AI Foundation Models in Surgery: Future Directions and Global Impact

Intelligent Health 2024

Basel, Switzerland – September 12, 2024

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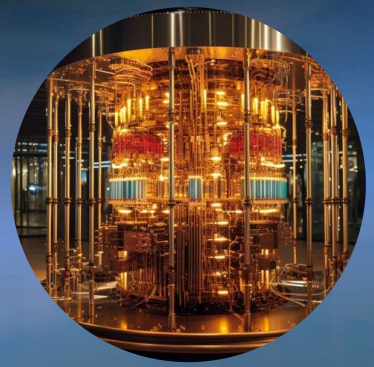
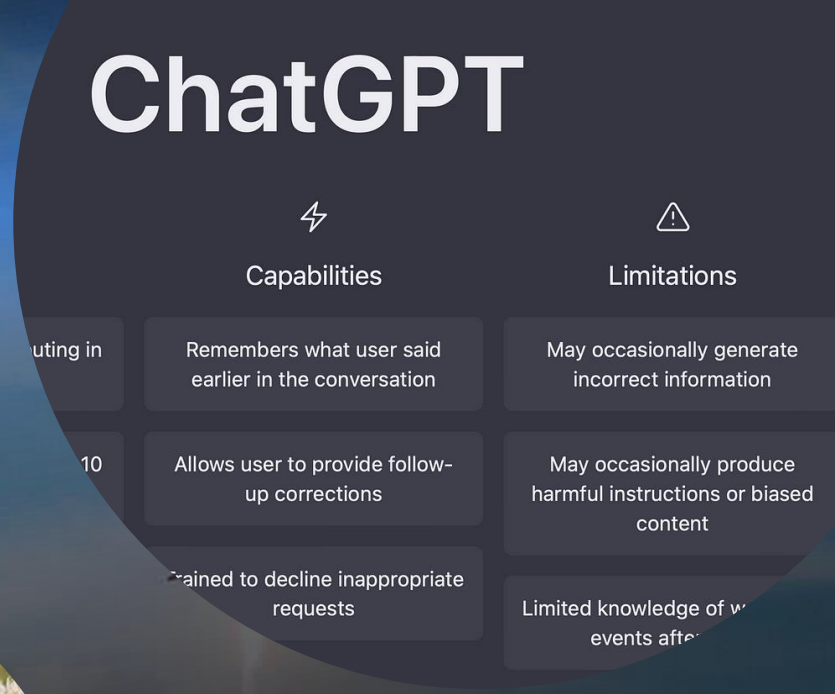
The Era of Technological Disruption





Innovation and Safety

"Technology is altering the landscape across various sectors. and the future is unfolding before our eyes."

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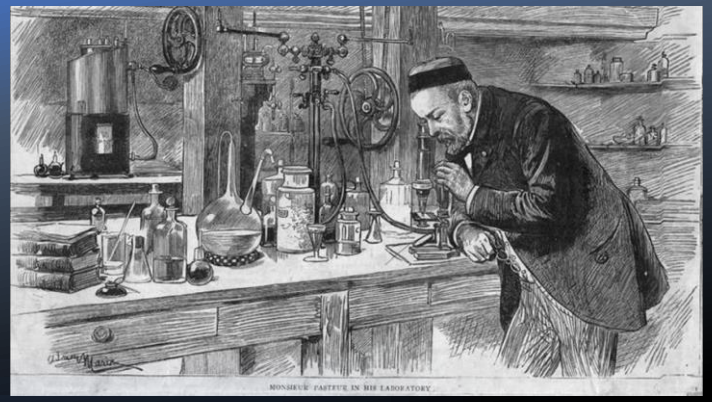
What is happening in the Operating Room ?

Surgical Revolutions (in the last 200 years)

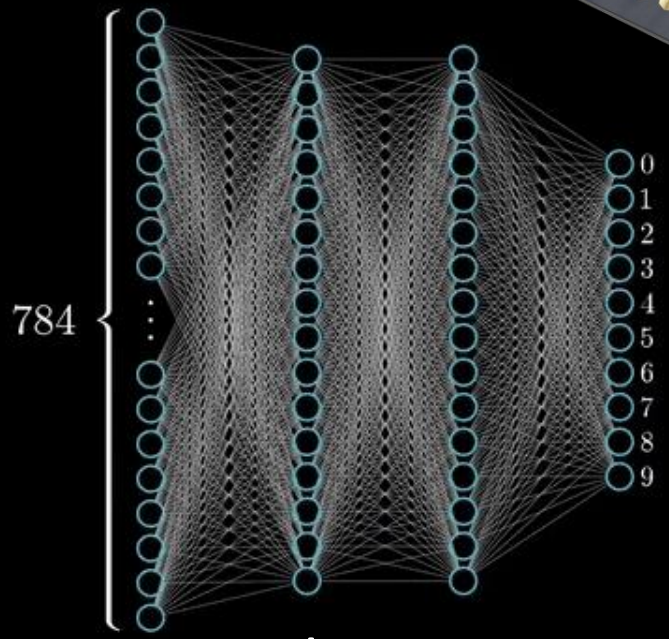
- General Anesthesia – 1840s
- Antiseptic Surgery – 1860s
- Endoscopic Procedures – 1960s
- Cognitive Computing – 2010s



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

Video DATA

More computing power



More powerful/efficient techniques

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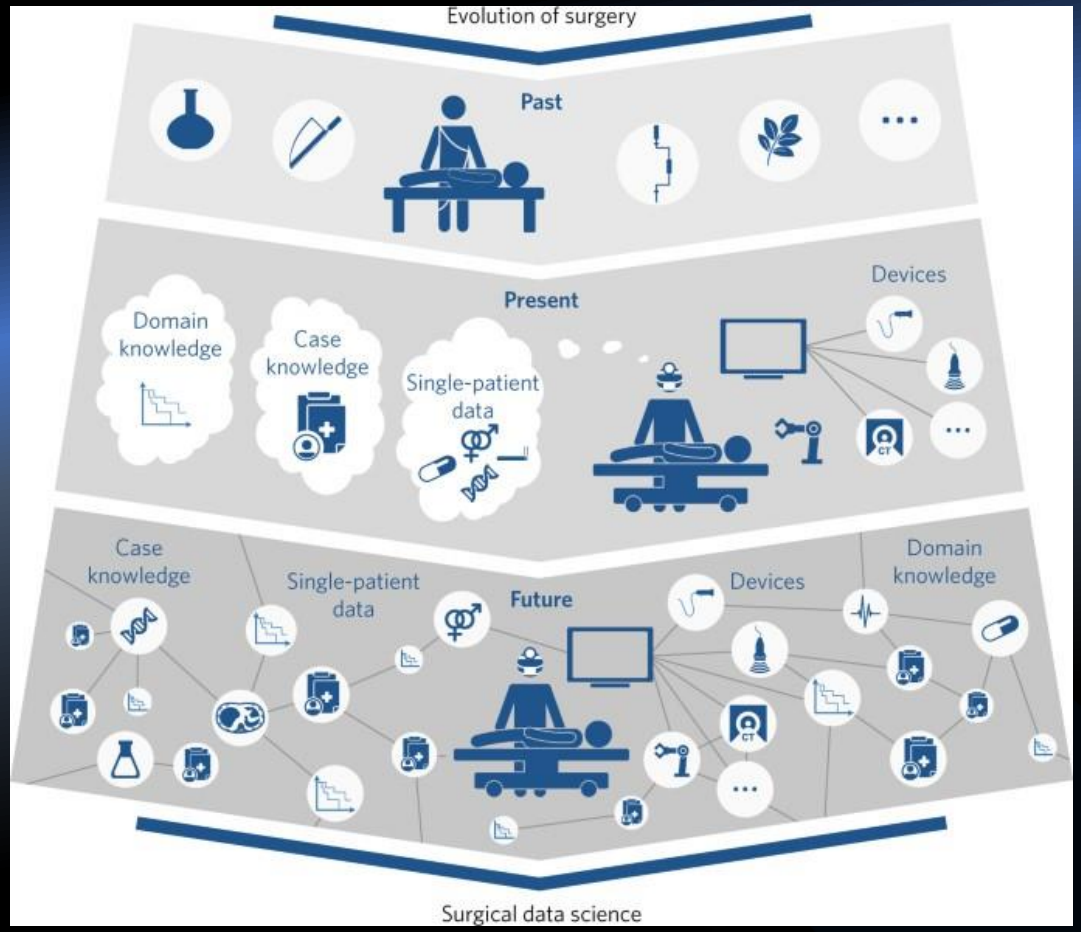
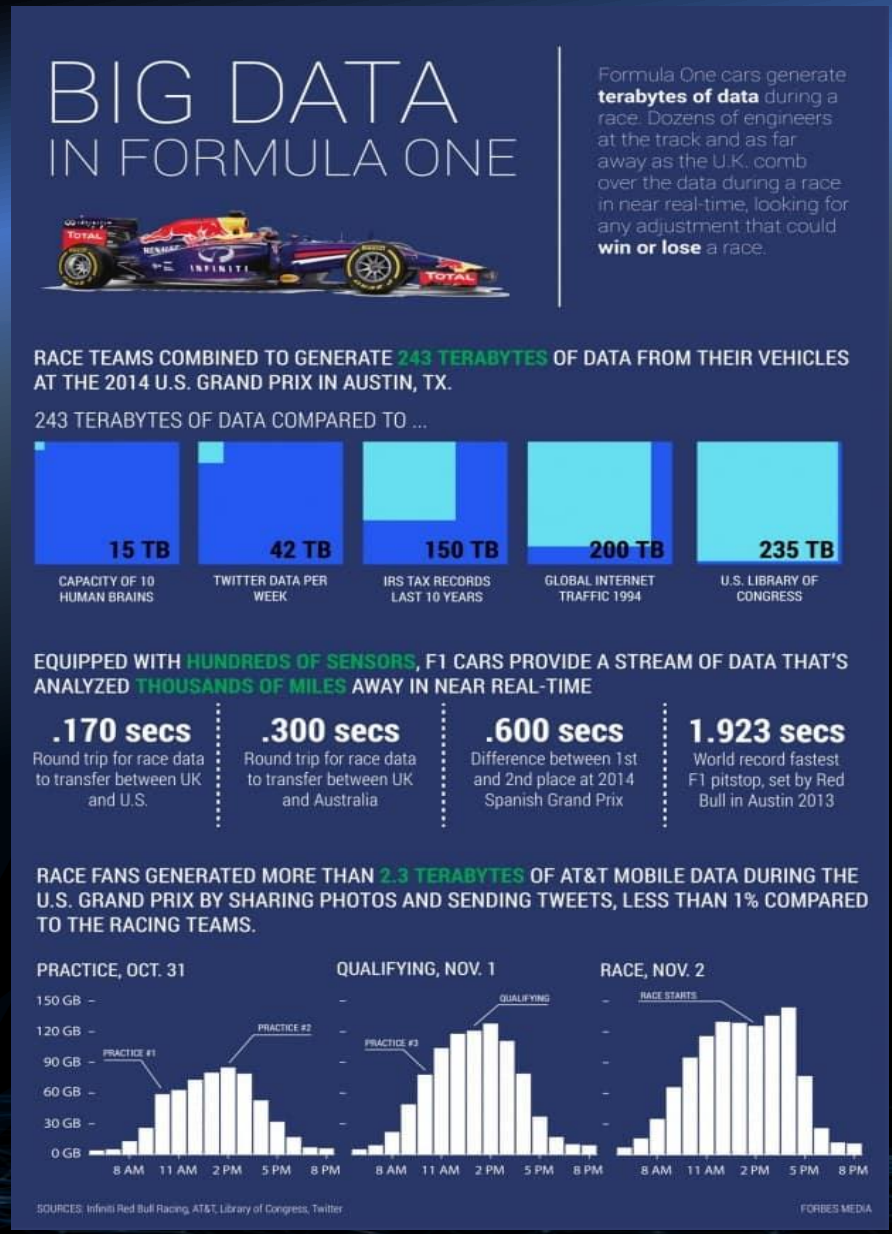
Large amount of DATA





The average hospital produces roughly 50 petabytes of data every year. That's more than twice the amount of data housed in the Library of Congress, and it amounts to 137 terabytes per day.

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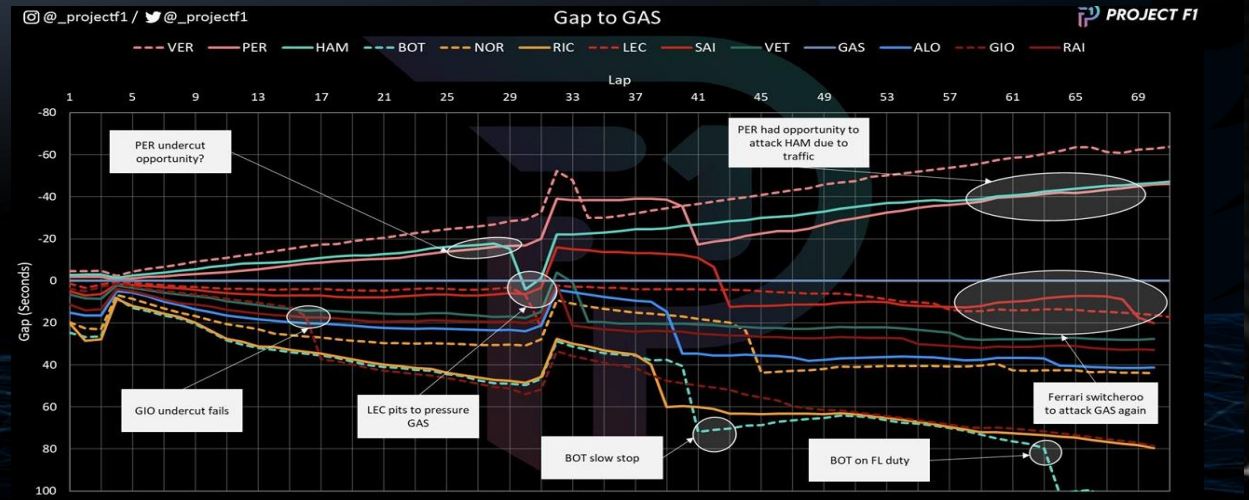

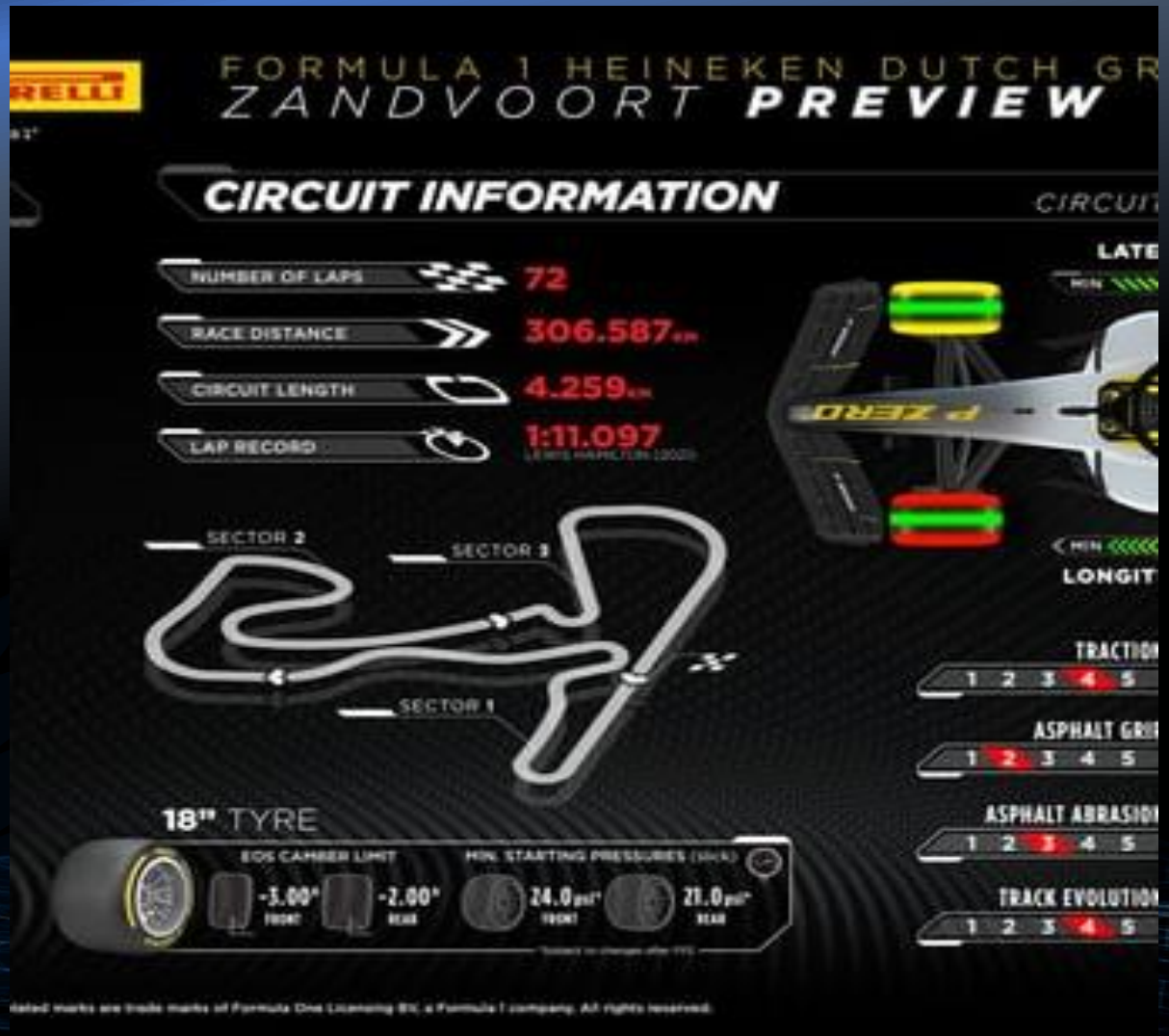

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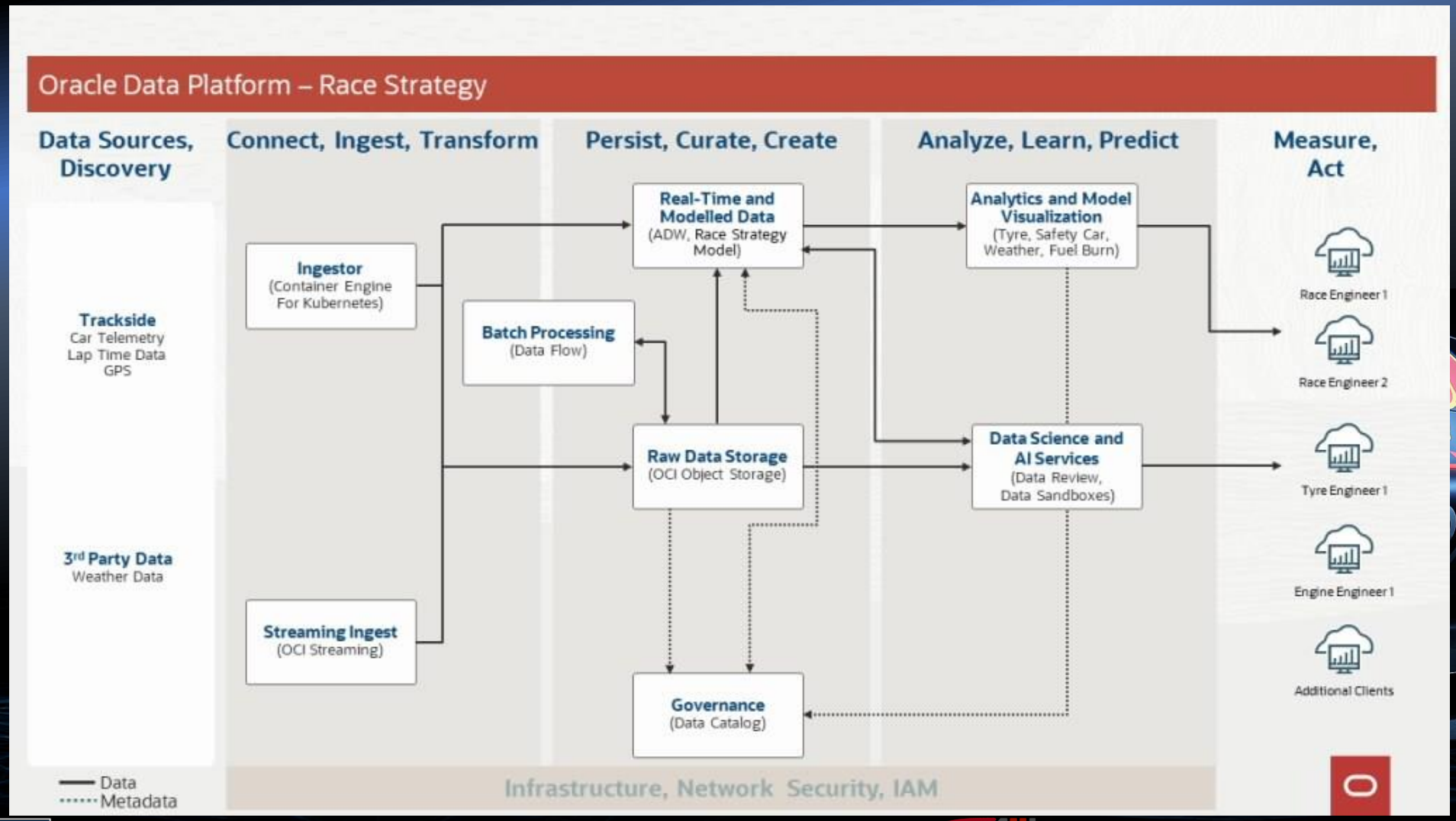
Error Handling and Recovery



Healthcare, specially in surgery is a sector where technology's promise has not been fully realized.

“We have advanced machinery and data analytics, but the operating room still relies heavily on human judgment, sometimes leading to inefficiencies”

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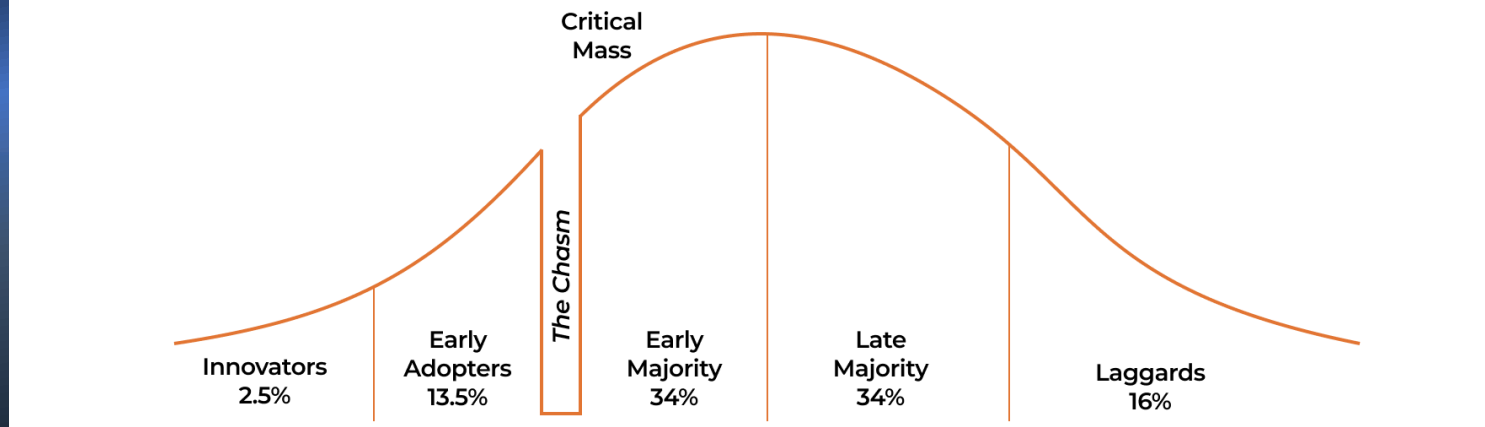
Diffusion of Innovation Theory

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



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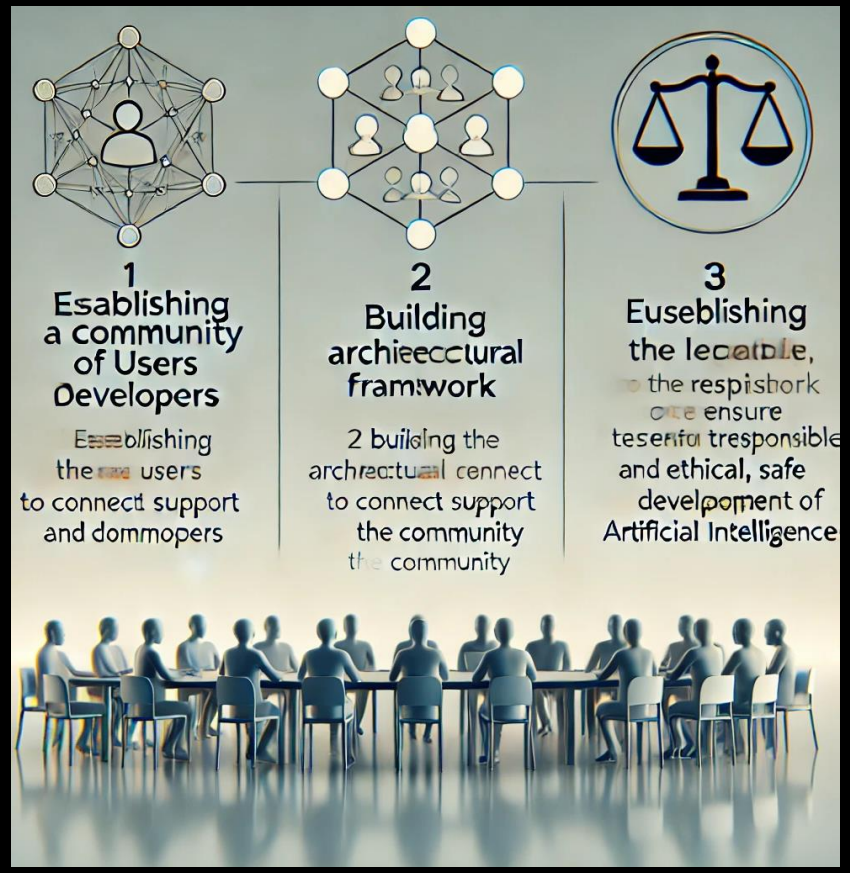
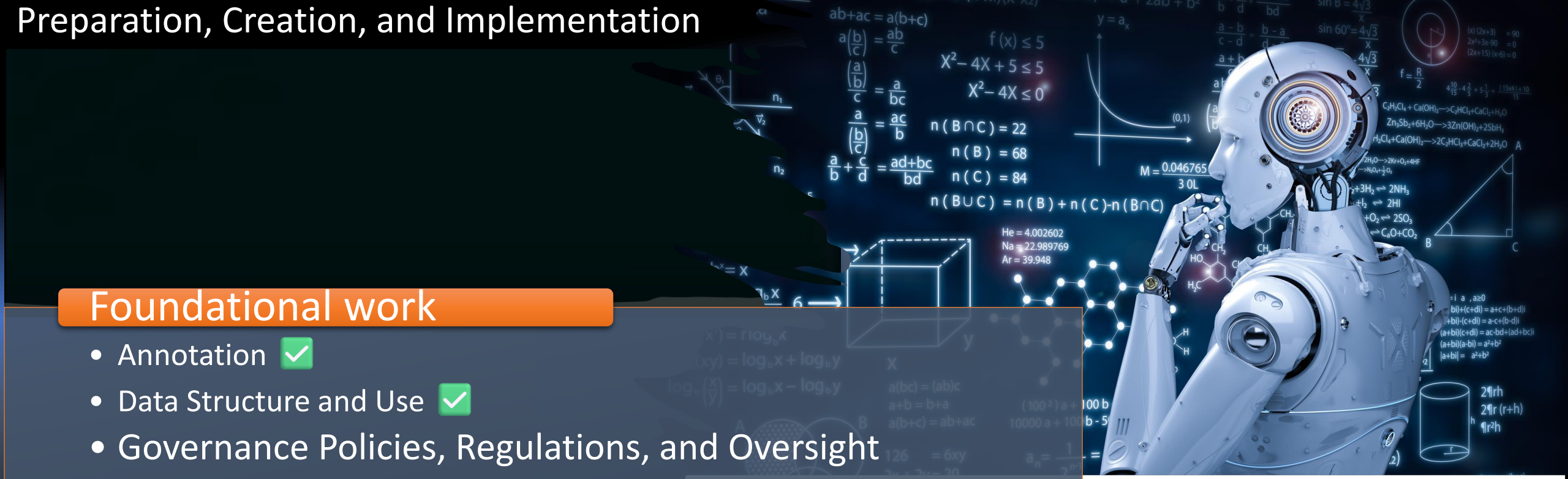
Three major pillars of development

- 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.



Preparation, Creation, and Implementation



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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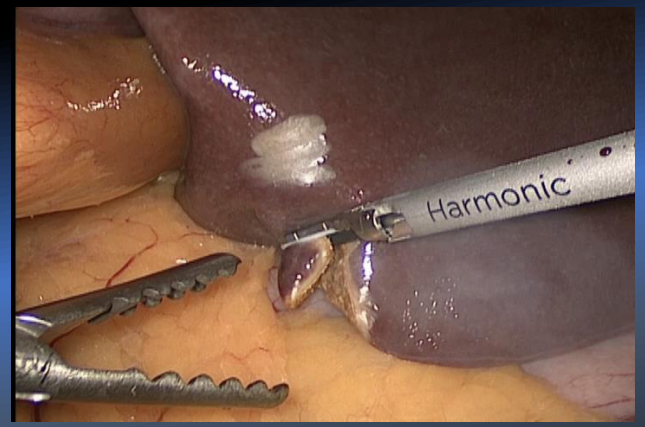
Surgical AI Standards

Foundational work

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

DATA collection



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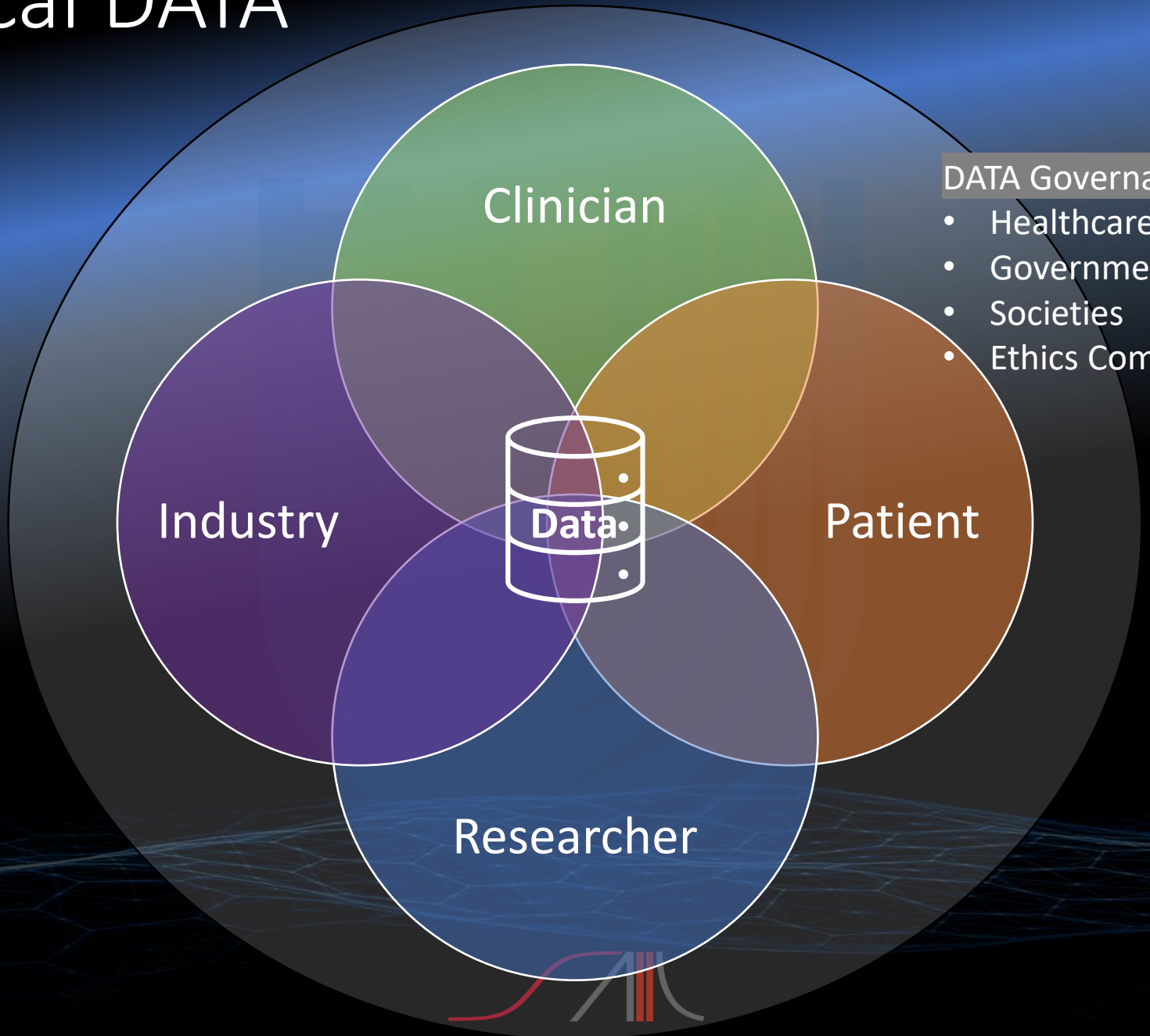
Surgical DATA



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)

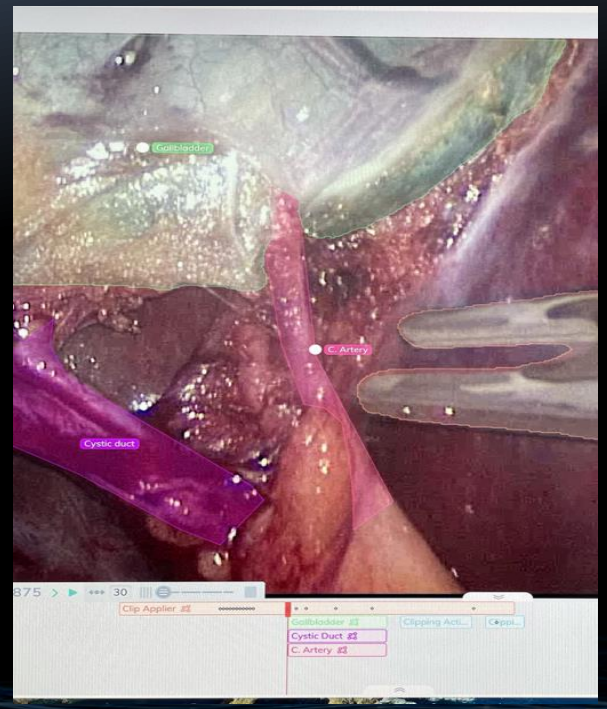
Spatial Events

Anatomic region

Specific anatomy

General anatomy

Tissue characteristics



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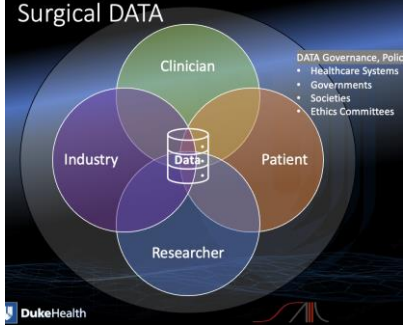
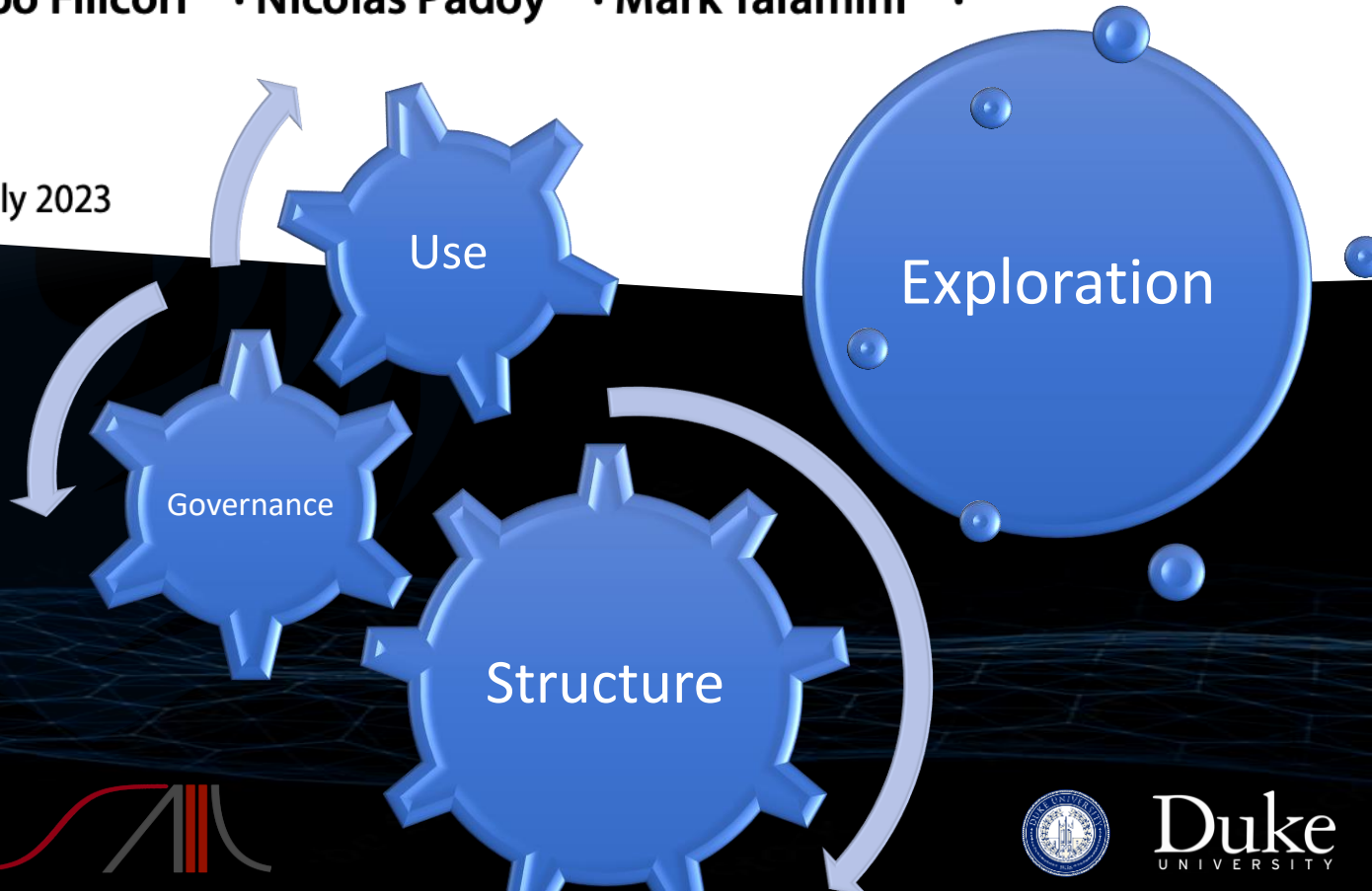
SAGES consensus recommendations on surgical video data use, structure, and exploration (for research in artificial intelligence, clinical quality improvement, and surgical education)



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]

Received: 4 May 2023 / Accepted: 5 July 2023 / Published online: 29 July 2023



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Use Cases

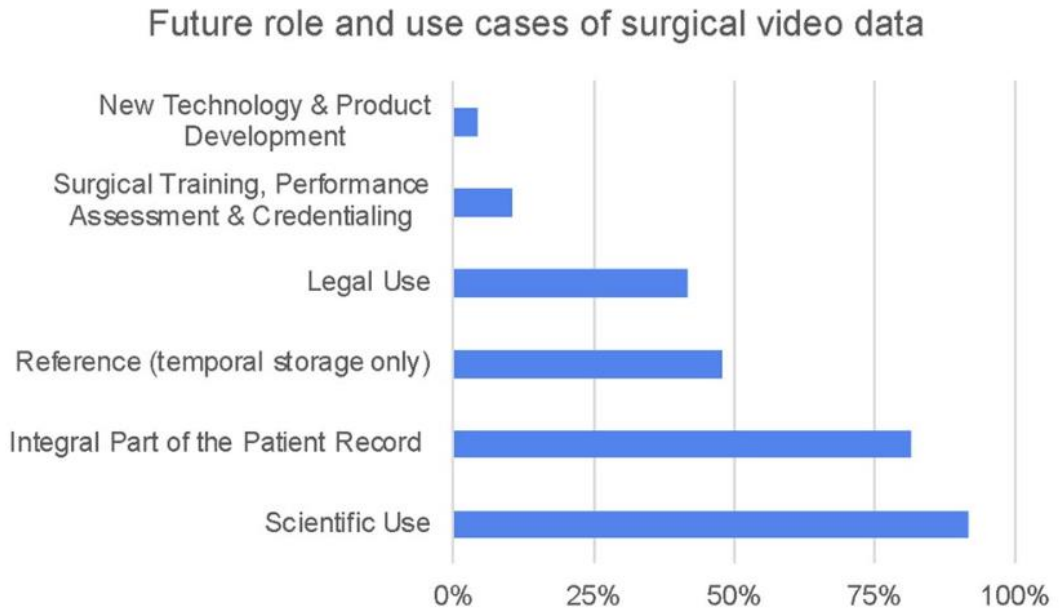
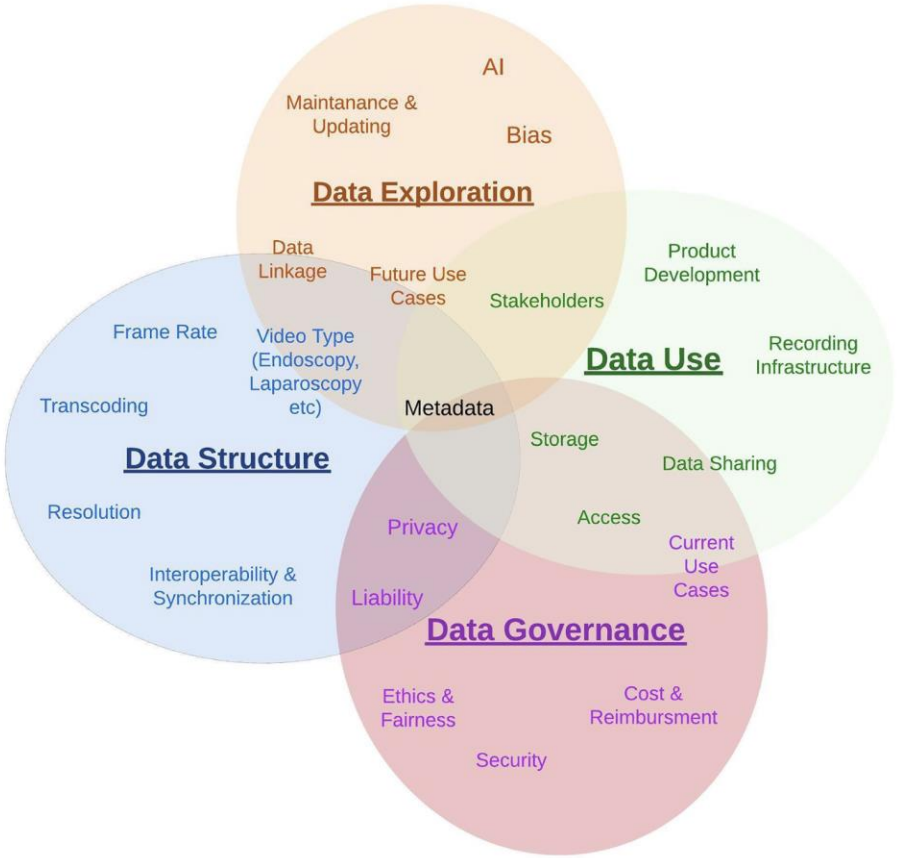


Fig. 7 Results of statement 8—future applications and use cases of surgical video data, identified by survey participants



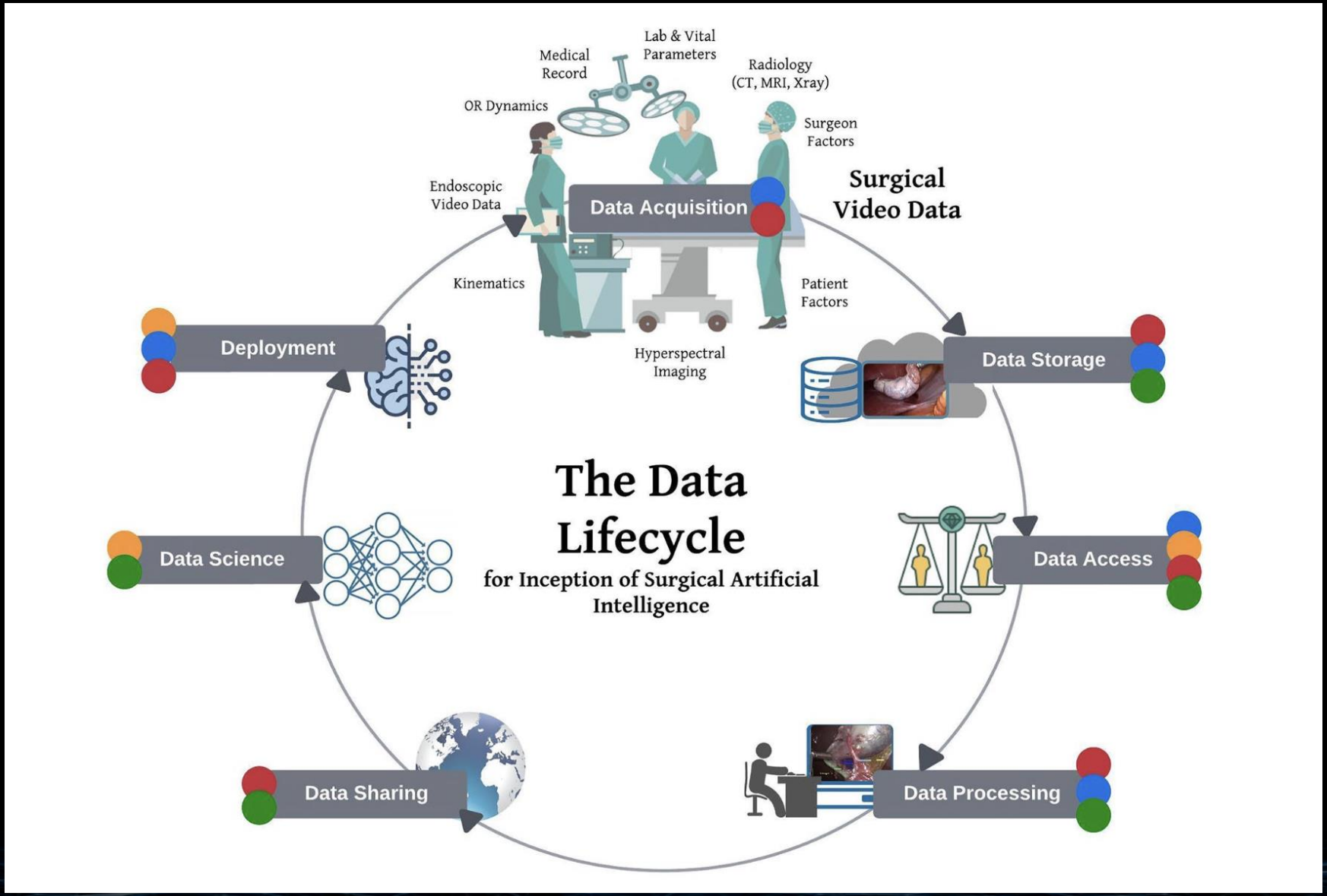


Fig. 1 The Data Lifecycle, highlighting stages of surgical video data en route to the creation of AI. Schematic outline of essential attributes of data architecture and infrastructure influencing current data use and future exploration and considerations for adequate governance

Community

Scientific efforts

Clinical Trials

Computer Vison Challenges

Multi-institutional collaborations

Academia and Industry partnership

Standards for Publications

Validation Studies

Promote Diversity

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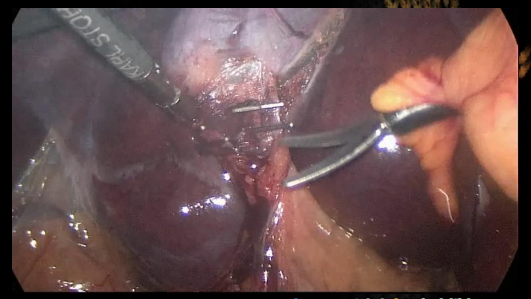
The Critical View of Safety Challenge

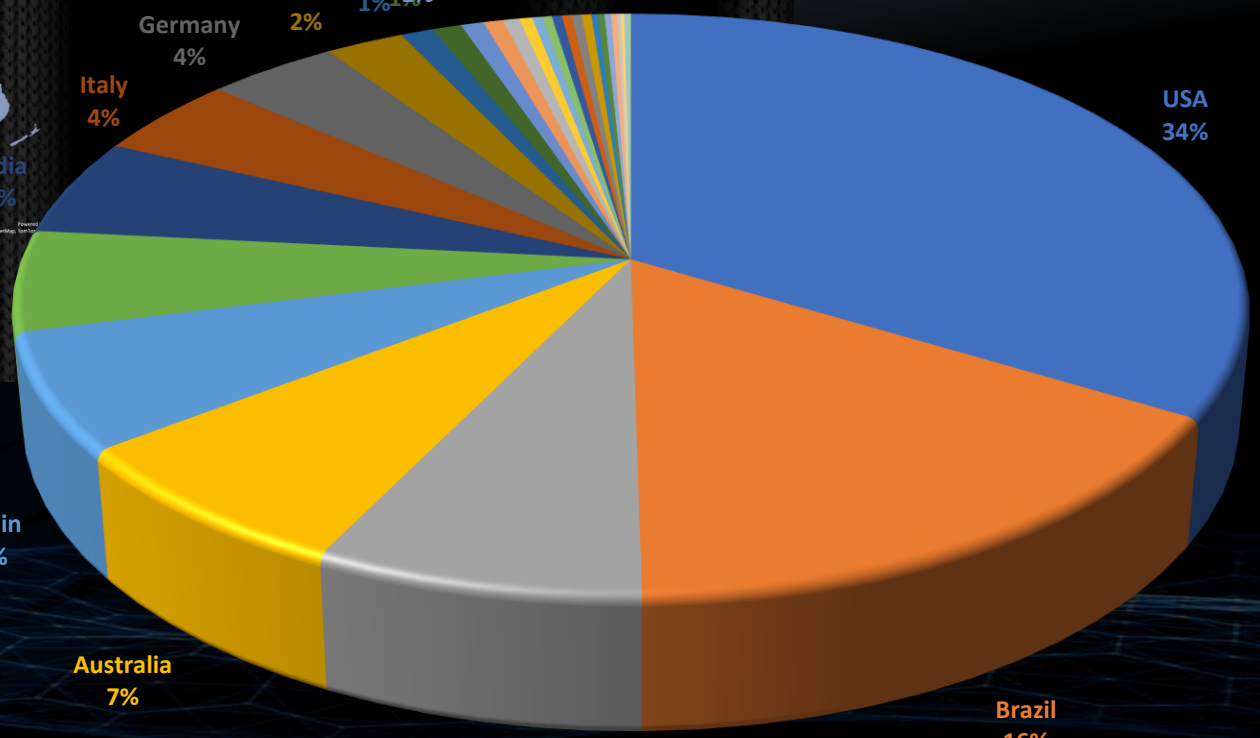


A SAGES Initiative

DATA Donors

Accounts: 155
Institutions: 64
Countries: 57

1700 +



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10.000 Unique Visitors

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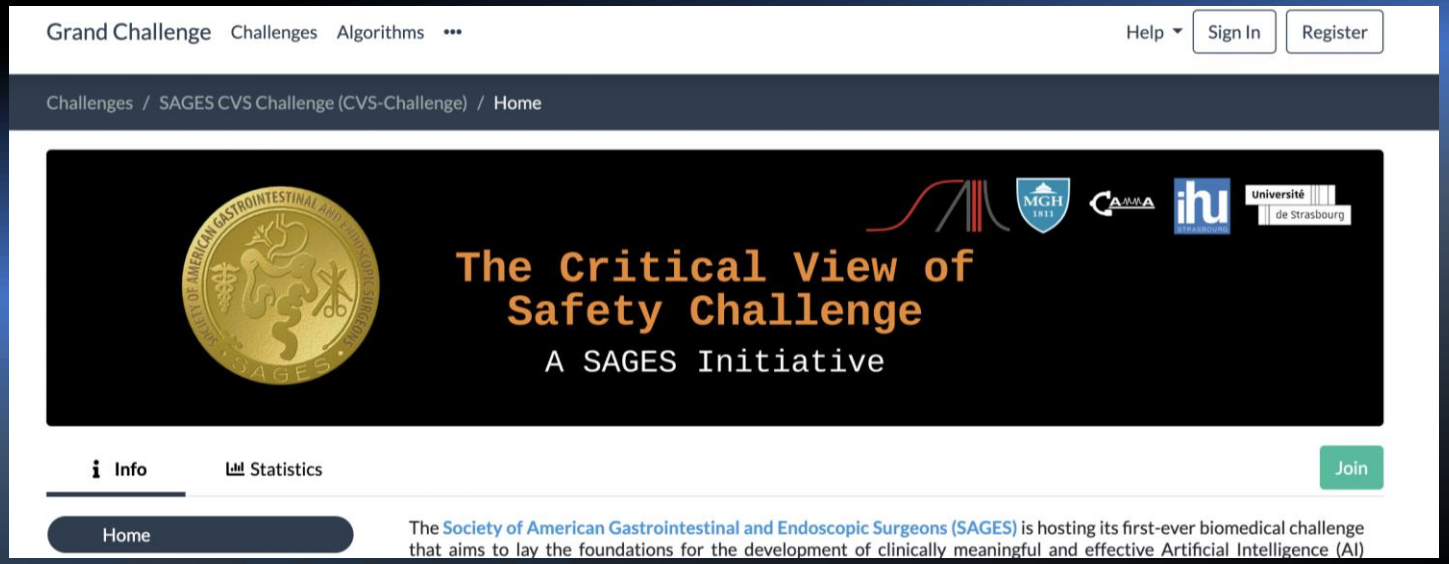
Competitors

- 36 Teams
- 16 Countries



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Education and Training

Scientific Meetings

Dedicated Fellowships

e.g. SAIIL

Medical School Curriculum

Publications

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Surgery & AI | Projects | Work with us | Team | SAIIL-Net | SAIIL-MGH | Sponsorship | Get Involved

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Welcome to SAIIL Public

At the Surgical Artificial Intelligence and Innovation Laboratory (SAIIL), we are committed to fostering a collaborative and open research community. We understand the value of sharing resources, datasets, tools, and insights with other researchers, students, and individuals interested in the field of surgical AI. To accelerate innovation and improve patient care worldwide, we are in the process of gradually making these resources available to the public.

Education and Training

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

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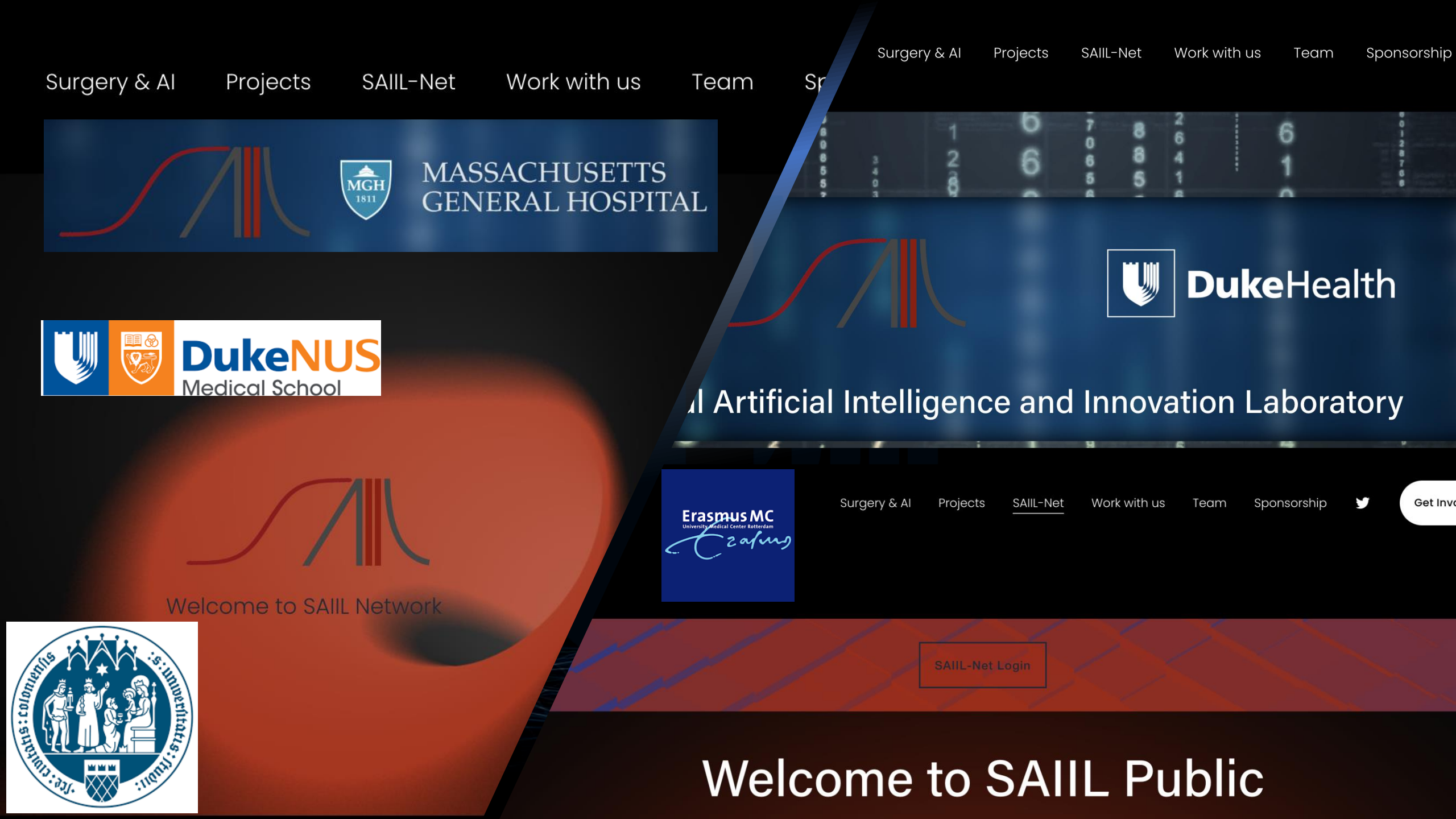
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Surgical Operating System Framework

- Open Access Model to Promote Collaboration
- Standardization
  - Annotation
  - Data Structure
- Clear Policies and Regulations
- Transparency and Oversight
- Address Ownership Issues

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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.

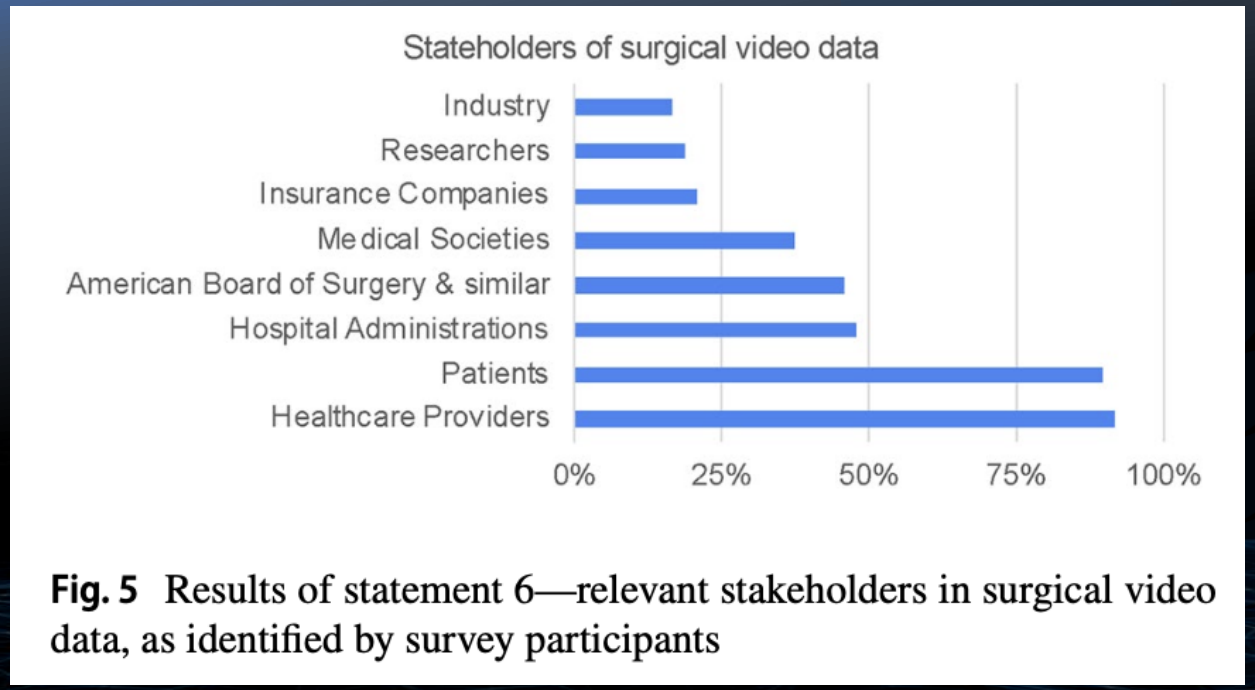
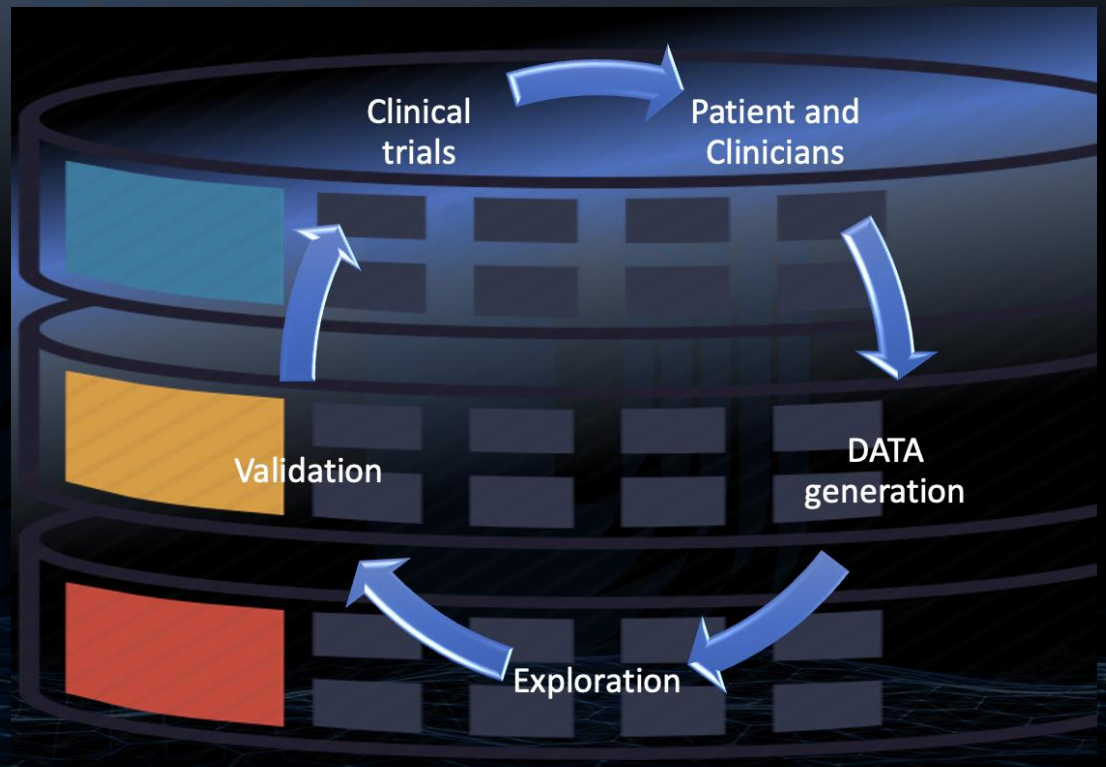


Fig. 5 Results of statement 6—relevant stakeholders in surgical video data, as identified by survey participants



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Trustworthy and Responsible AI Network (TRAIN)

New consortium of healthcare leaders announces formation of Trustworthy & Responsible AI Network (TRAIN), making safe and fair AI accessible to every healthcare organization

March 11, 2024 | Microsoft Source

AMSTERDAM — June 17, 2024 — Monday, at HLTH Europe, the Trustworthy & Responsible AI Network (TRAIN), a consortium of healthcare leaders, announced its expansion to Europe with the objective to help organizations in the region operationalize responsible AI through technology-based guardrails. Organizations that have come together to form the European TRAIN include Erasmus MC (the Netherlands), HUS Helsinki University Hospital (Finland), Sahlgrenska University Hospital (Sweden), Skåne University Hospital (Sweden), Universita Vita-Salute San Raffaele (Italy), and University Medical Center Utrecht (the Netherlands), with Microsoft as the technology enabling partner. Foundation 29, a nonprofit organization that aims to empower patients and transform healthcare through data-driven initiatives and innovative technologies, has also joined European TRAIN. The network is open to other healthcare organizations in Europe interested in joining.

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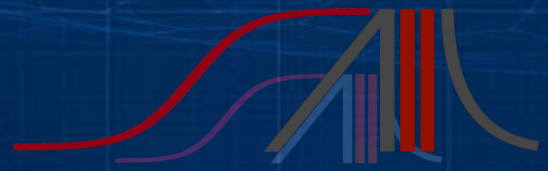
Designing a Surgical Operating System (S.OS)

A Blueprint for the Future of Surgery



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- Ethical and Trustworthy Data Generation, Model Development, and Validation

- Addressing the Critical Need for Benchmarking and Ethical Considerations

    - Data Privacy Generation
    - AI Model Development
    - Validation
    - Data Privacy and Governance

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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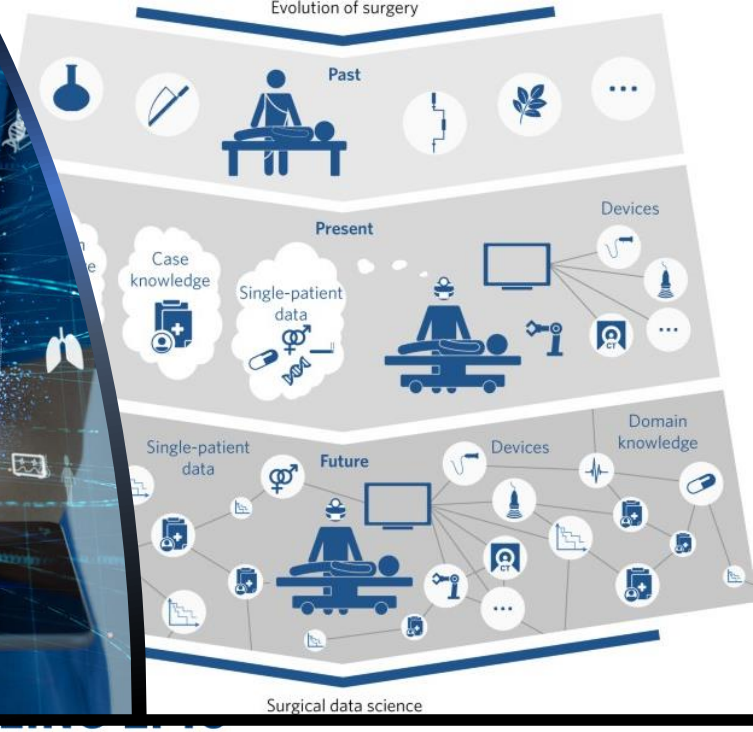
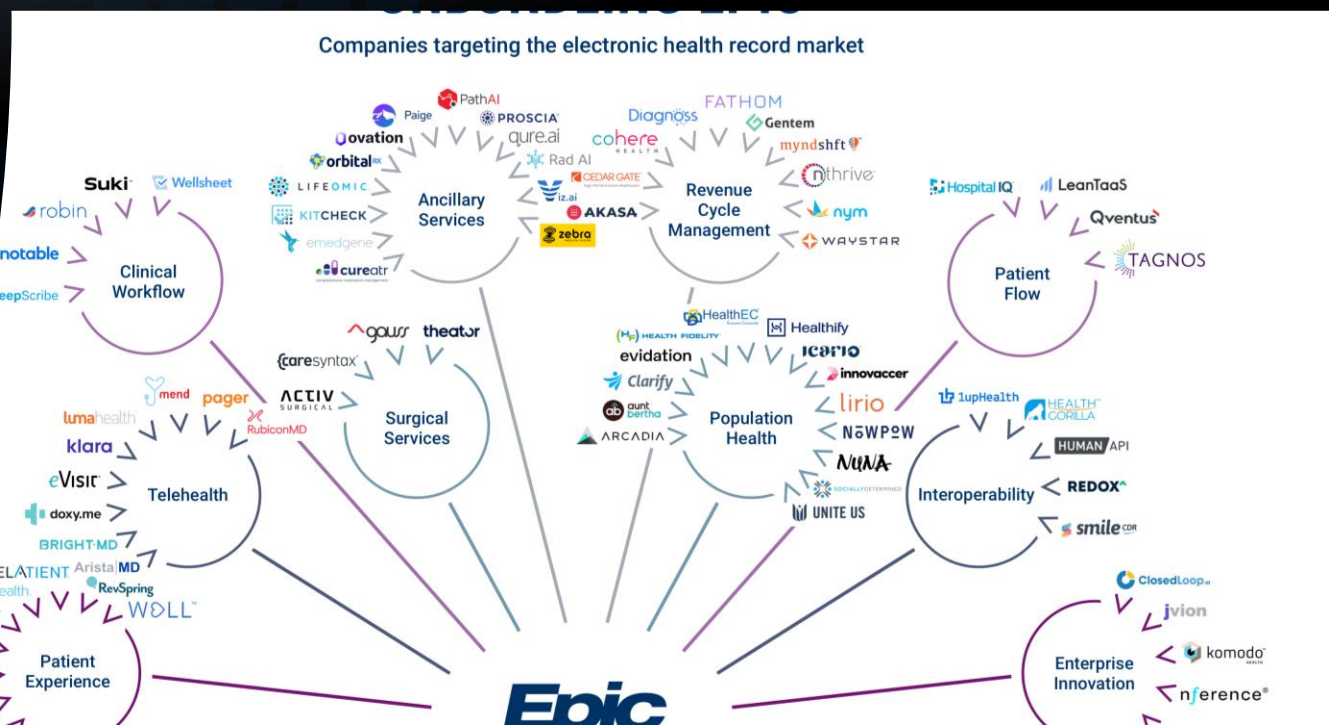
Data Generation and Management

Organizing Critical Information

Maintenance of structure data





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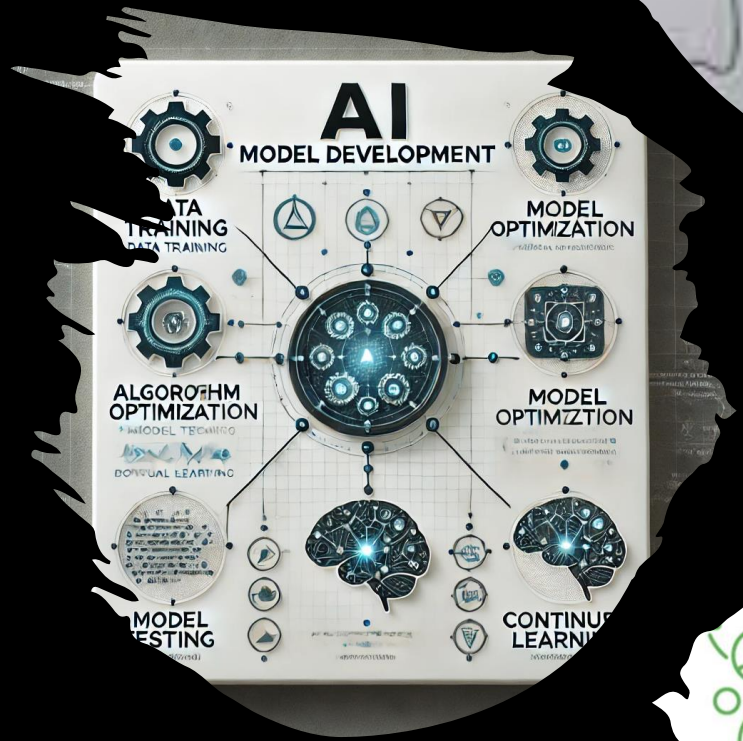
Model Development

- 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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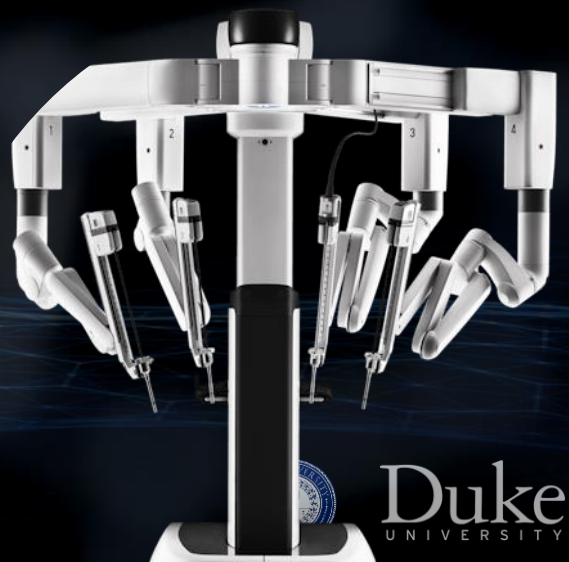
Solution Management



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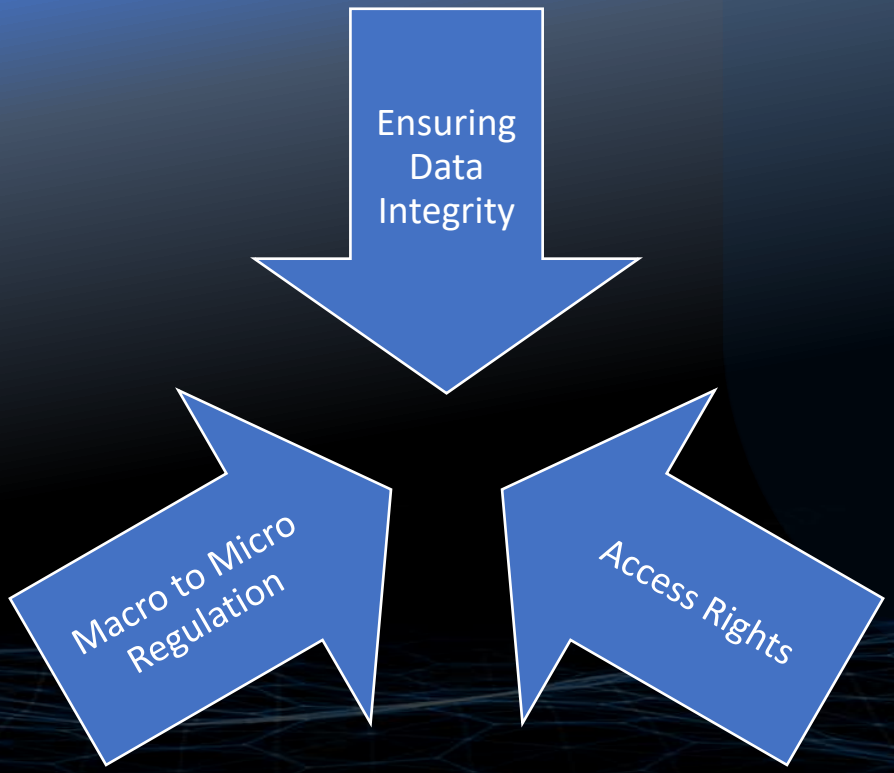
Security and Access Control



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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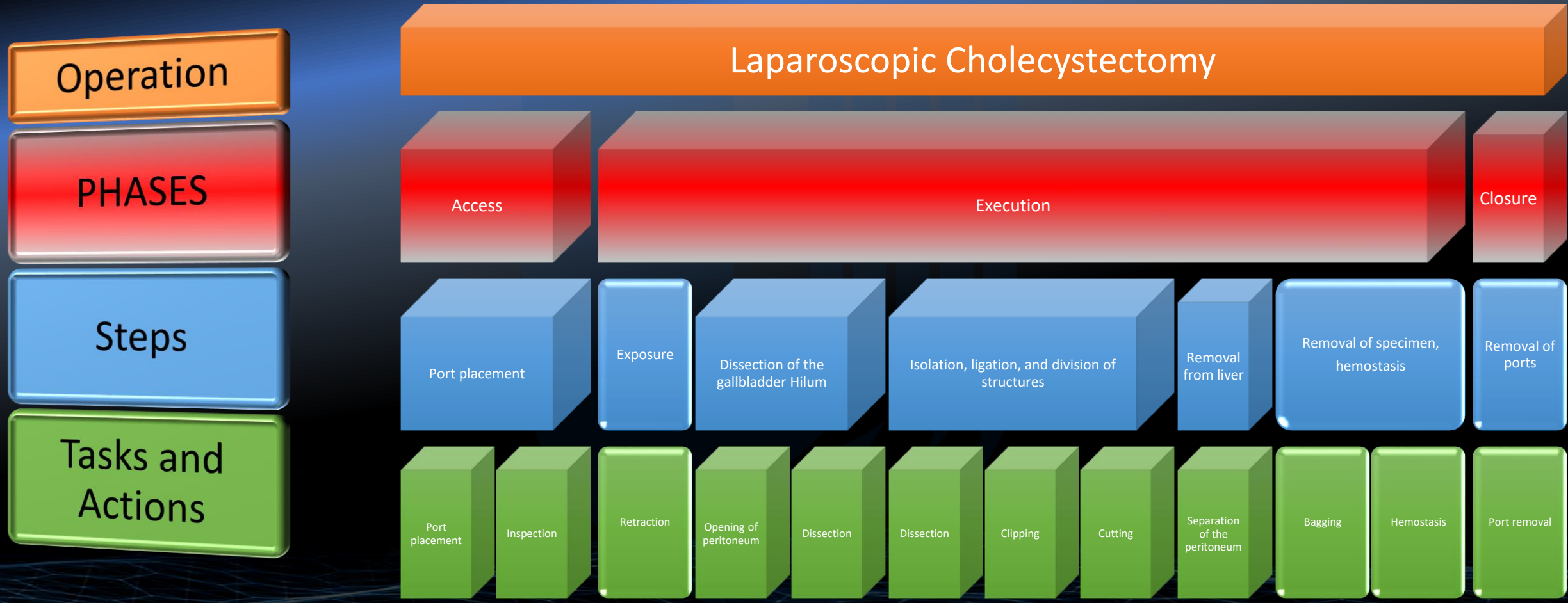
Surgical Video Foundation Models

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



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Annotation

Spatial Hierarchy

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Transfer Learning

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

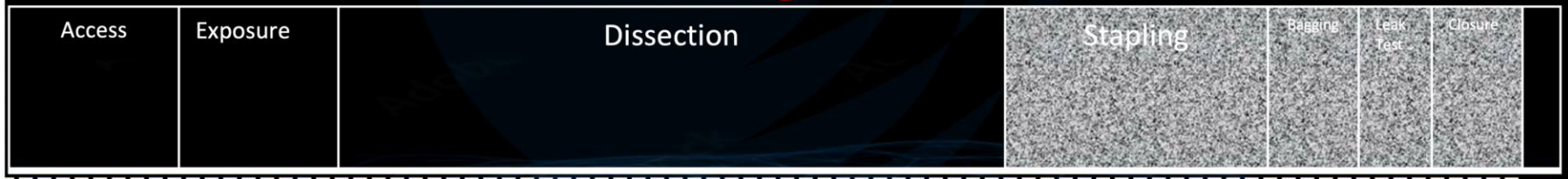
Experimental Phase

Abnormal case

Abnormal
Surgical Fingerprint

Detecting Deviations

Normal Range



Deviation

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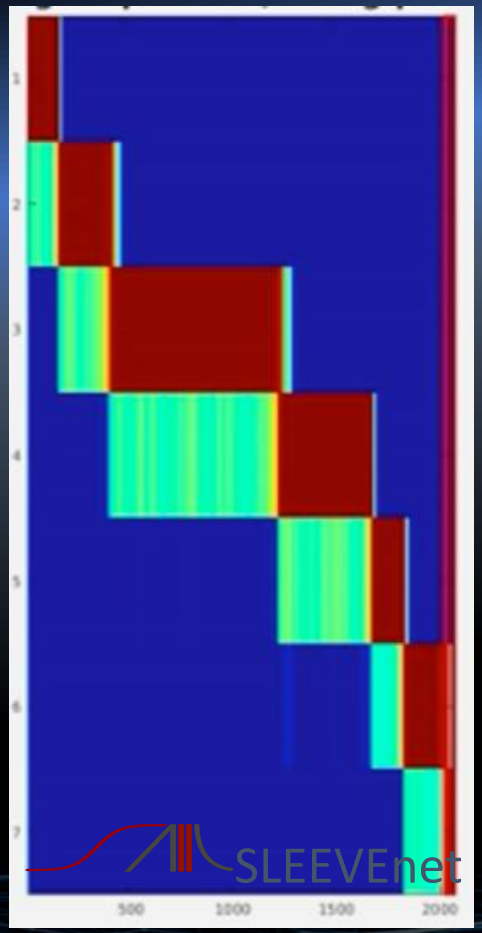
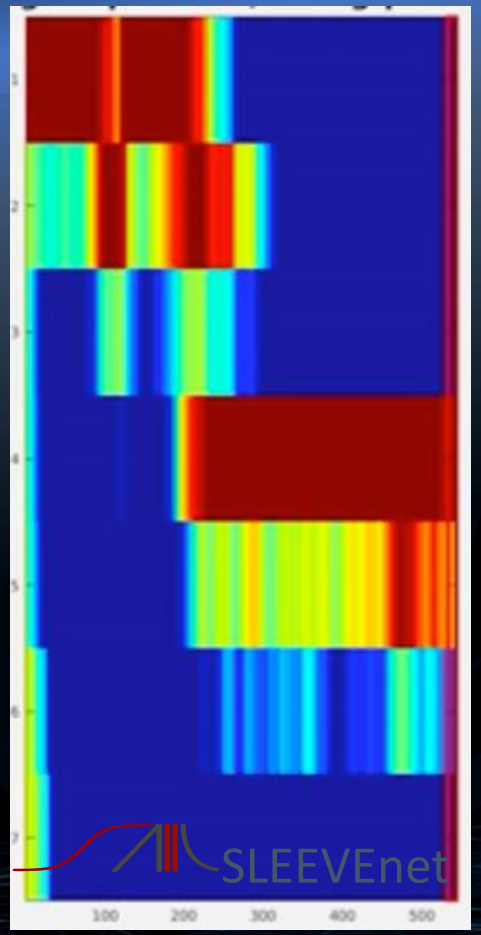
Surgical Fingerprint – Sleeve Gastrectomy

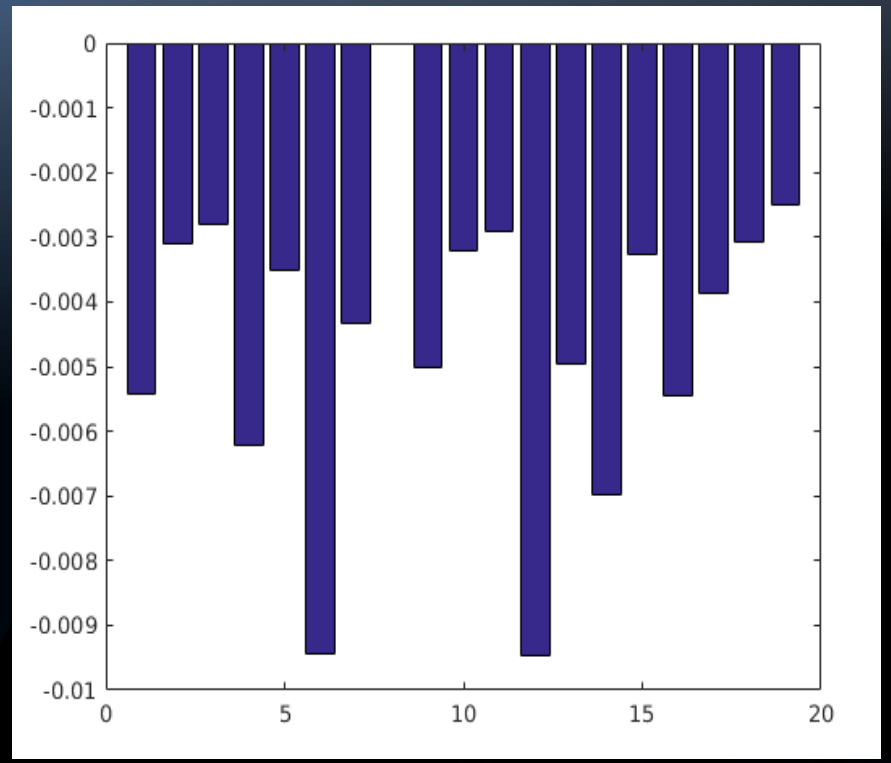
Case A



Case B



Normalized Cumulative log Probability



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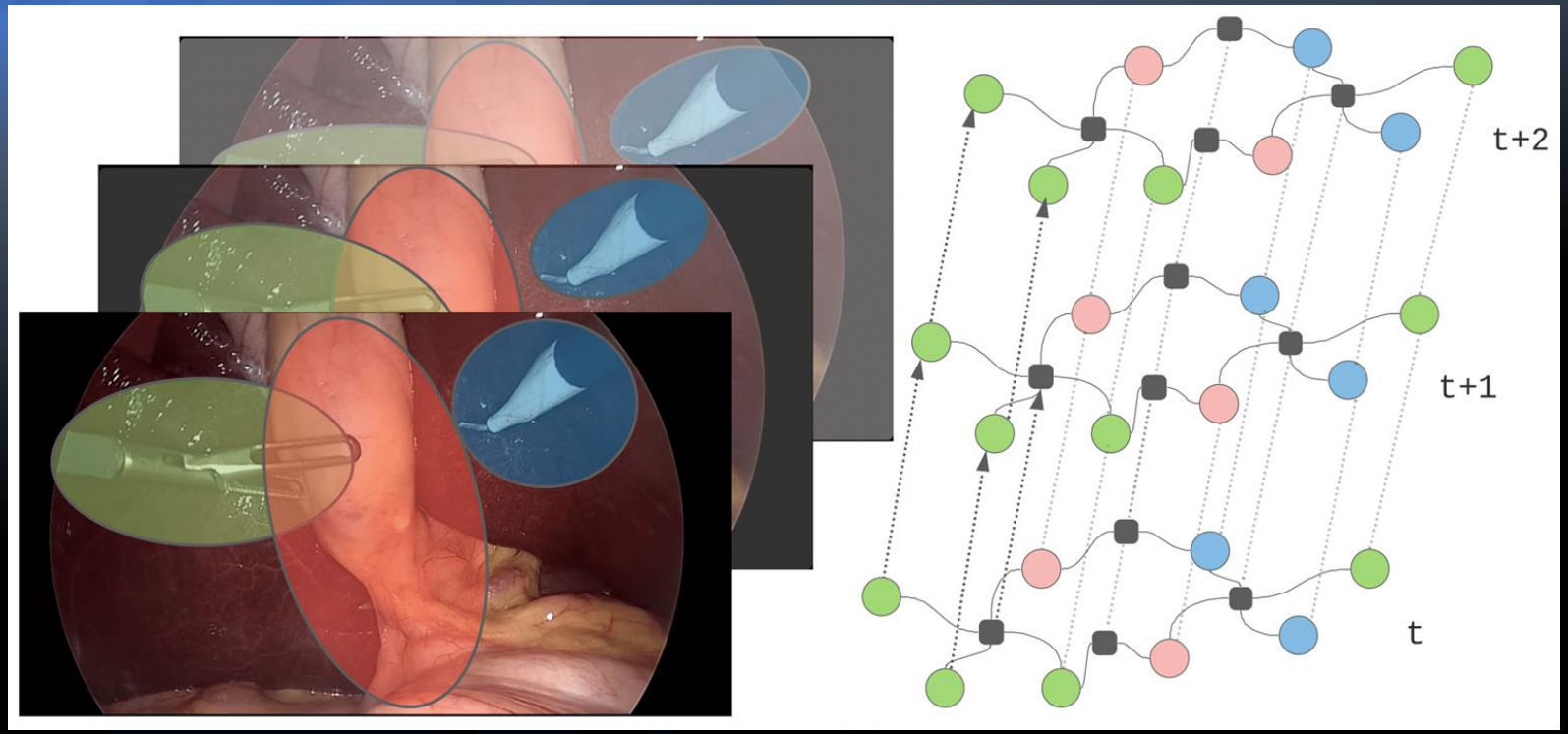
Knowledge Graph in Surgery

which can be used for

- Interactions of objects in surgery
  - Tool-action-tissue interactions.
- Relations of abstract concepts
  - Parkland scale and its components



Concept Graph Neural Networks for Surgical Video Understanding
Y. Ban, J. Eckhoff, T. M. Ward, D. A. Hashimoto, O.R. Meireles, D. Rus, G. Rosman
Under revision to IEEE Transactions on Medical Imaging 2022

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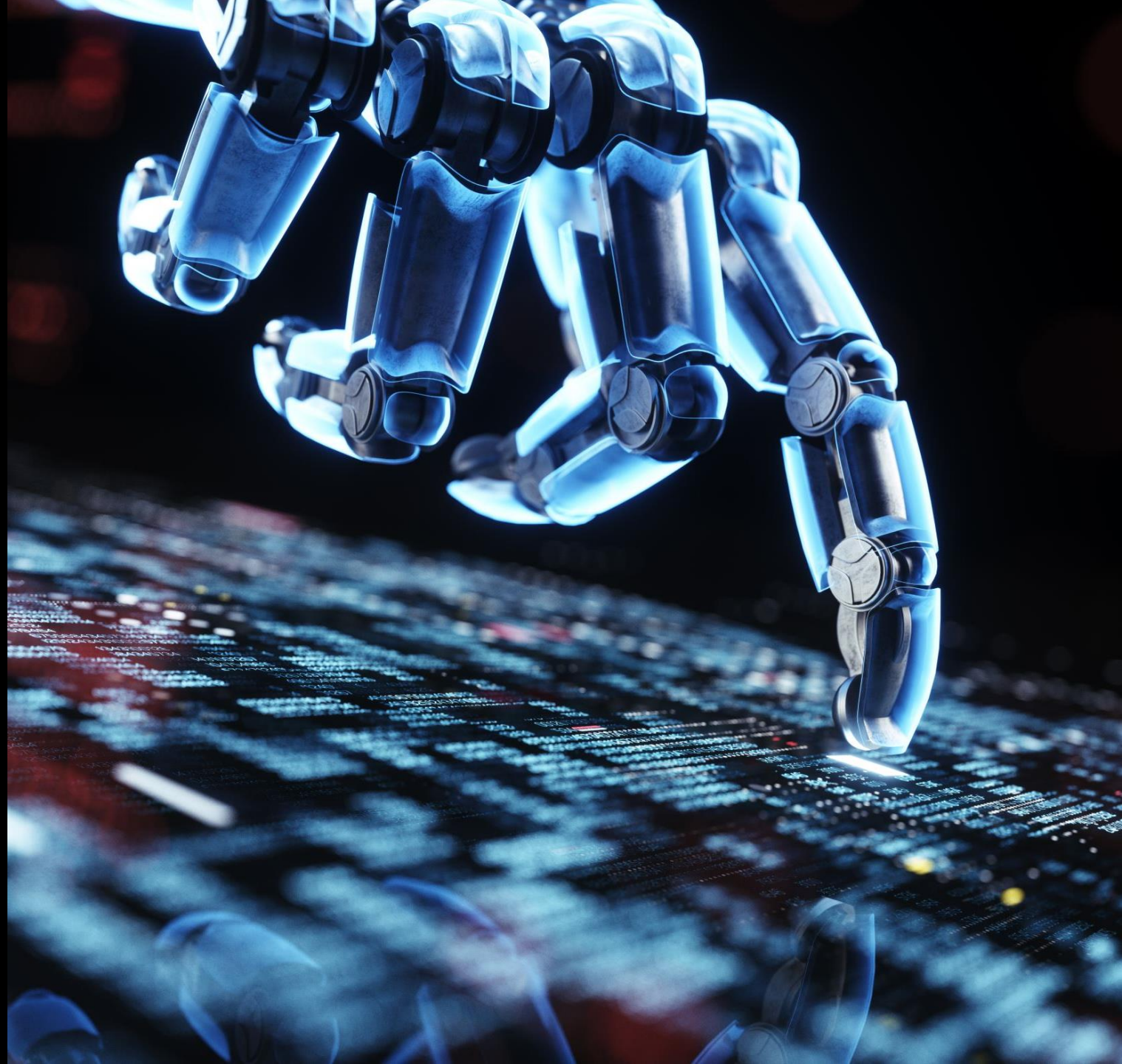
Utilities and Apps

Automation



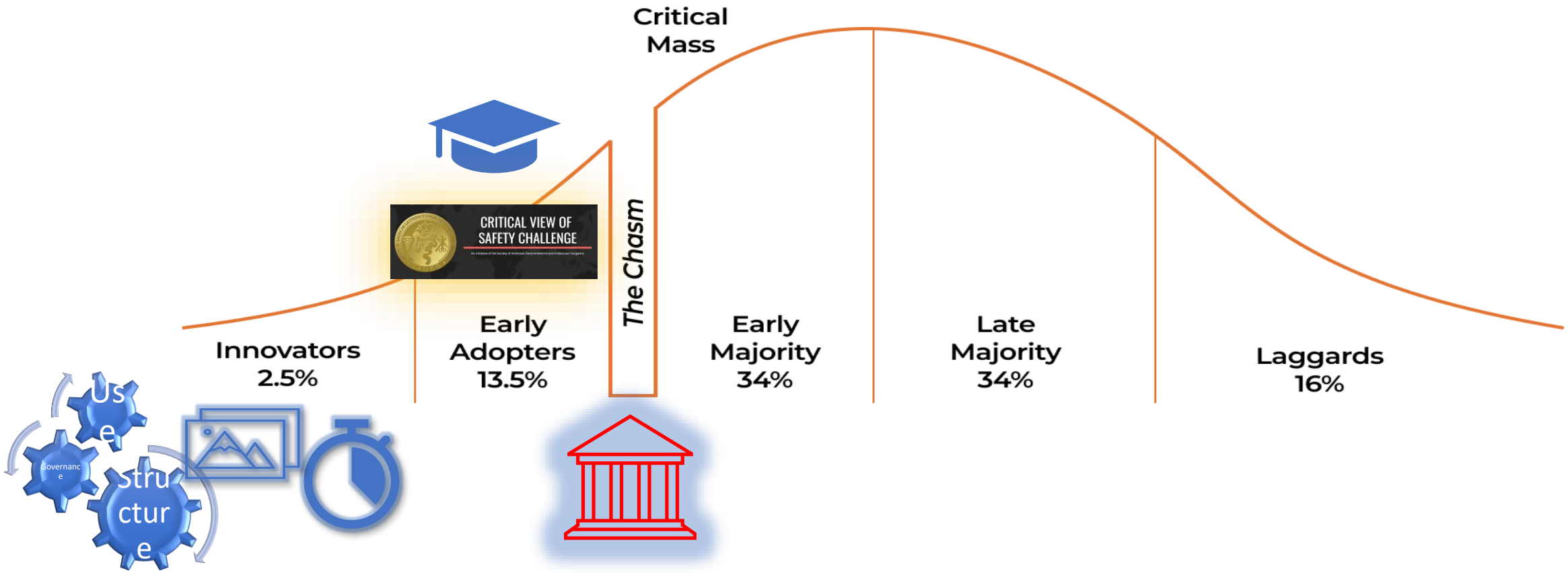
Potential Current Applications - S.OS Apps

- Attending Notification System
- Operative Report Generation
- Billing
- Compliance Monitoring
- Resource Prediction, and Allocation

- Tele-mentoring
- Operative Case Length Prediction
- Attention Awareness

Future Steps

Surgical AI Development



Cultural Transformation

SHARING DATA

SHARING KNOWLEDGE

CULTURAL DIFFERENCES

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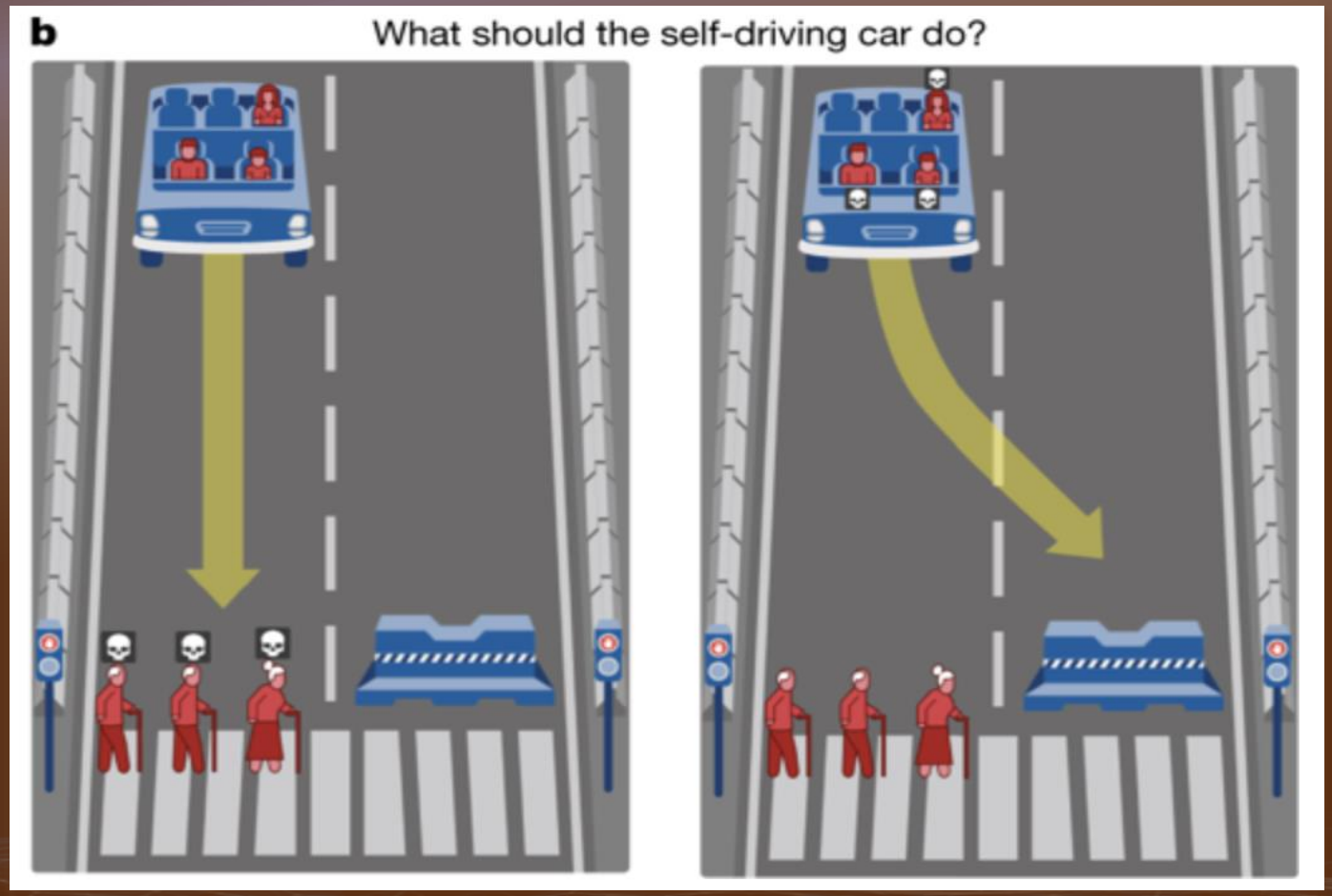
Ethical considerations

The Moral Machine

http://moralmachine.mit.edu



Awad et al. 2018. *Nature*

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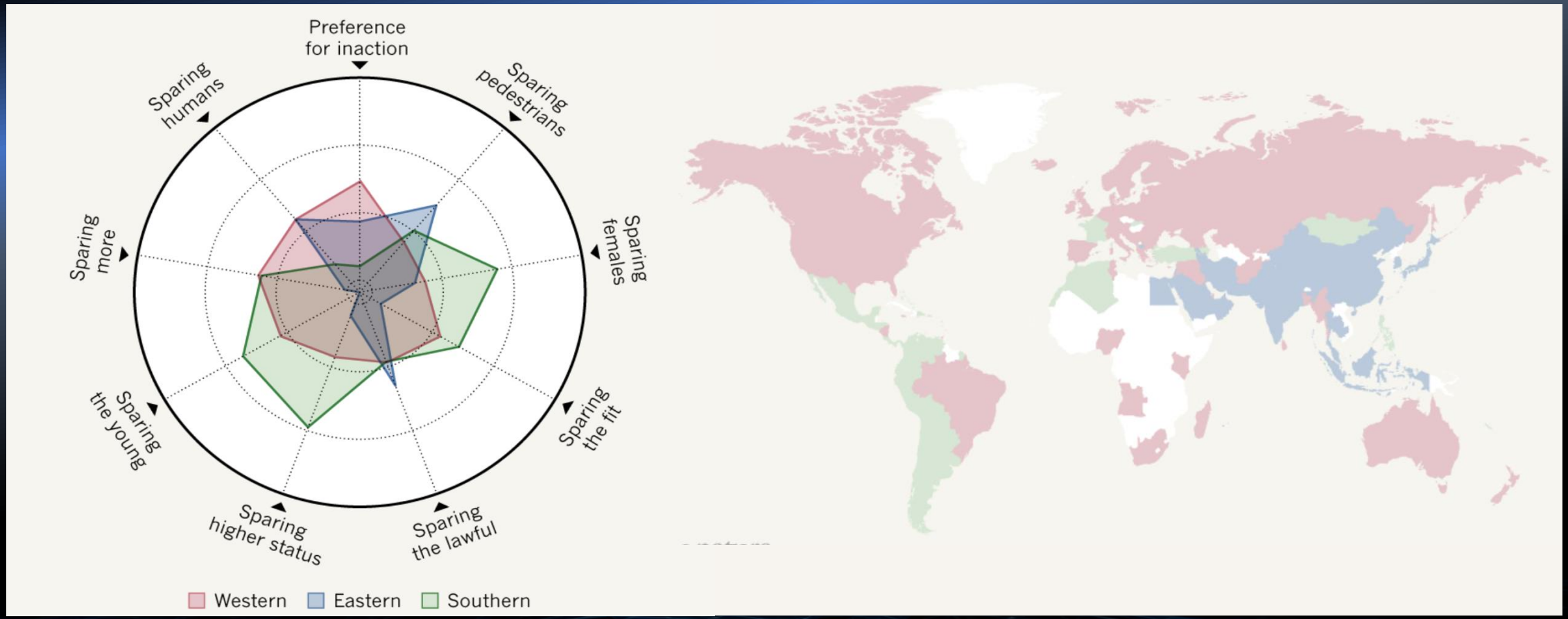
Ethical according to whom?



http://moralmachine.mit.edu

Awad et al. 2018. *Nature*

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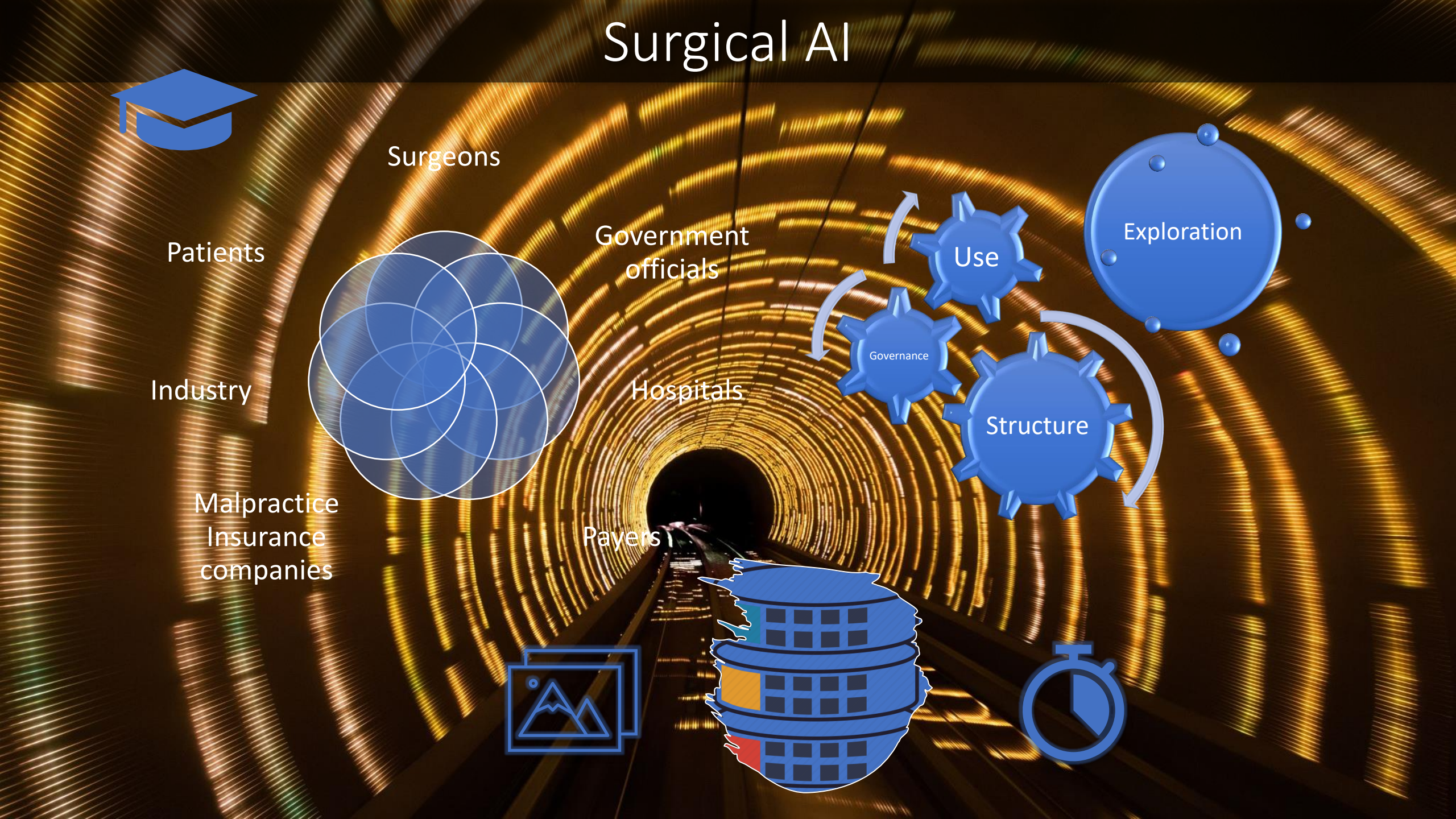
Surgical AI


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

A few years from now .....

At your local hospital.

Initializing..... S.OS ..... /

A Blueprint for the Future of Medicine

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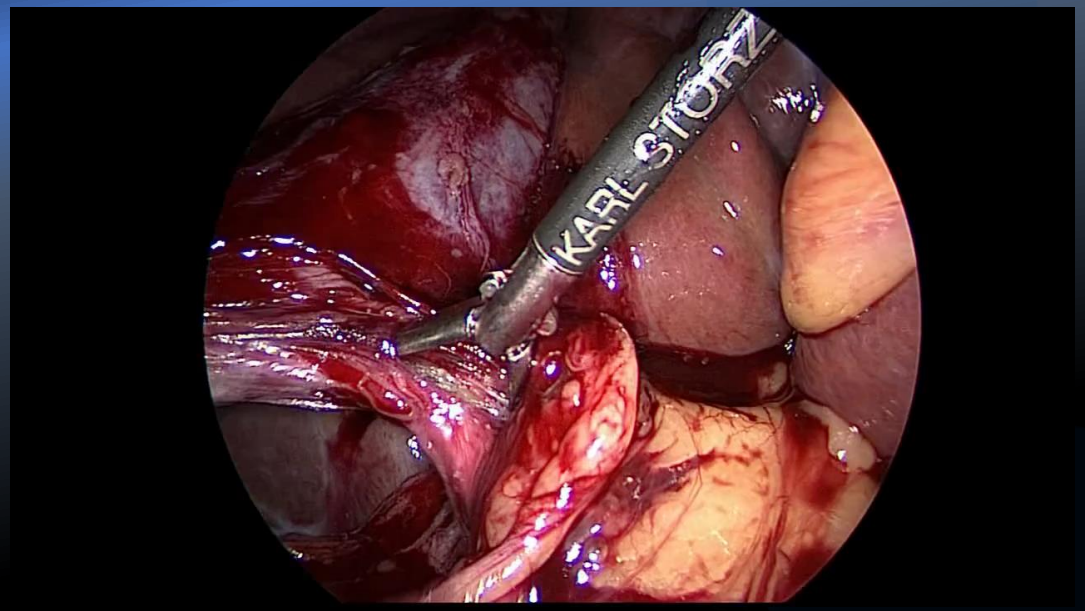
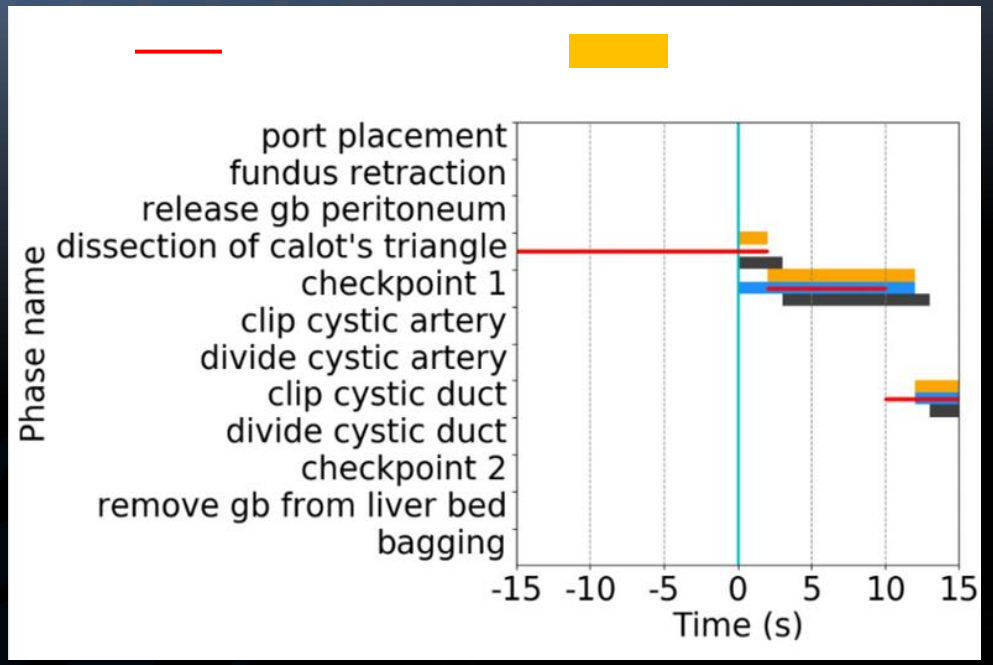
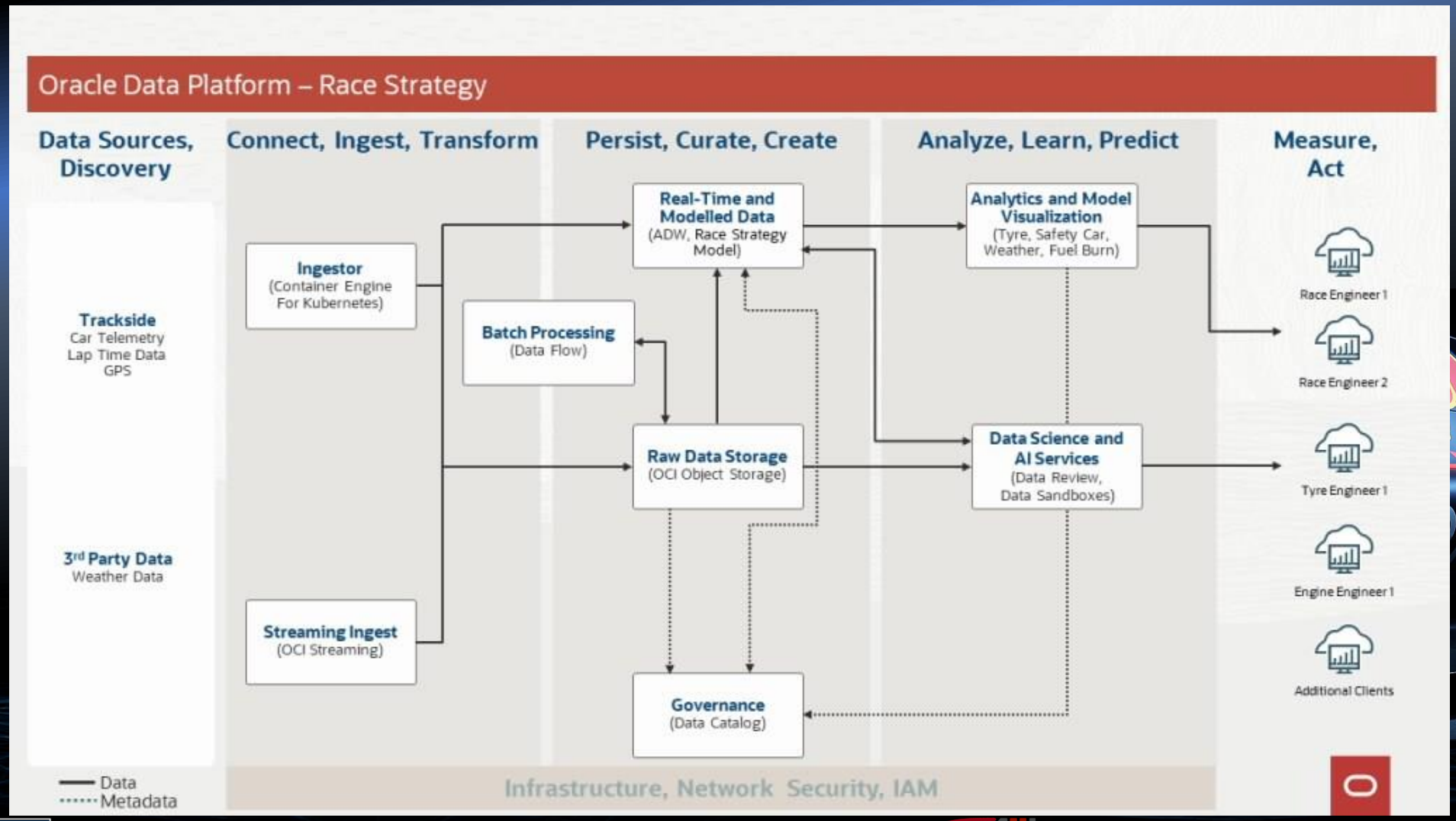
Surgical Event Real Time Prediction





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

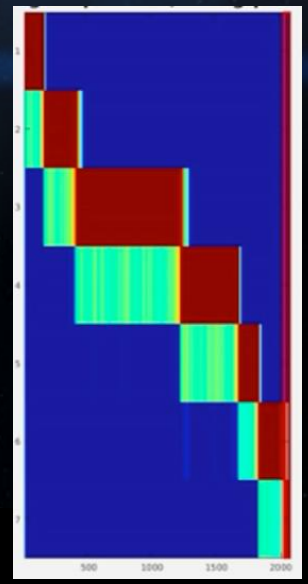
Error Handling and Recovery



Analysis of intraoperative video *with Decision Support .*

Conceptual Phase

Case 3 – Preventing Complication



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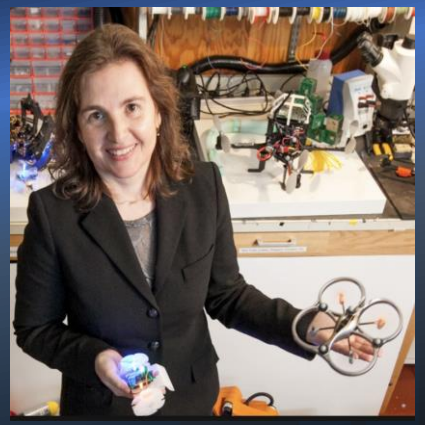
Assoc Director, Engineering



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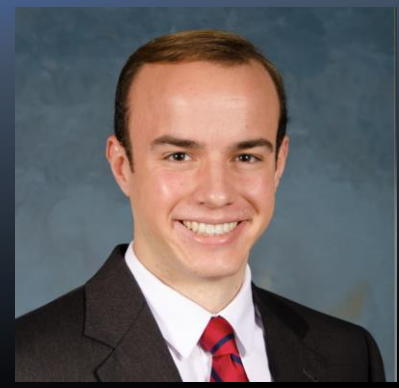
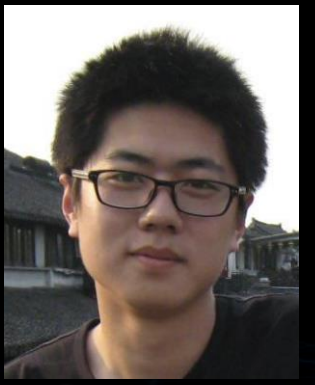


Thomas Ward, MD
Former Fellow



Yutong Ban, PhD
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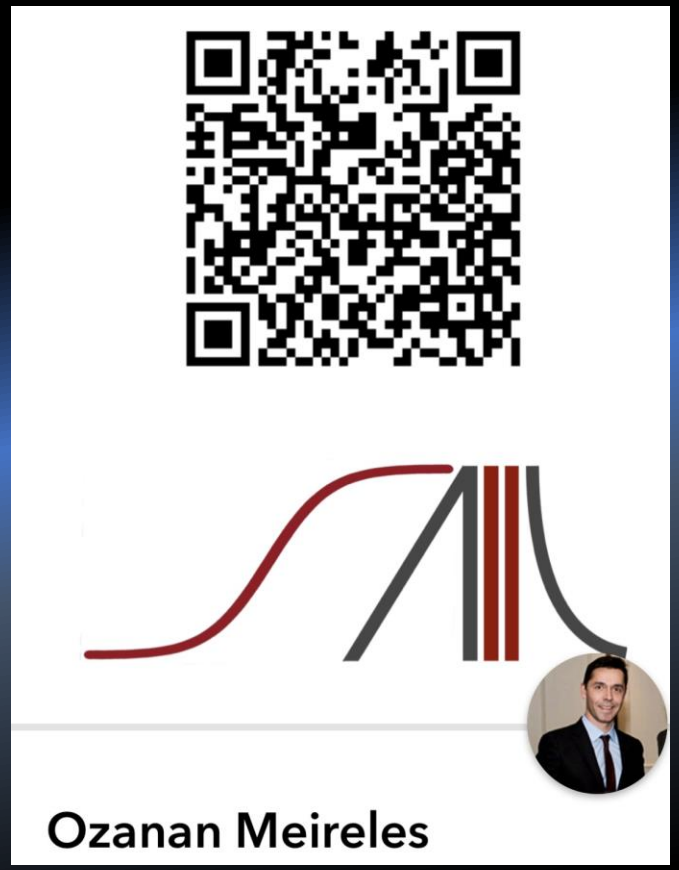
Thank you!



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