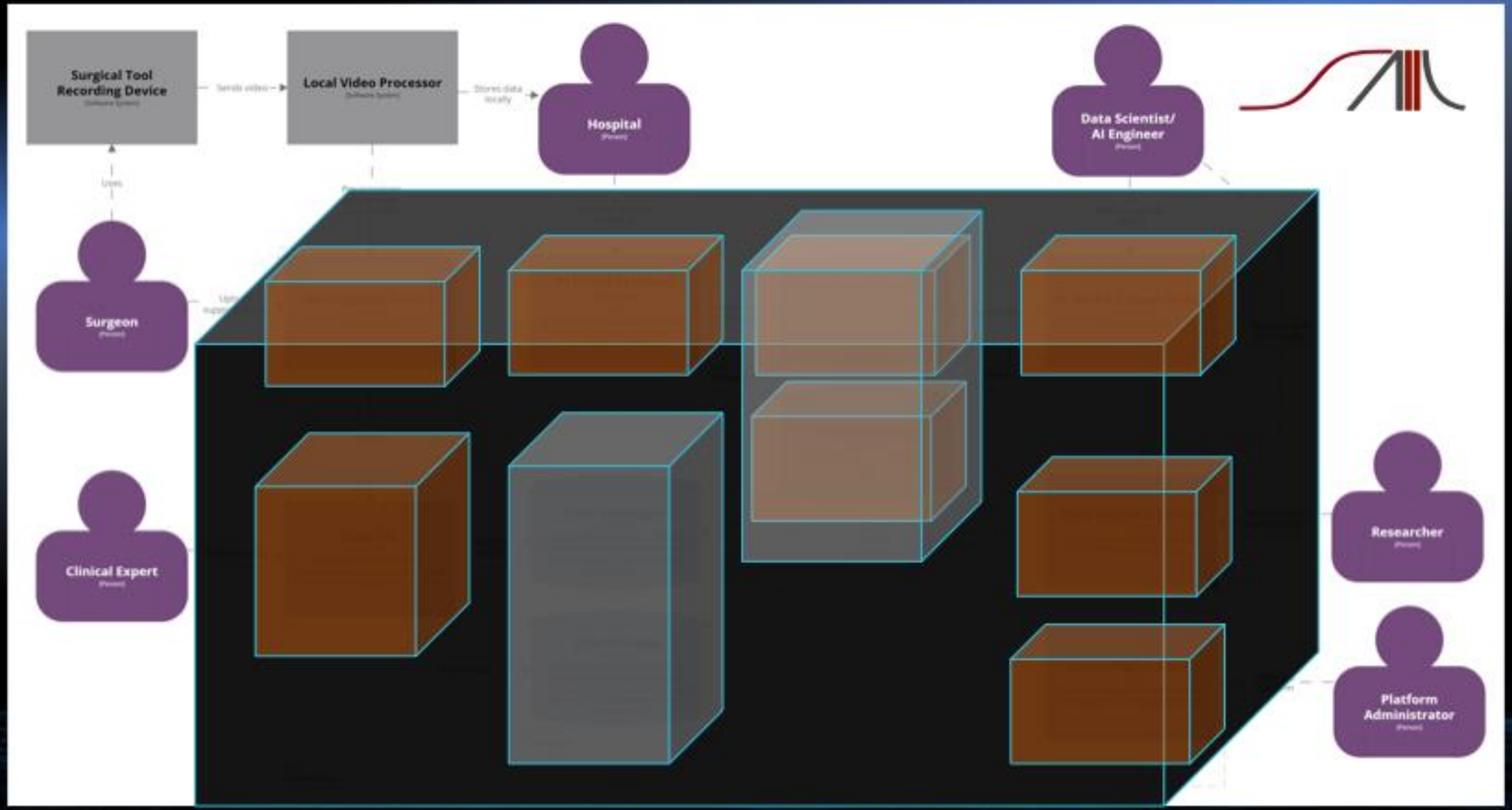
Data Scientist

Researcher

Surgical Team

Operators
Define / import service blueprints Provision AI environments

Functional overview of SAIIL S.OS Platform



WHAT IF...?

User: .....
Password: .....

S.OS is a conceptual framework that aims to seamlessly integrate surgical teams, operating rooms, patient data, and devices.

Standardization

Efficiency

Safety

S. OS Features

- Efficiency & Scheduling
- Data & Safety Management
- Technological Integration
- User Interface & Experience
- Security & Access Control
- Communication & Collaboration
- Analytics & Monitoring
- Utilities & Special Features

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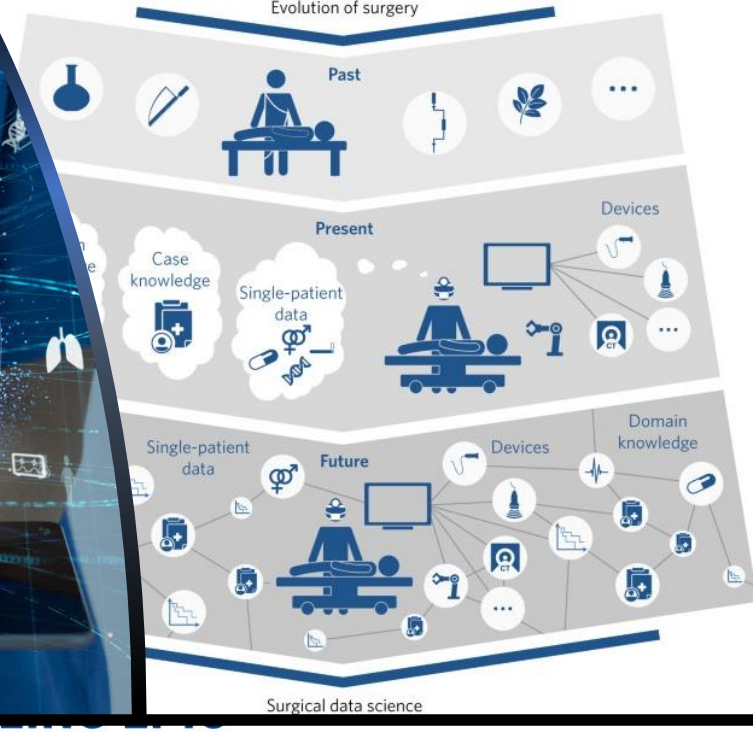
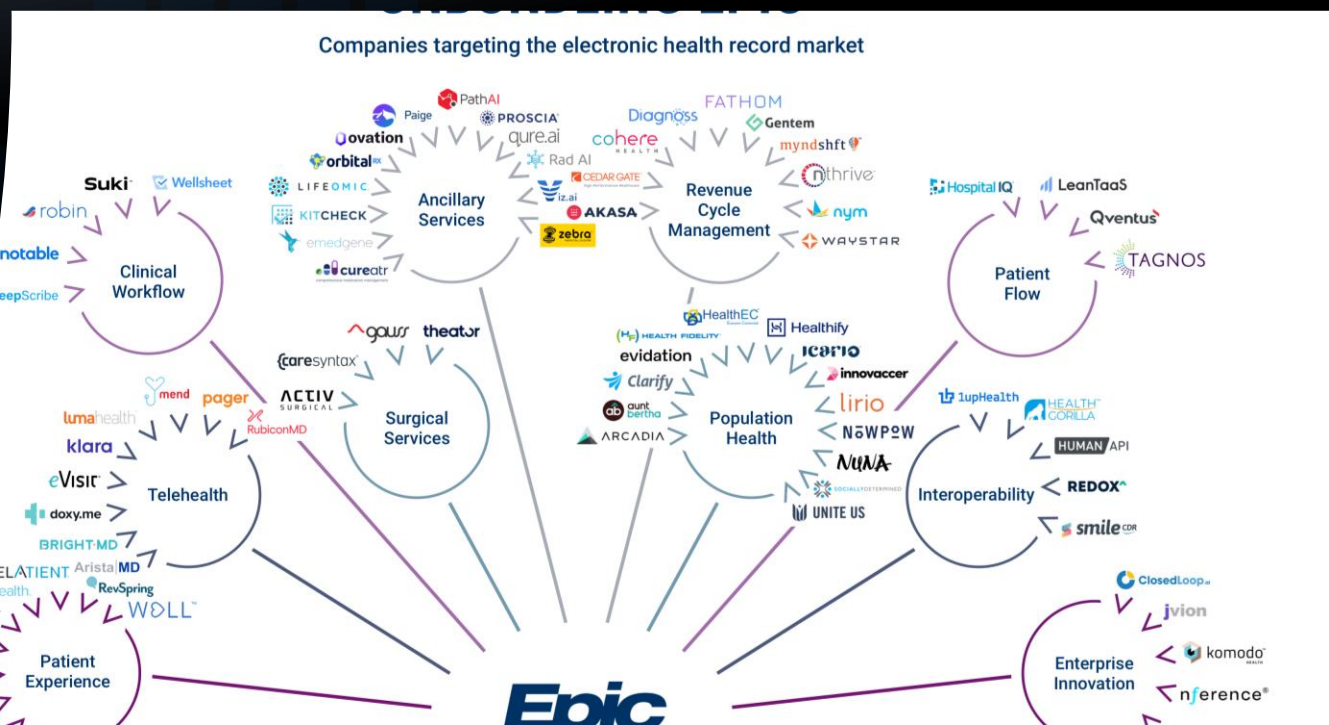
Data Generation and Management

Organizing Critical Information

Maintenance of structure data





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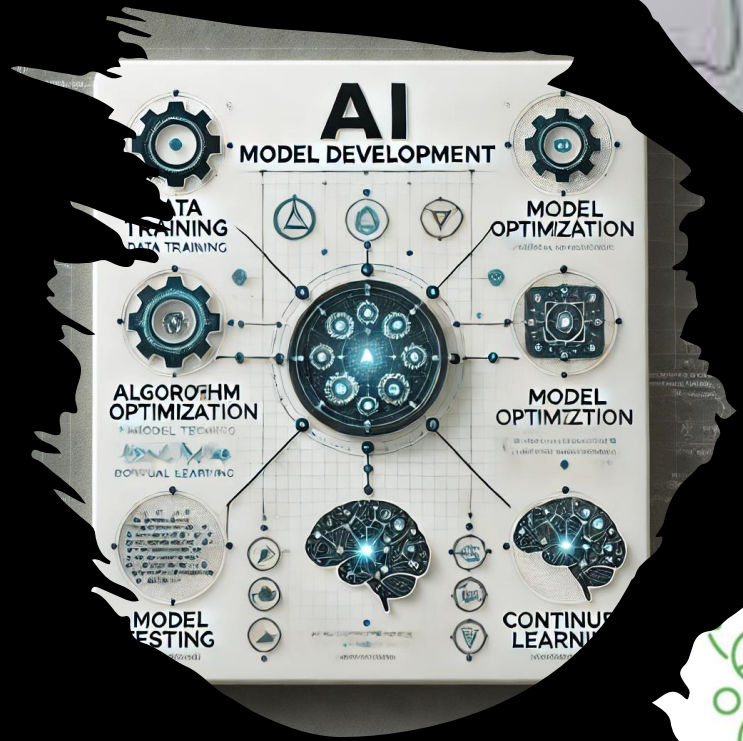
Model Development

- Data training
- Algorithm optimization
- Model testing
- Continuous learning and improvement



Trustworthiness of AI Systems Assurance:

- Thorough validation
- Benchmarking
- Ensure AI systems are accurate, safe, and ethical.

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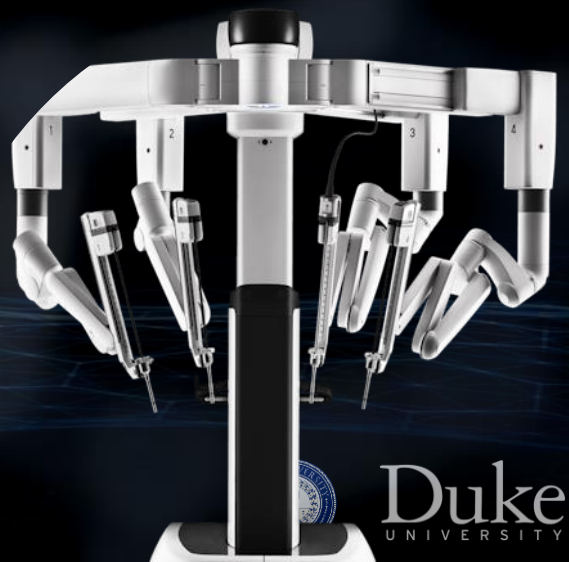
Solution Management



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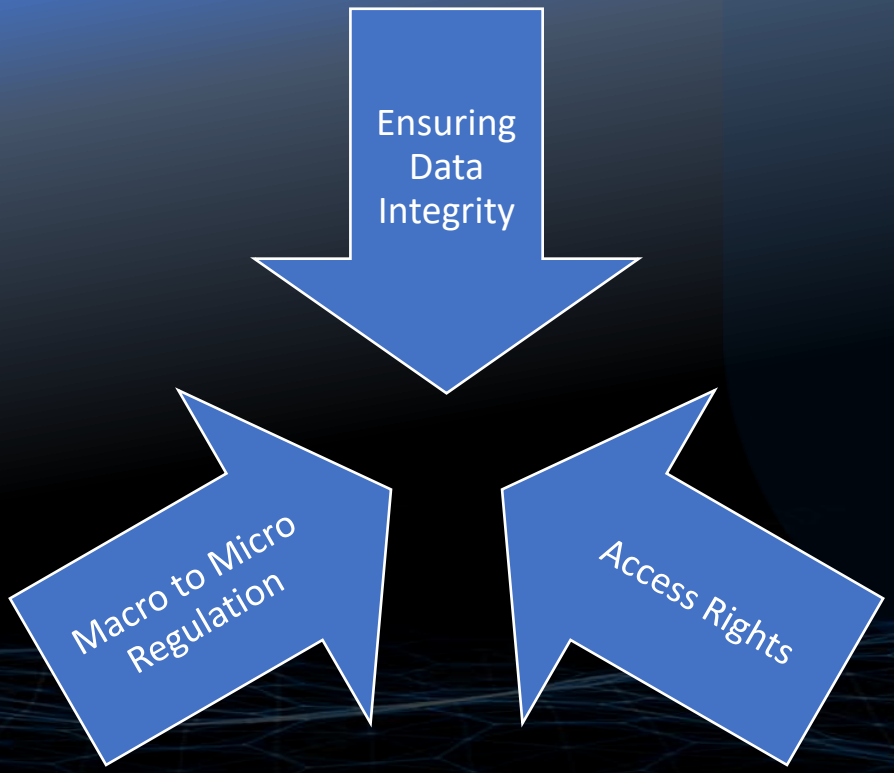
Security and Access Control



pdpc PERSONAL DATA PROTECTION COMMISSION SINGAPORE

DEPARTMENT OF HEALTH & HUMAN SERVICES · USA
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Office for Civil Rights

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S. OS

Marketplace for Cognitive Augmentation

- Information
- Guidance
- Safety
- Operational Efficiency

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Analysis of intraoperative video

Experimental Phase

Normal case

Normal
Surgical Fingerprint

Normal Range

Access	Exposure	Dissection	Stapling	Bagging	Leak Test	Closure

Deviation

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Real-time Analysis and Deviation Detection

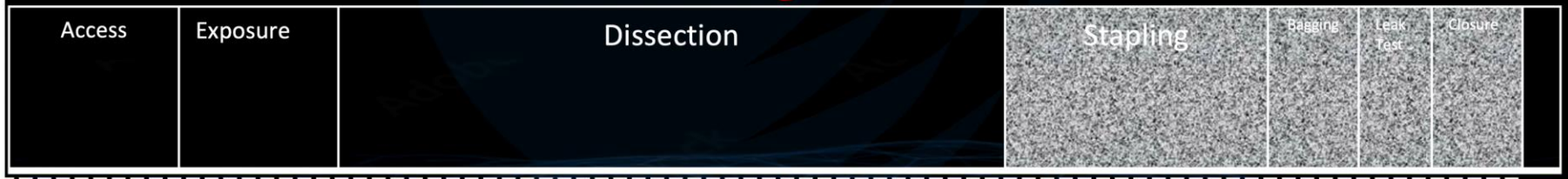
Experimental Phase

Abnormal case

Abnormal
Surgical Fingerprint

Detecting Deviations

Normal Range



Deviation

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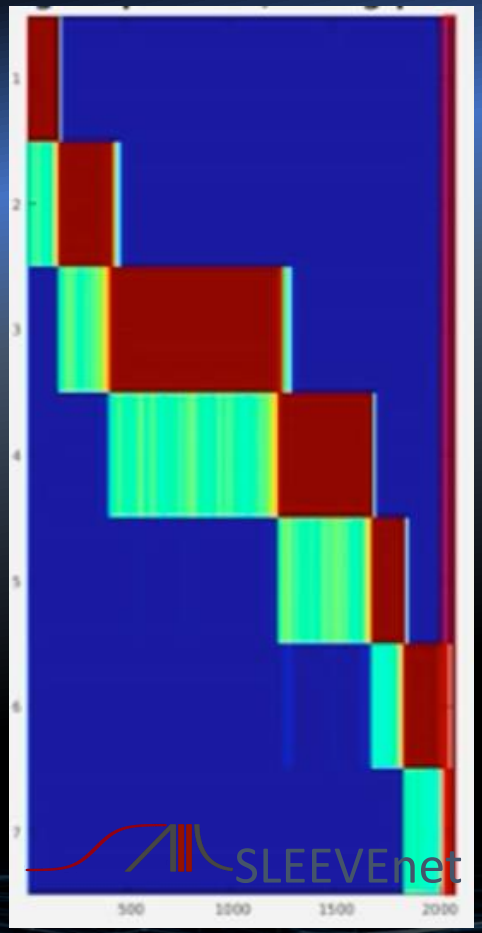
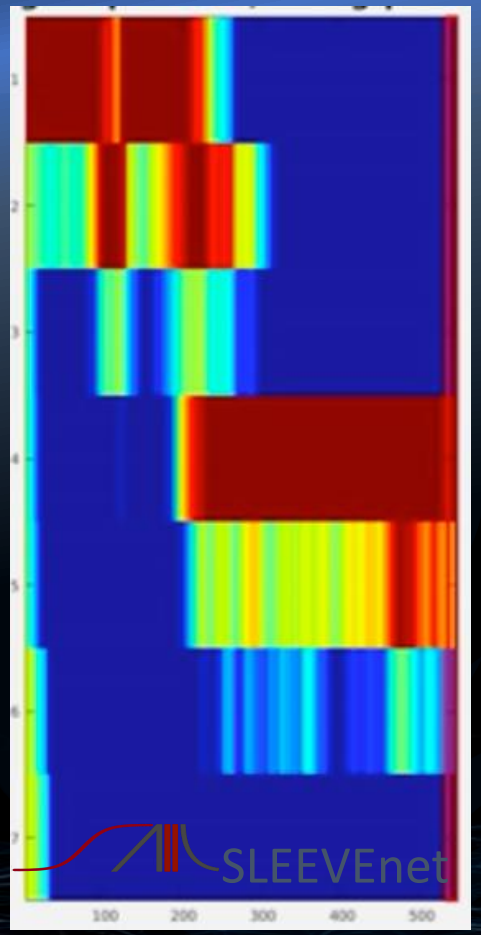
Surgical Fingerprint – Sleeve Gastrectomy

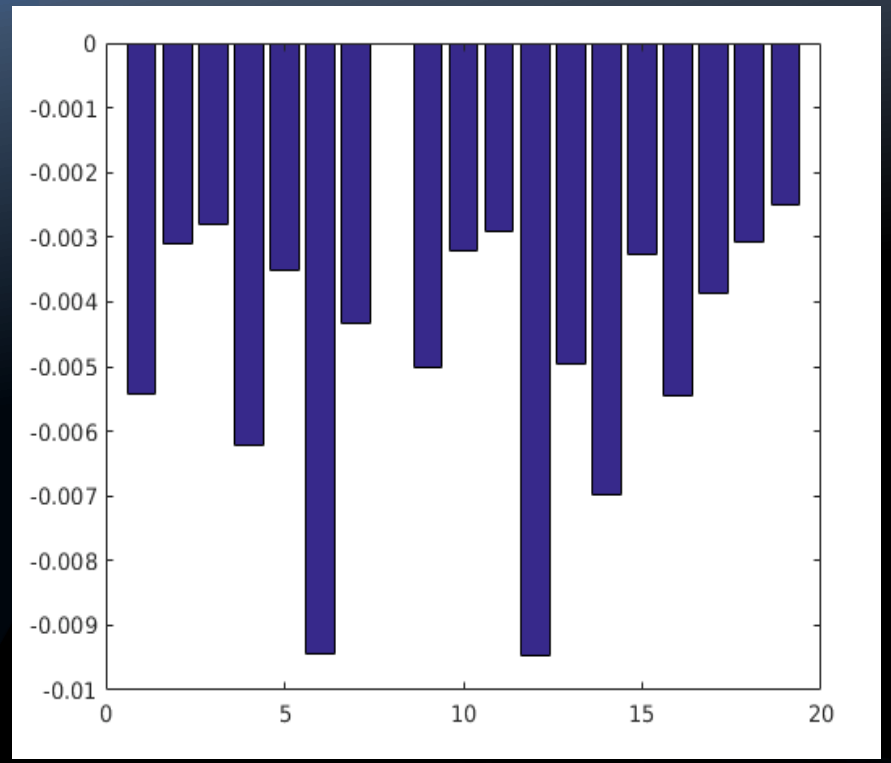
Case A



Case B



Normalized Cumulative log Probability



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Future Steps

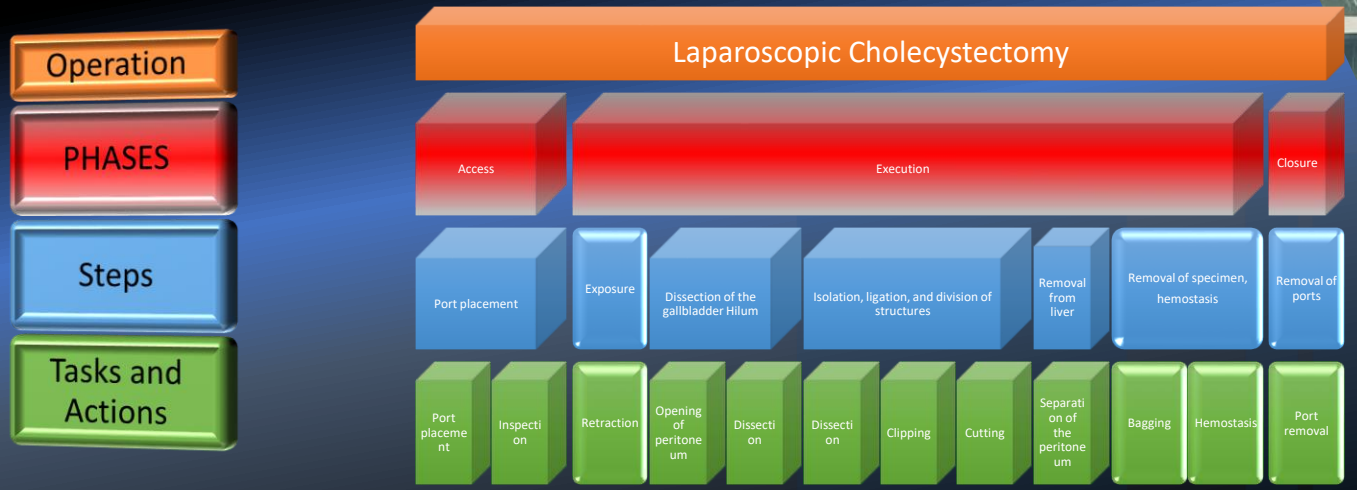
Surgical Video Foundation Models

These models serve as a fundamental base, trained on large datasets, and can be adapted to a variety of surgical tasks such as:

- Video analysis
- Complication prediction
- Real-time guidance
- Automation

Annotation

Temporal Hierarchy



Spatial Hierarchy

Transfer Learning

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AI Models Benchmarking

Sustainability (ROI)

- Data monetization
- Model co-development
- Application subscriptions
- Contracting clinical trials
- Pre and Post market evaluation

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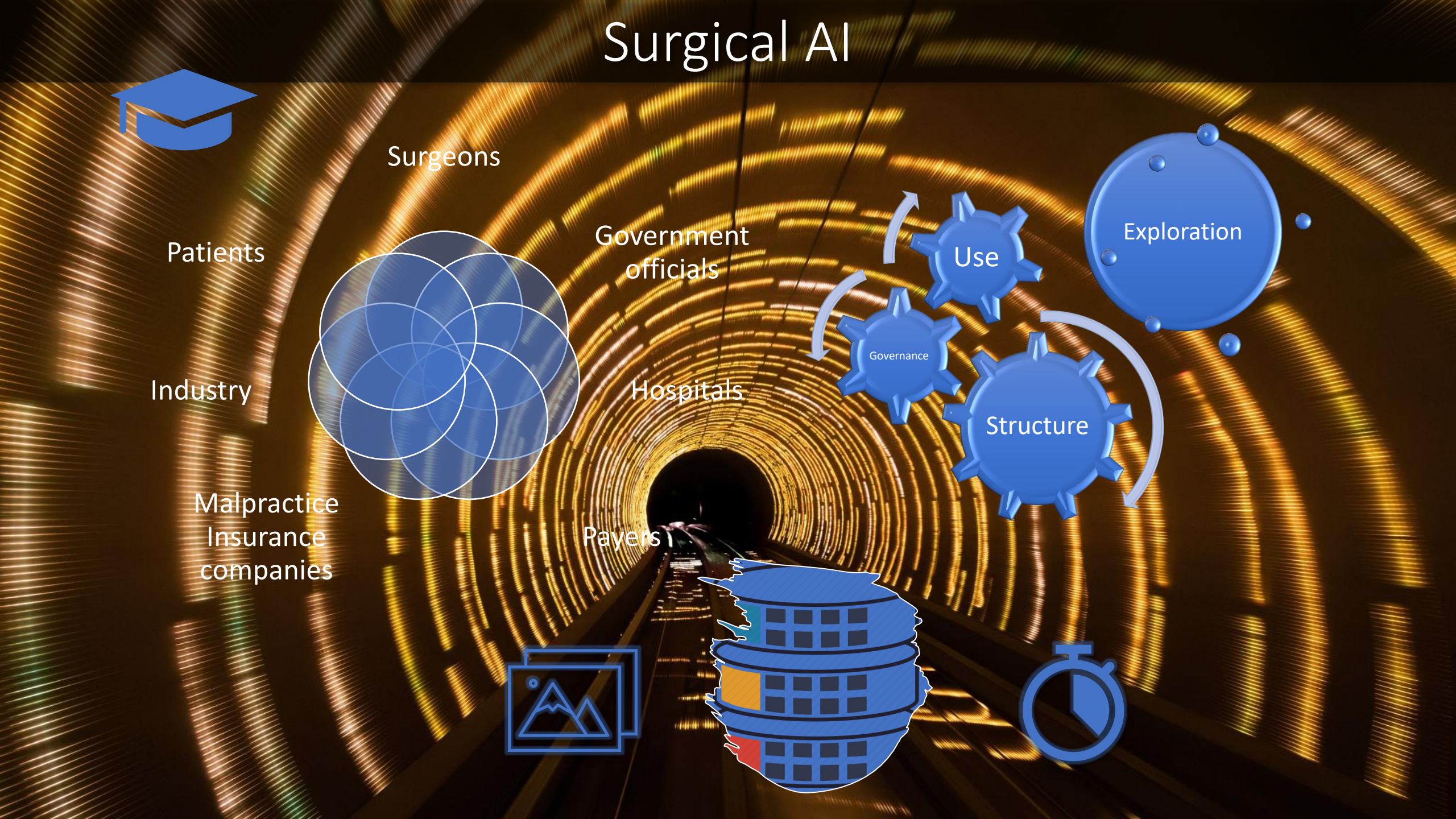
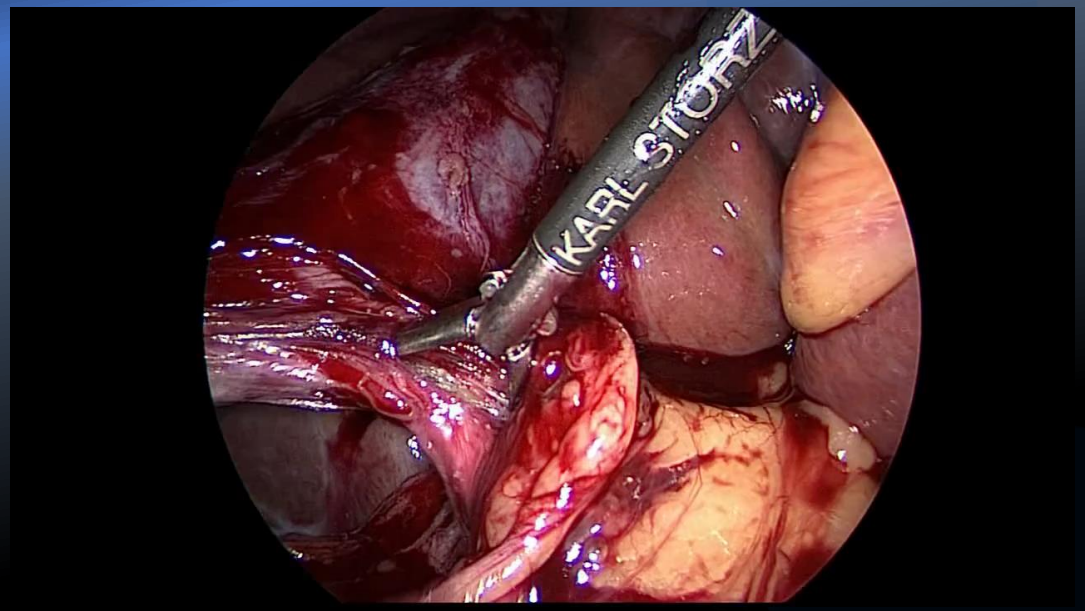
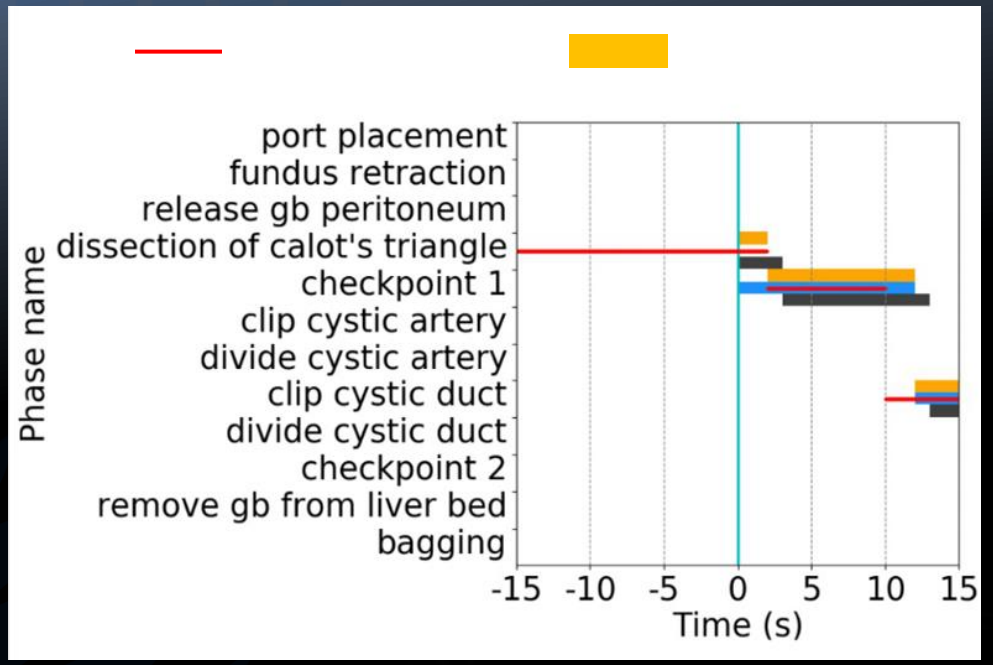
Surgical AI


Surgeons
Patients
Government officials
Industry
Hospitals
Malpractice Insurance companies
Payers
Use
Exploration
Governance
Structure

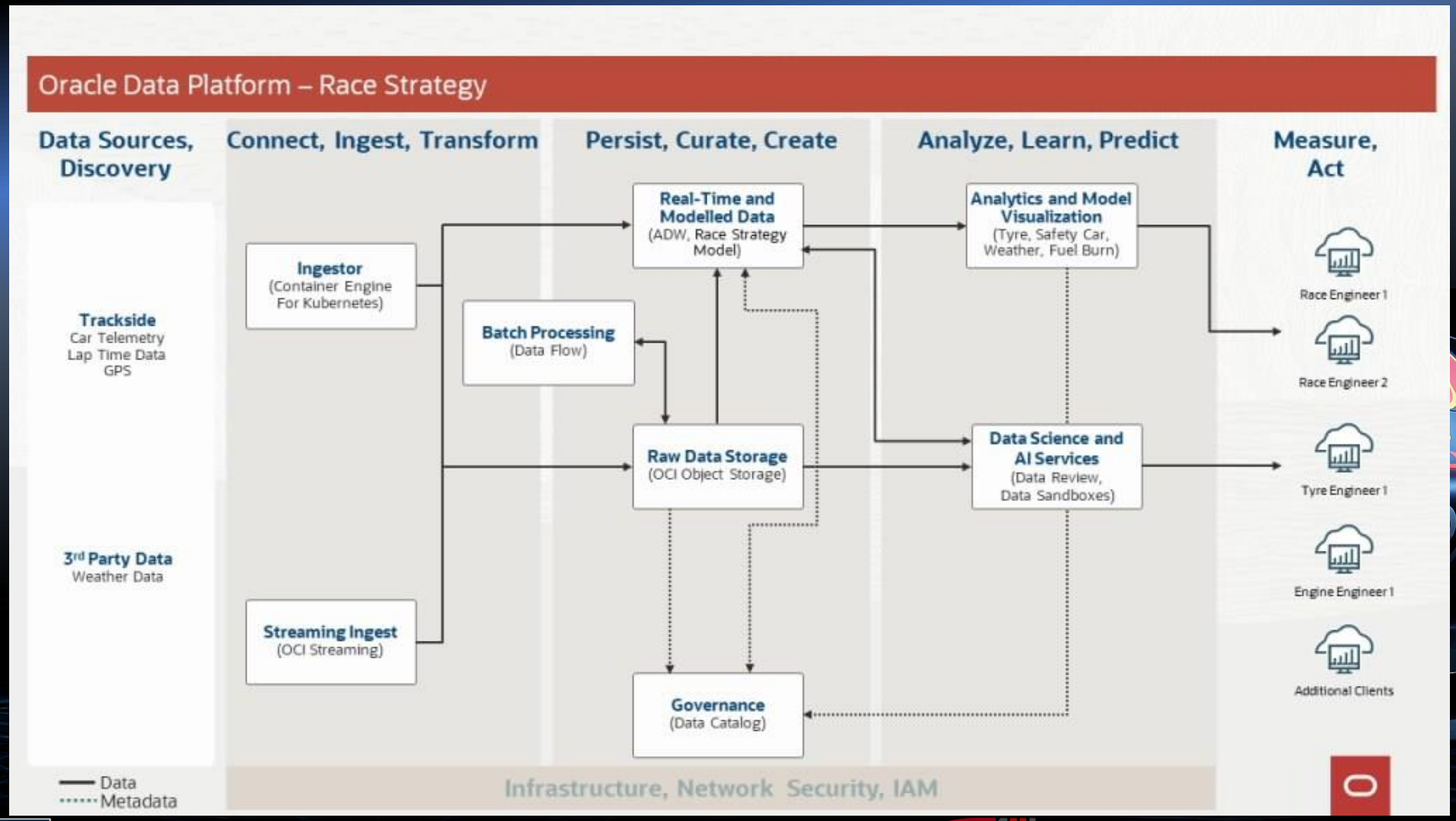
Surgical Event Real Time Prediction





SUPR-GAN: SUrgical PRediction GAN for Event Anticipation in Laparoscopic and Robotic Surgery

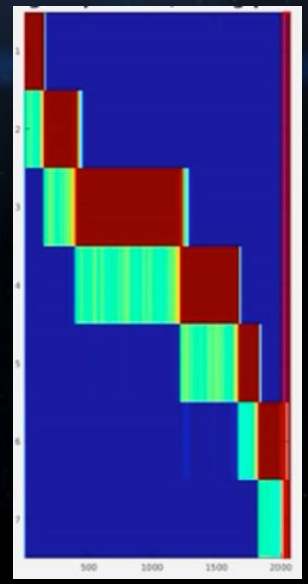
Error Handling and Recovery



Analysis of intraoperative video *with Decision Support .*

Conceptual Phase

Case 3 – Preventing Complication



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SAIIL Team

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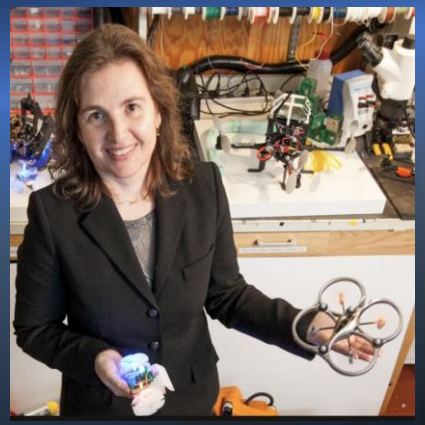
Guy Rosman, PhD
Assoc Director, Engineering



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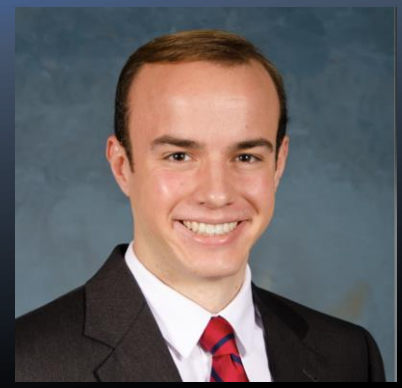
Daniel Hashimoto, MD MS
Former Fellow



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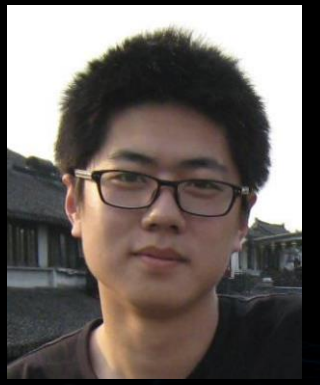
Former Fellow

Jennifer Eckhoff, MD
Former Fellow



Yutong Ban, PhD
Former Fellow

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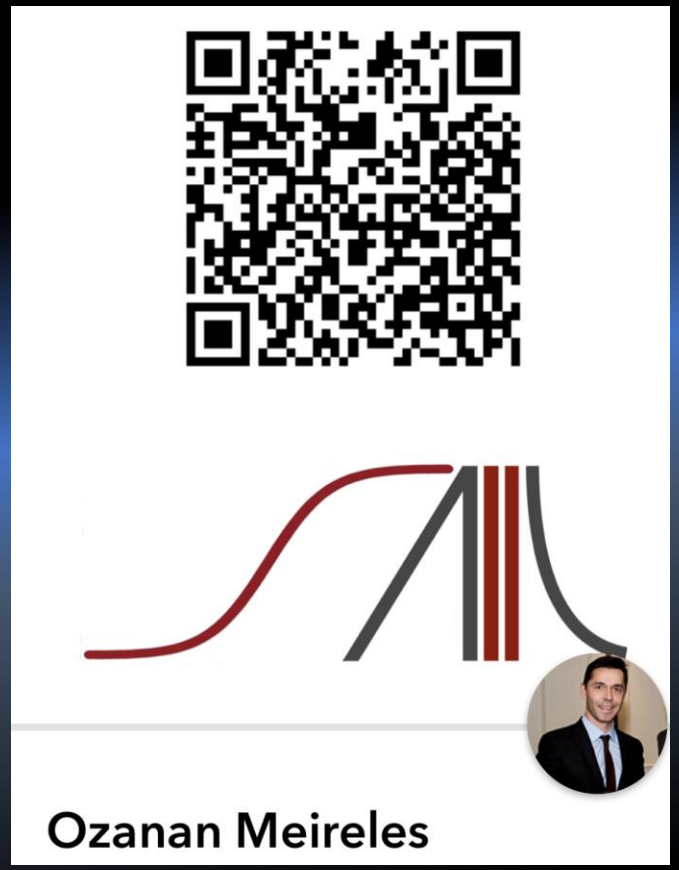

Thank you!

GET INVOLVED

www.SAIIL.org

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