

Evolution of Telesurgery During the Robotic Surgery Renaissance and a Systematic Review of its Ethical Considerations

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Dr. Frenkel is board certified in general surgery and specializes in head and neck cancer surgery, reconstruction and transoral robotic surgery. She also manages benign and malignant head and neck lesions of the oral cavity, throat, larynx, thyroid, parathyroid, salivary glands, skin and soft tissues.

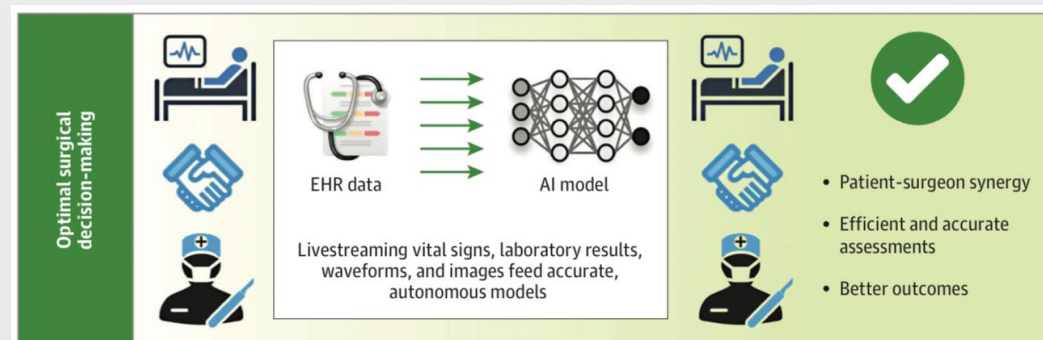
She serves as assistant professor of head and neck in the Surgical Oncology Department at Atrium Health Levine Cancer Institute. Dr. Frenkel is an American College of Surgeons-MacLean Center Surgical Ethics Fellow with special expertise in head and neck cancers in immunosuppressed and transplant patients. She has received numerous awards, including the Vosburgh Scholarship for Medical Ethics from the Alden March Bioethics Institute at Albany Medical College, the American College of Surgeons Leadership Scholarship, the John Hunter Award for Excellence in Surgical Skills and the David J. Kreis Jr. Award for Excellence in Trauma Surgery.

In addition to her achievements, Dr. Frenkel has published numerous peer-reviewed articles in various journals.

Dr. Frenkel received her medical degree at Albany Medical College and completed her residency at Stony Brook University. She then completed her fellowship at the University of Pennsylvania.

Disclosures

- Dr. Catherine Frenkel is a Consultant for EMD Serono. All relevant financial and nonfinancial relationships have been mitigated.
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(Loftus et al., 2020)

Learning Objectives

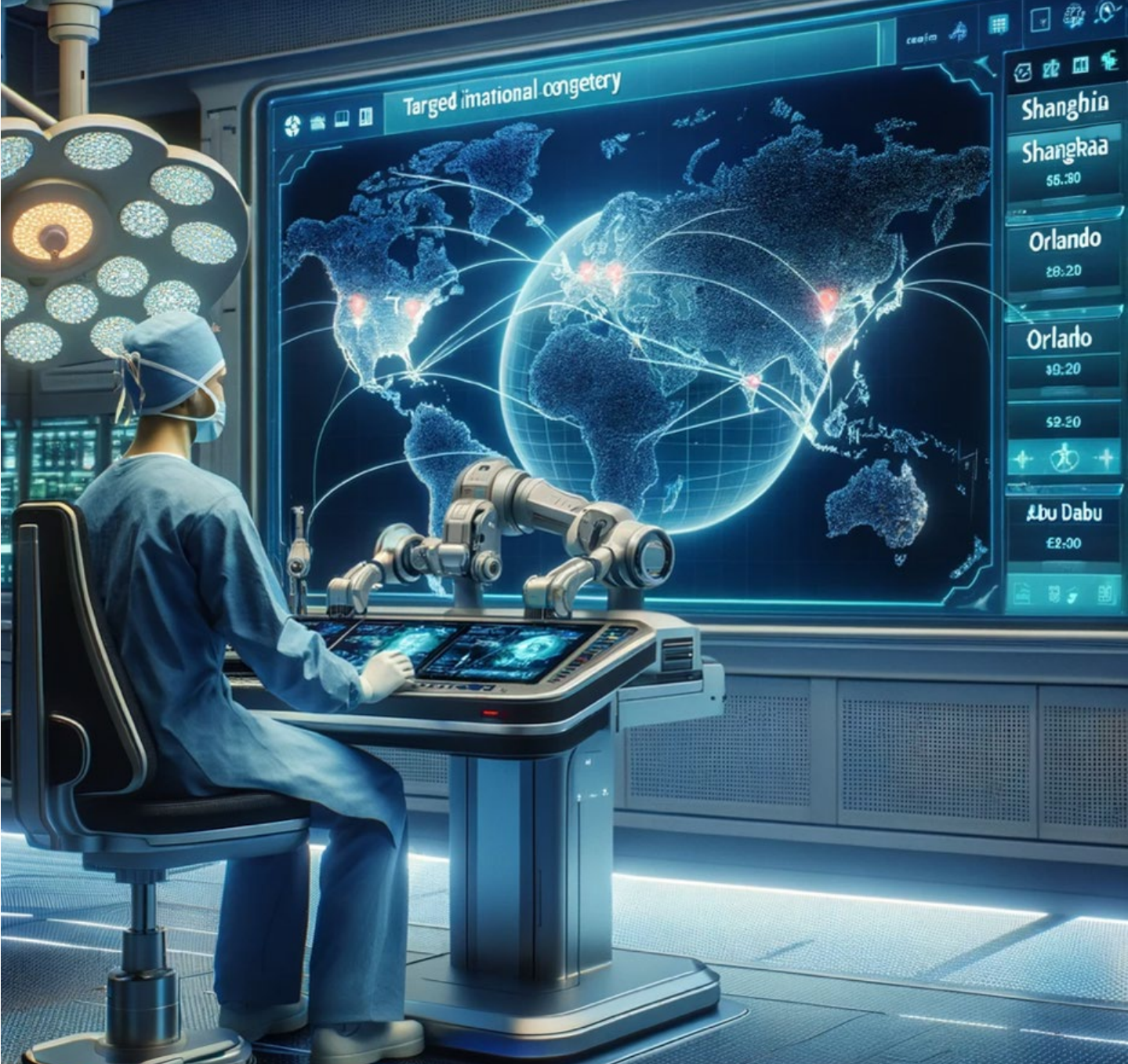
At the conclusion of this activity, participants will be able to:

1. Describe the historical evolution of telesurgery.
2. Identify the current state of telesurgery technology.
3. Outline the ethical challenges telesurgery faces in the future.

TORS- Transoral Robotic Surgery



History of Telesurgery



“The idea of telesurgery was born in 1993, after Marescaux attended a lecture by a US military physician who envisioned its use on a battlefield in space.”

ircad
France

BATTLEFIELD
SPACE

Professor Jacques Marescaux



5 Components for Successful Telesurgery

1. **Augmentation** – 3rd arm
2. **Ergonomics** – “Overcome the limits of humanity,” e.g. extended wrist ROM
3. **Enhancement** – more natural dexterity than a surgeon, without tremor or fatigue
4. **Image-guidance** – Input from MRI/CTs during surgery
5. **Data transmission** – Fast, reliable, minimal signal latency

-Yulun Wang

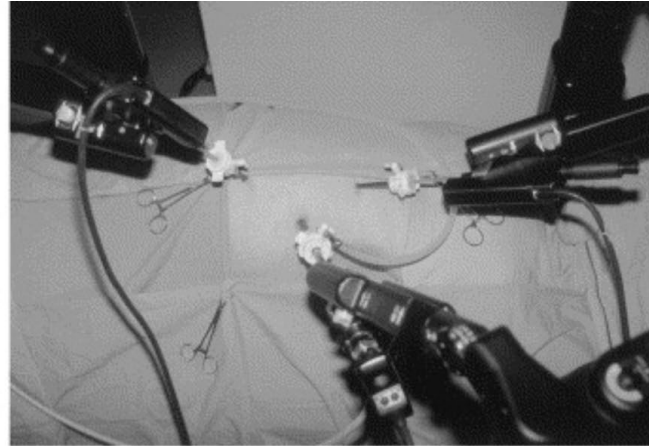
Chief Scientific Officer

Zeus robotic system

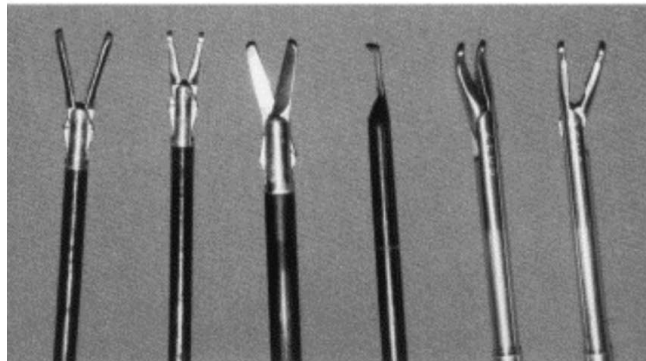
Previous NASA employee



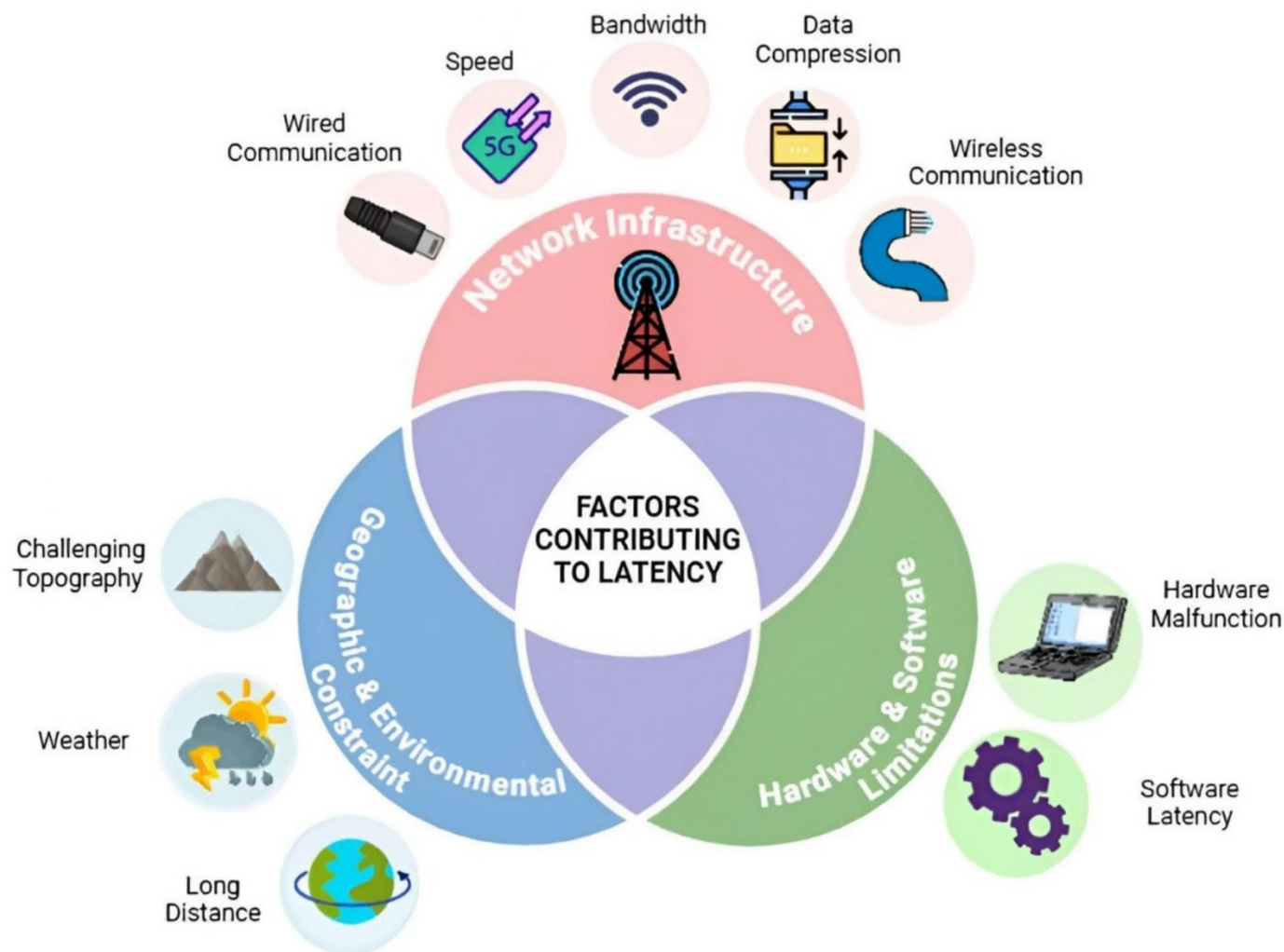
A



B



Zeus Robotic System



Acceptable failure rate $<0.001\%$

(equals estimated incidence of the surgeon experiencing syncope while operating)

Table 2 High-level summary of the requirements on latency, rate, and reliability [1]

	Roundtrip latency [ms]	Rate [Mbps]	Reliability [%]
Kinesthetic control	10s-200	< 1	99.999
Audiovisuals	10s-400	10s (2D), 100s-1,000 (3D)	> 99
Tactile feedback	10s-400	< 1	> 90

Lindbergh Operation NY – France 2001

First clinical robotic telesurgery

Demonstrated trans-Atlantic
feasibility, control latency <200 ms

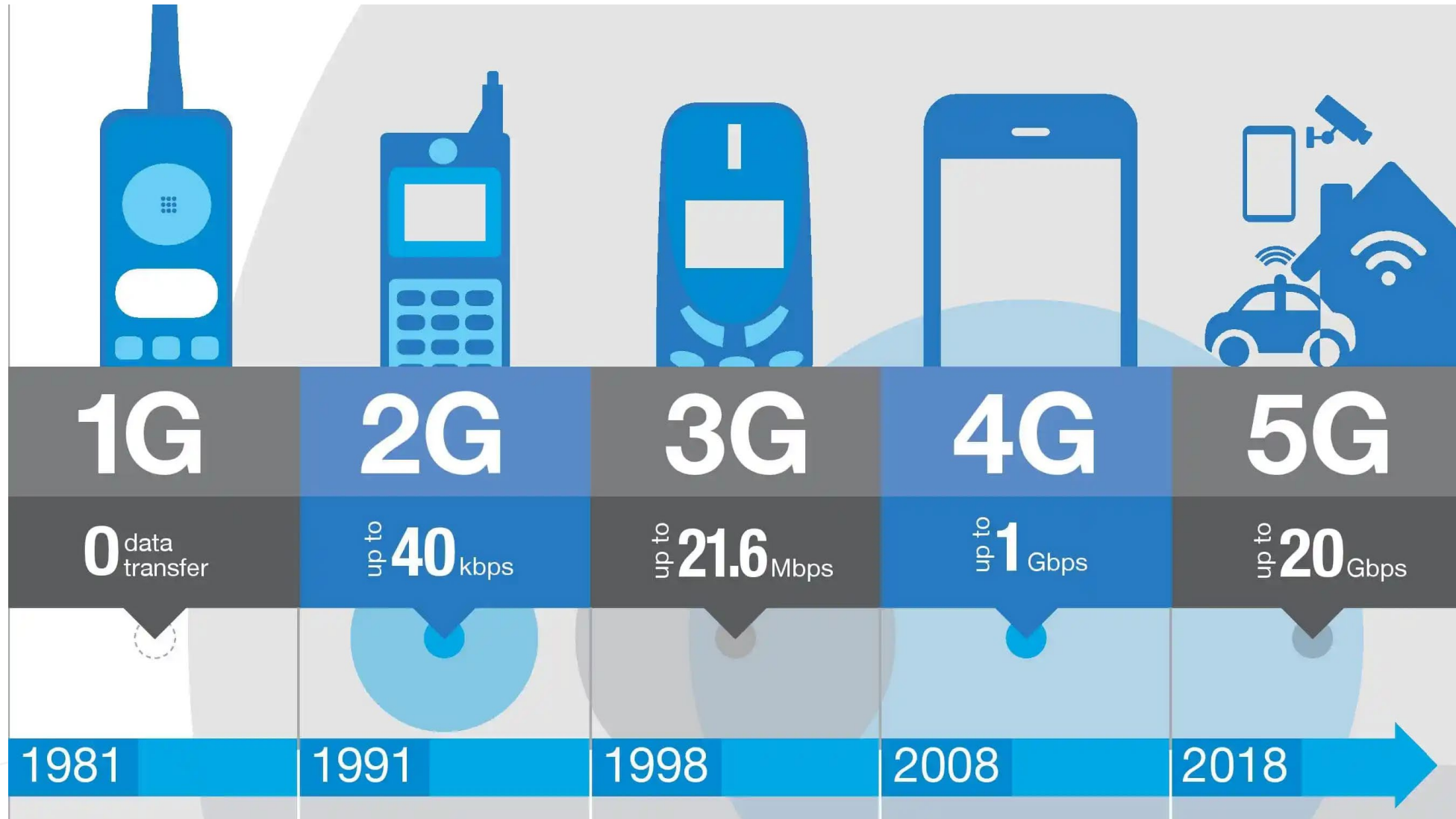
1 million Euro 45 min
cholecystectomy

ZEUS robotic system

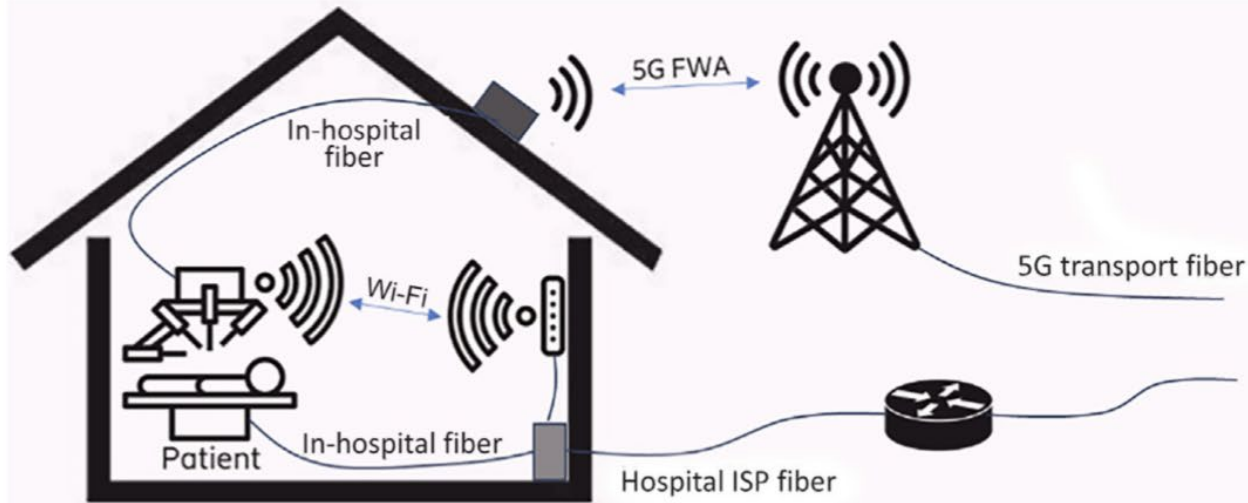
Professor Jacques Marescaux



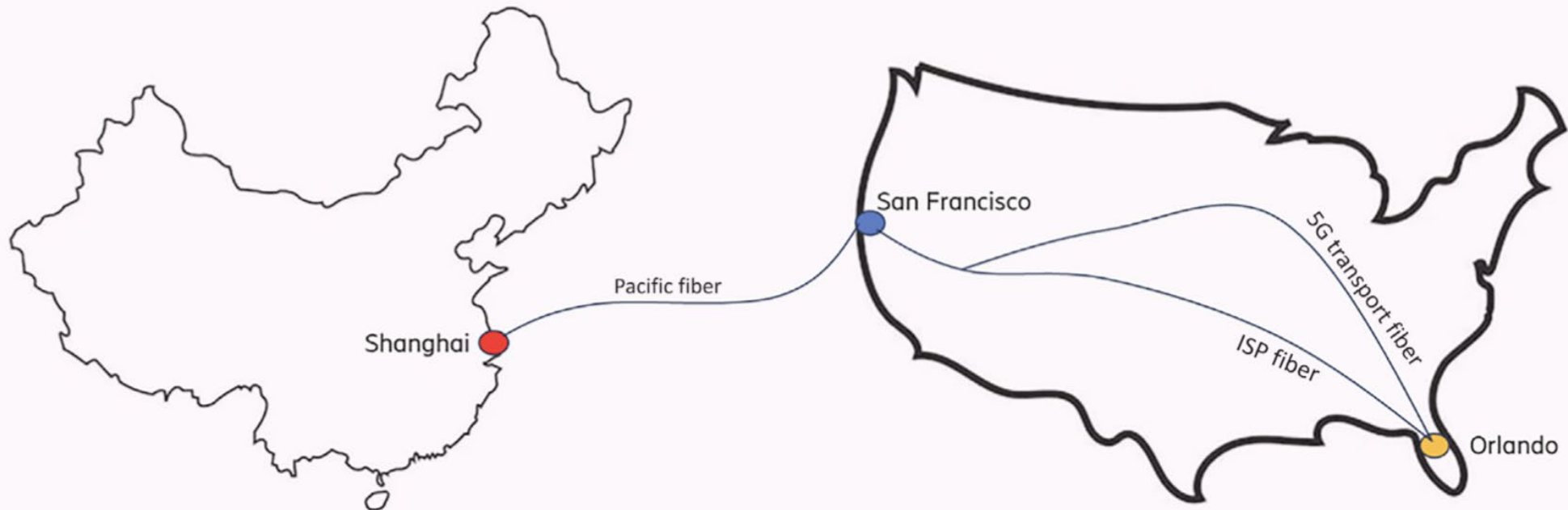
Network



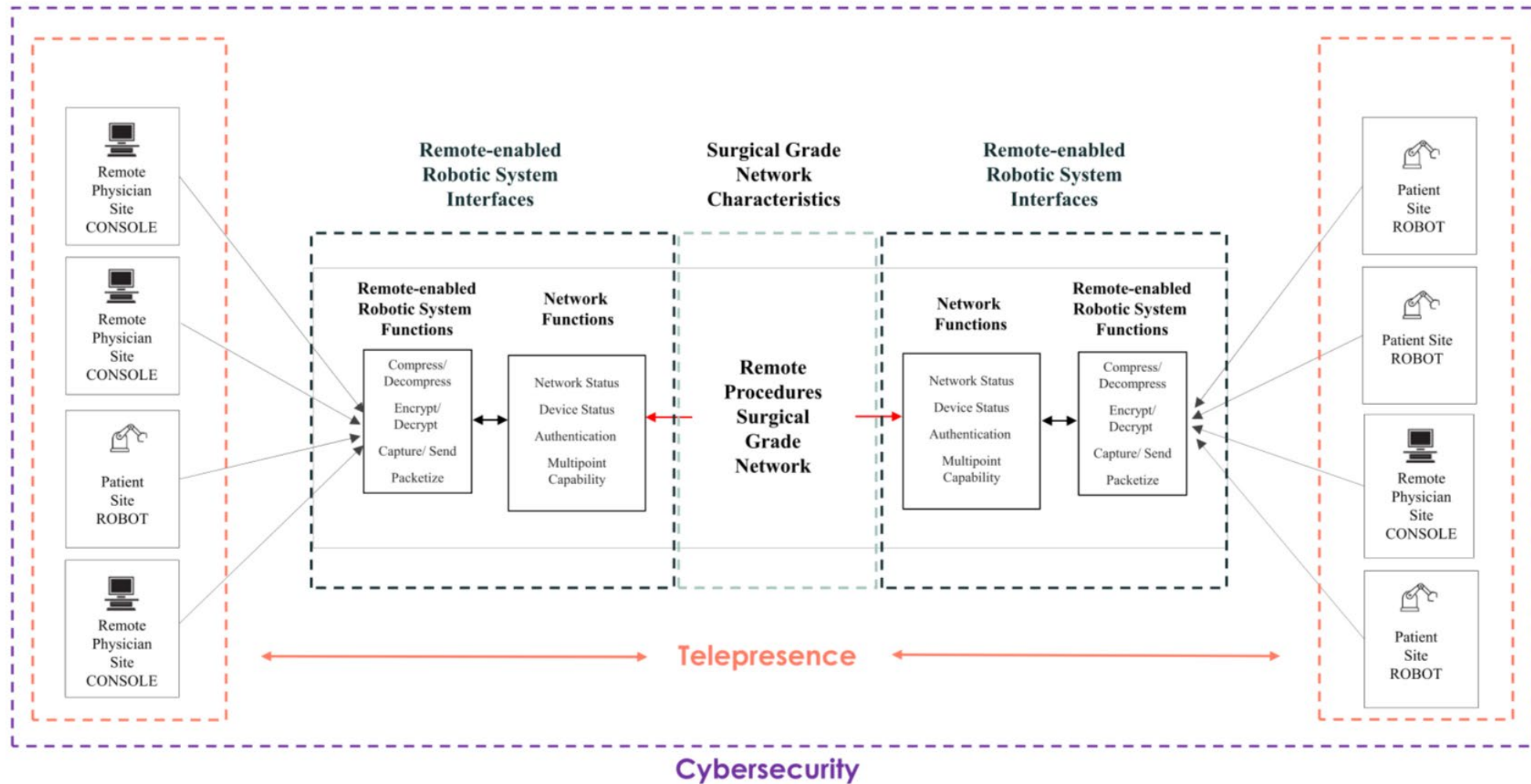
Connectivity



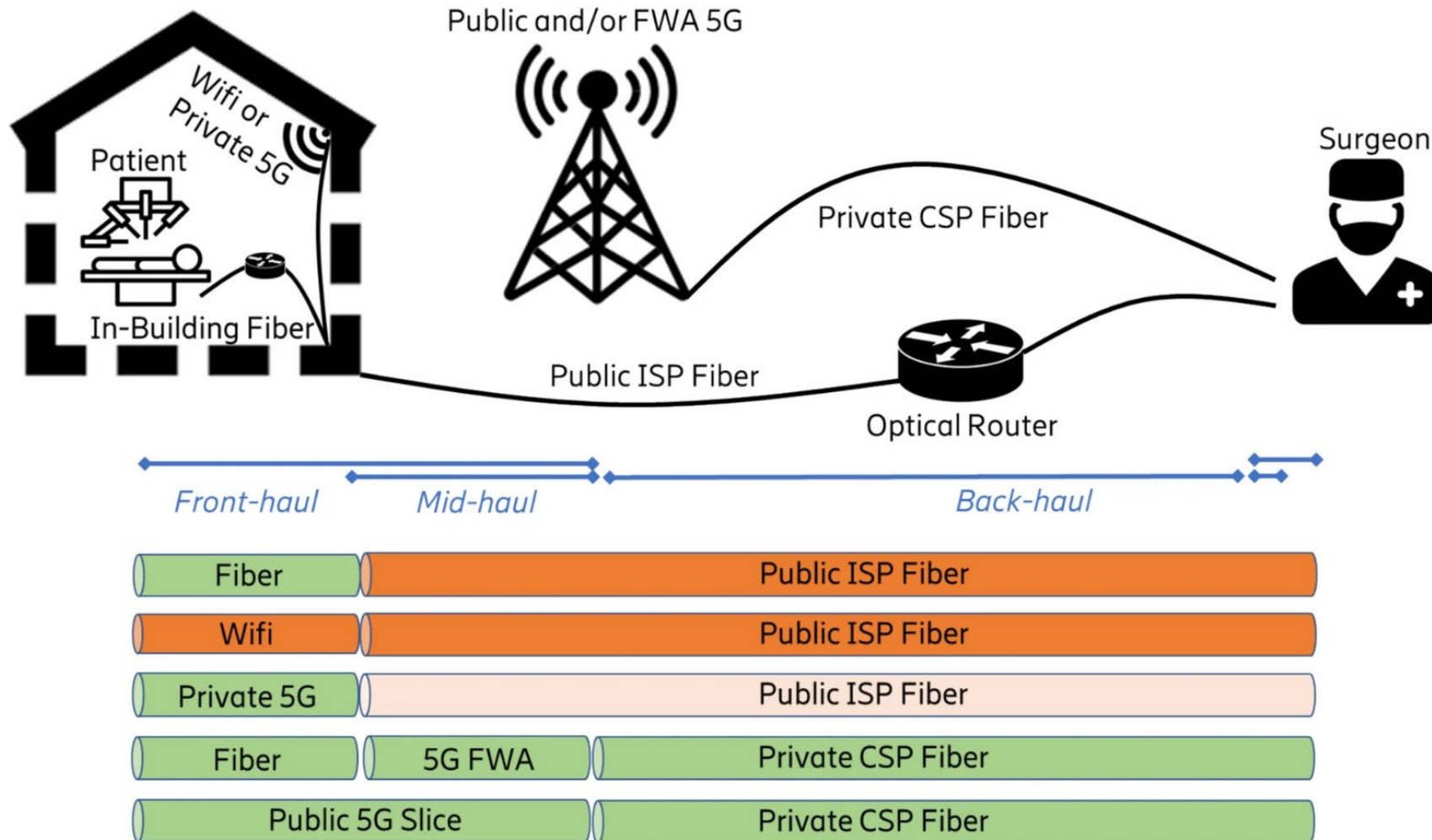
- Example schematics of connectivity between Orlando and Shanghai
- Surgeon side is symmetrical from a connectivity point of view
- In the trial, public 5G and not Fixed Wireless Access (FWA) has been used



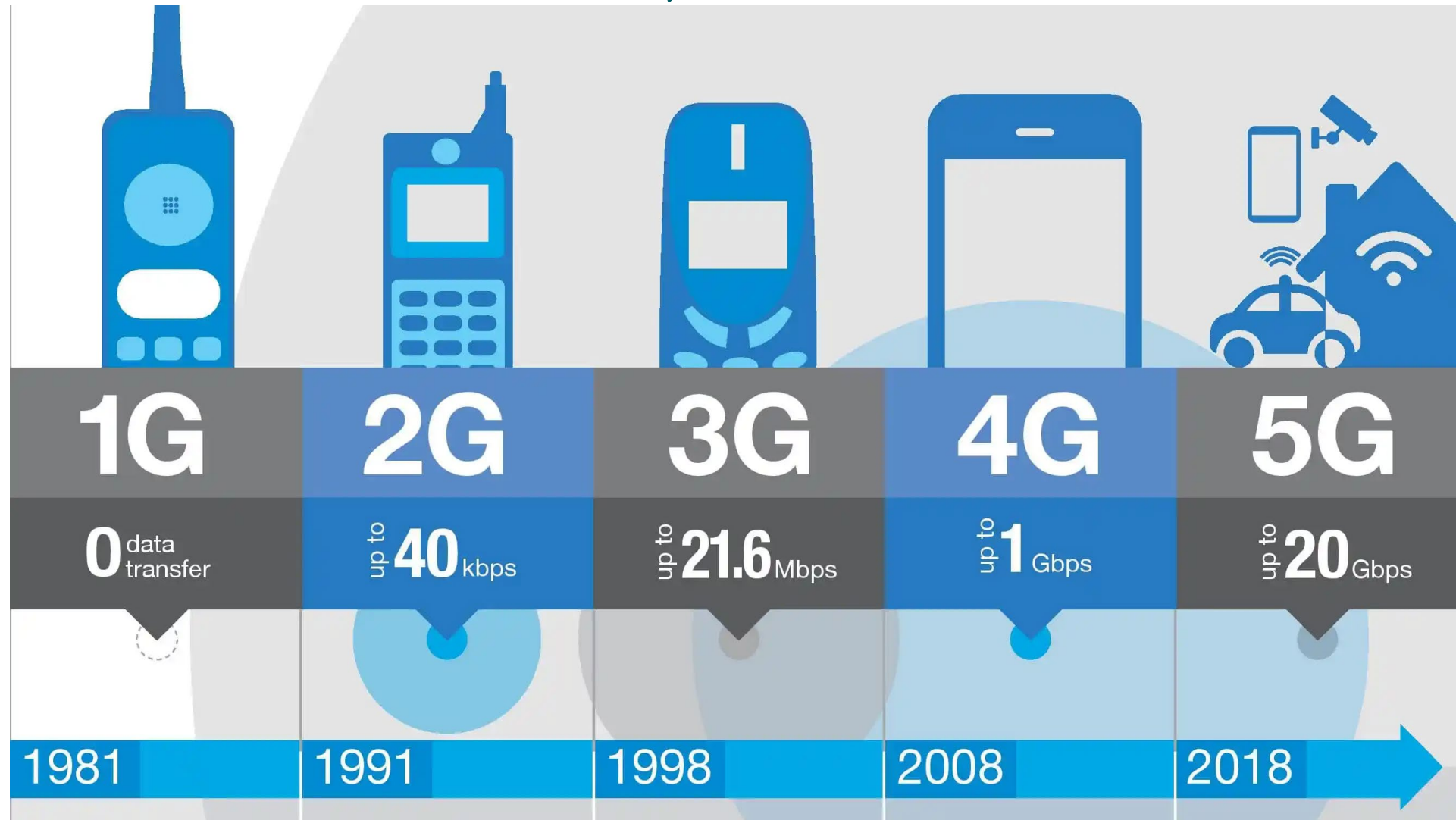
Technical Guidelines Components



Connection



Network, continued



Mobile World Congress, Barcelona 2019

Dr. Antonio Lacy

Remote endoscopic
colon polyp removal
overseen

4 km away from patient
bedside



International Congress of Digestive Surgery, Rome 2019

Dr. Giorgio Palazzini

360-degree visor
immersion

Remote consultation
during laparoscopic
gastrectomy



The Future of Telesurgery Project Angola 2025

- U.S. Food and Drug Administration (FDA) approved transcontinental clinical trial protocol
- Telesurgical radical prostatectomy
- Two qualified surgeons at patient bedside
- Microport MedBot



(<https://www.adventhealth.com/news/historic-telesurgery-connects-central-florida-and-angola-world-first-medical-breakthrough>)

“Telesurgery can act as a bridge, enabling expert surgeons to deliver lifesaving interventions”

- Patient welfare must remain the primary objective
- Tool for managing complex cases & enhancing surgical training
- At this stage, surgeons at both ends of the connection must be experts



(Moschovas et al, 2025)



SRS2025
ANNUAL MEETING
JULY 16-20, 2025

STRASBOURG, FRANCE



**World Health
Organization**

2025 Joint Initiative to Advance Telesurgery

Robotics, Telesurgery and Surgical AI Collaborative Community

Benefits of Telesurgery

- Global surgical healthcare equity
- Enhanced surgical training and collaboration
- Improved surgical outcomes
- Error prevention/rescue

Cost reduction?

Challenges

- Better telecom reliability & redundancy to achieve SAFETY
- Cybersecurity
- Robotic capability improvement
 - *ergonomics, enhancement and image-guidance*
- Inadequate healthcare infrastructure
- Currently COSTLY
- Governmental regulation: international data transfer, licensure/credentialing
- COMPATIBILITY between robotic systems, global internet networks
- Uncharted ETHICAL territory

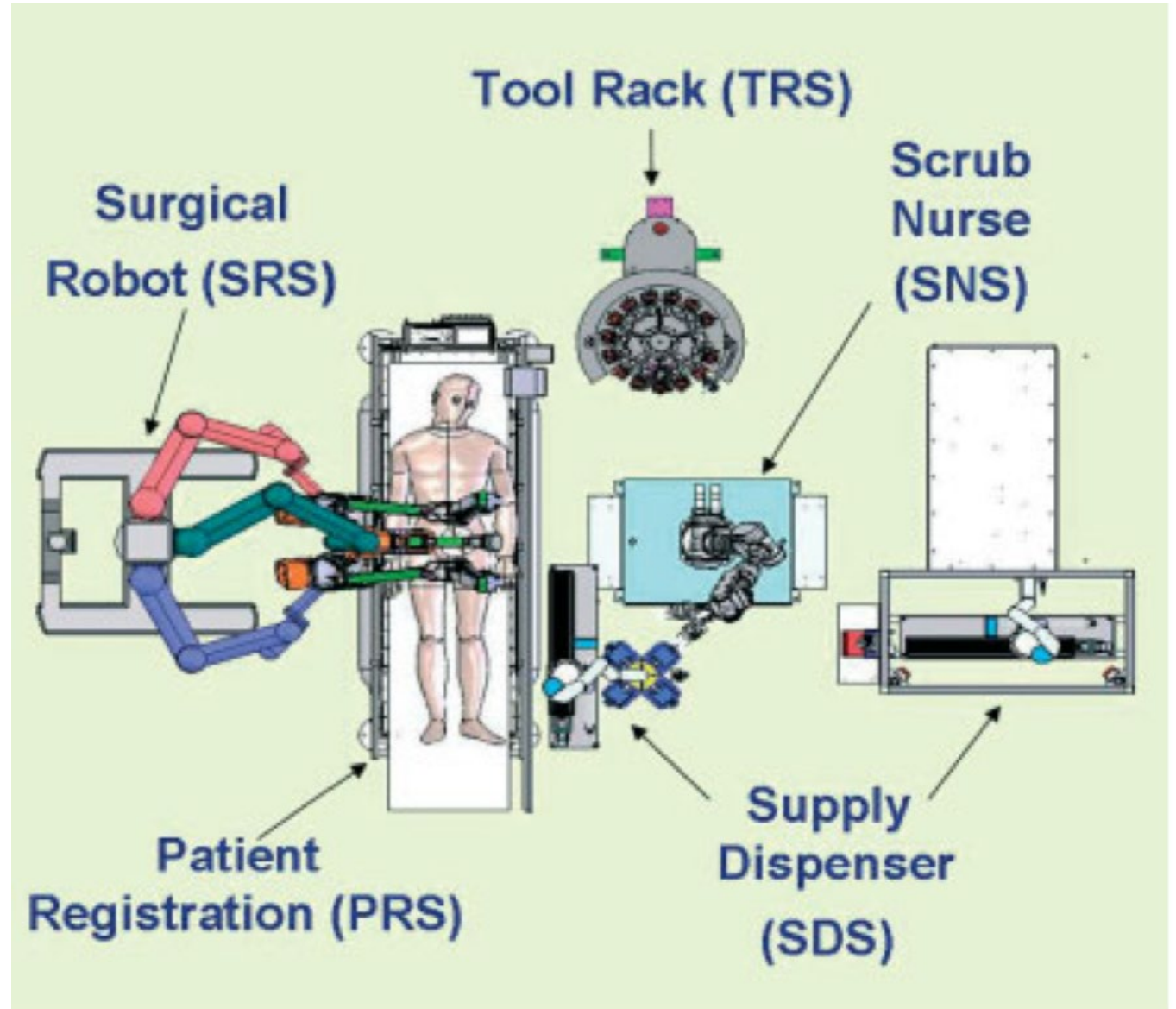
Trauma Pod: In-field unmanned telesurgical platform



DARPA- Defense Advanced Research Projects Agency



SRI- Stanford Research Institute



Trauma Pod Subsystems

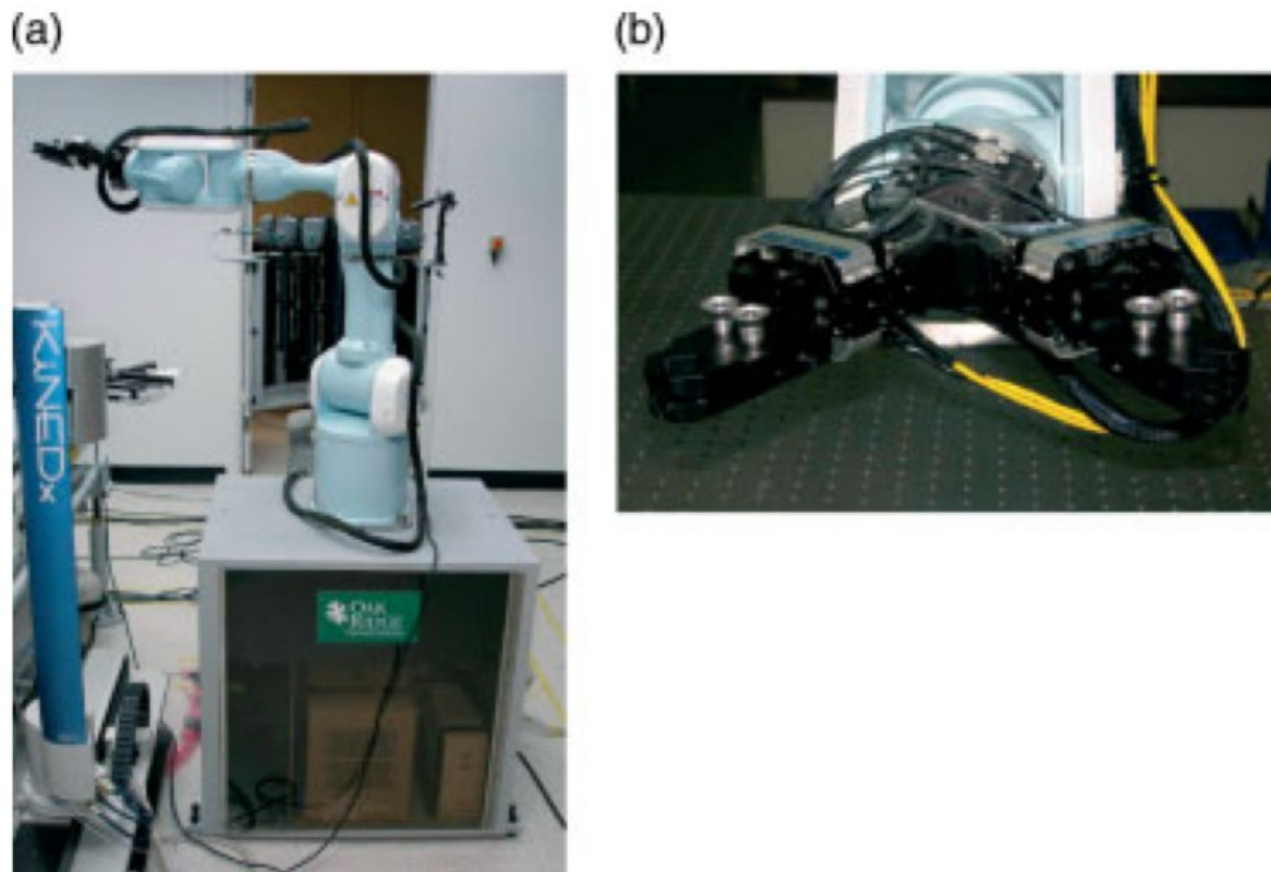


Table 1. Trauma pod subsystems

	Subsystem	Developer
SRS	Surgical Robot Subsystem	Intuitive Surgical, Inc.
AMS	Administrator and Monitoring Subsystem	SRI International
SNS	Scrub Nurse Subsystem	Oak Ridge National Laboratory
TAS	Tool Autoloader Subsystem	Oak Ridge National Laboratory
SDS	Supply Dispenser Subsystem	General Dynamics Robotics
TRS	Tool Rack Subsystem	University of Washington
SCS	Supervisory Controller Subsystem	University of Texas
PRS	Patient Registration Subsystem	Integrated Medical Systems
PIS	Patient Imaging Subsystem	GE Research
MVS	Machine Vision Subsystem	Robotic Surgical Tech, Inc.
RMS	Resource Monitoring Subsystem	University of Maryland
SIM	Simulator Subsystem	University of Texas
UIS	User Interface Subsystem	SRI International

Figure 4. Scrub nurse subsystem (SNS): (a) Mitsubishi PA10 robot on a pedestal base; (b) dual gripper end-effector

The Future of Telesurgery Robotic Surgery Test Demo 2024

- Robotic procedures controlled from Earth, performed on the International Space Station
- Dr. Ted Voloyiannis (Colorectal, UT Houston)
- 250 miles above earth – up to 8,000 miles by orbit



(<https://www.nasa.gov/podcasts/houston-we-have-a-podcast/robotic-surgery-in-space/>)

The Future of Telesurgery

The Raven



- RAVEN I, II, III
- 'Lightweight'
- US Military development
- Open-source platform fosters collaborative innovation
- Not FDA approved



Goals of Military Telesurgery

Preserve Life

- Surgeon safety
- Accessible to patients on a battlefield

Task Automation

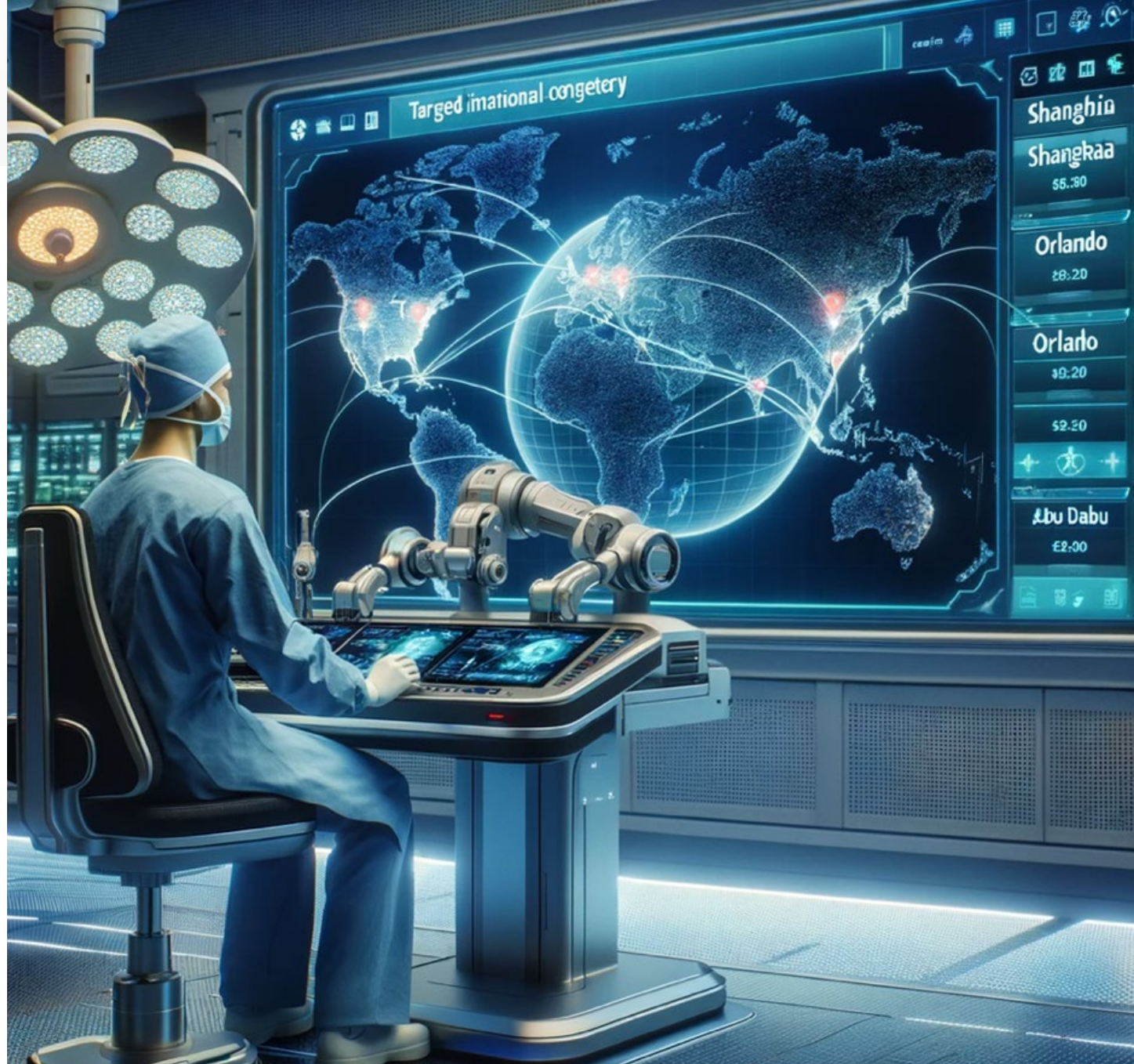
- Overcomes network limitations
- Semi-autonomous, delegation of low-level maneuvers

Cricothyroidotomy Automation

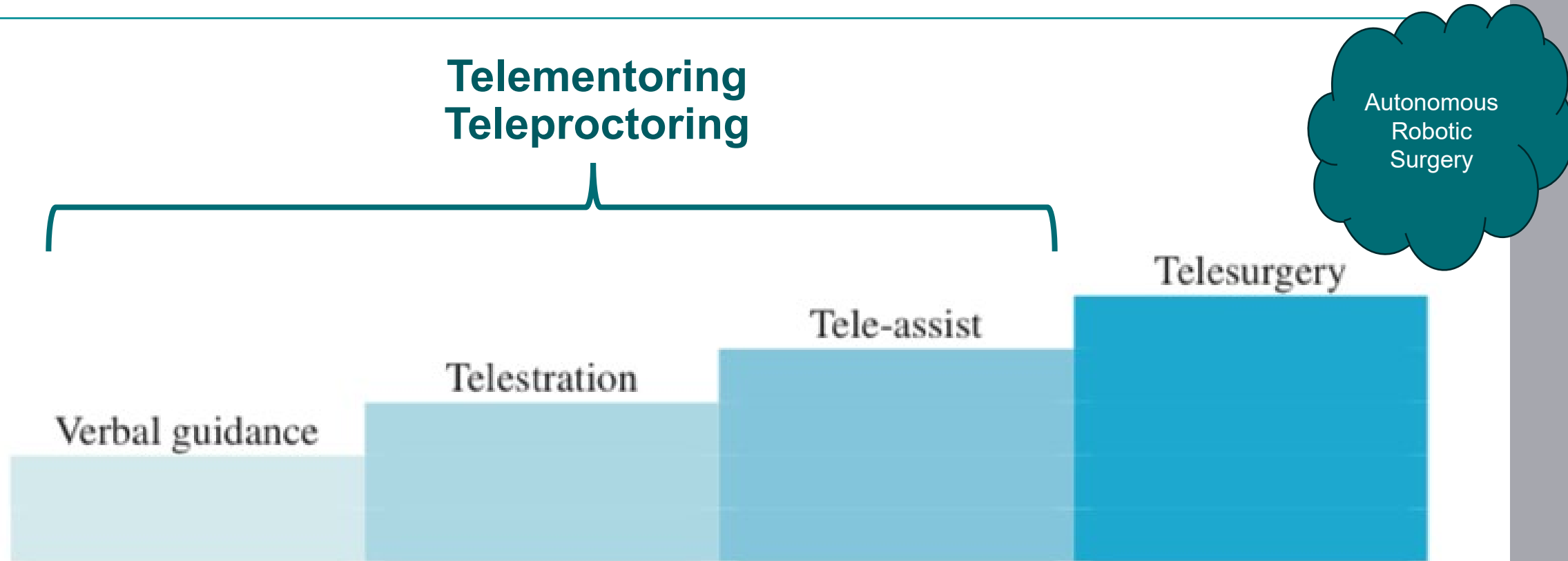
(Balakuntala et al., 2023)



Define Telesurgery?



Stepwise progression of remote surgeon engagement



SAGES, 2000



Society of American
Gastrointestinal and
Endoscopic Surgeons

1st guidelines to promote safe, high-quality telemedicine technology in surgical practice in the context of new telecommunication interactions

SAGES Framework for Post-Residency Surgical Education and Training, which previously defined key terminology: Proctor, Preceptor, Trainee, Competence, etc.

Defines appropriate training, attaining competence, and gaining privileges in advanced surgical procedures not learned during a formal residency program

SAGES, 2000

New terminology defined for the surgical practice of telemedicine

TELECONSULTANT

- Patient and/or patient data evaluation by a provider at a remote site

TELEMANAGEMENT

- Remote surgical evaluation and follow-up

TELEMENTORING

- Live interactive teaching of a procedure to a student by a remote expert
- Appropriate use on a live human ONLY with an qualified preceptor also ON-SITE

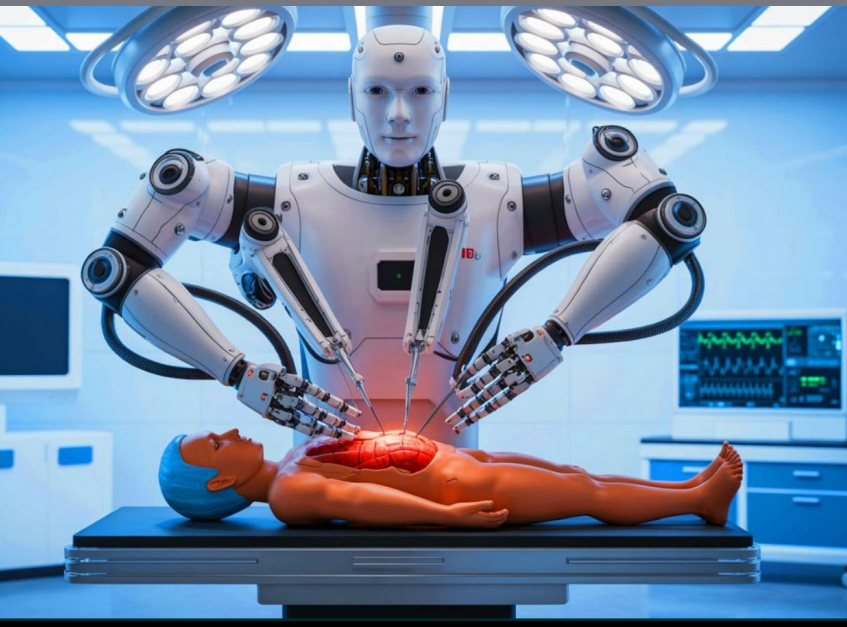
TELEMONITORING

- Live interactive monitoring to document surgeon competence in a specific technique

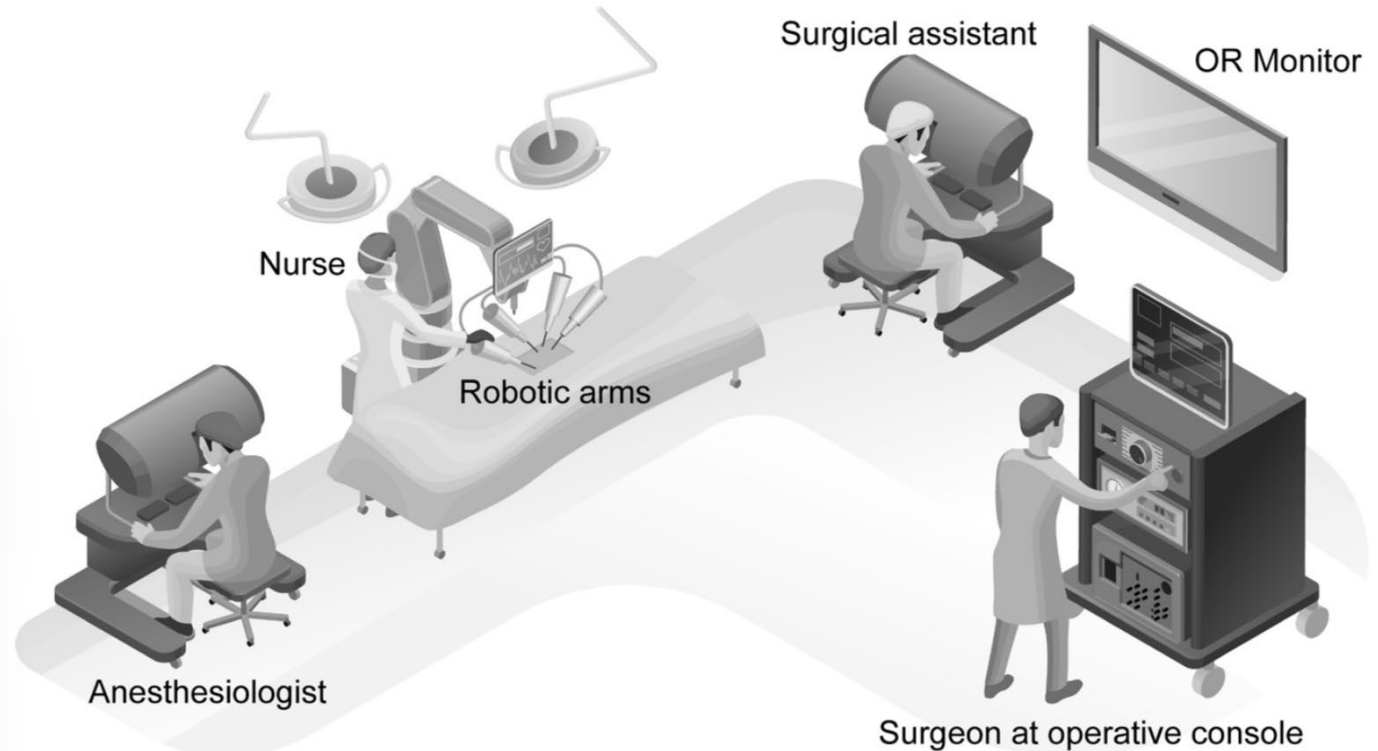
TELESURGERY

- Live remote patient surgery
- Appropriate with IRB APPROVAL & with a qualified surgeon ON-SITE

Autonomous Robotic Surgery



(https://www.sustainability-times.com/research/not-a-single-mistake-worlds-first-autonomous-surgical-robot-completes-complex-procedure-with-100-accuracy-and-zero-human-intervention/#google_vignette)



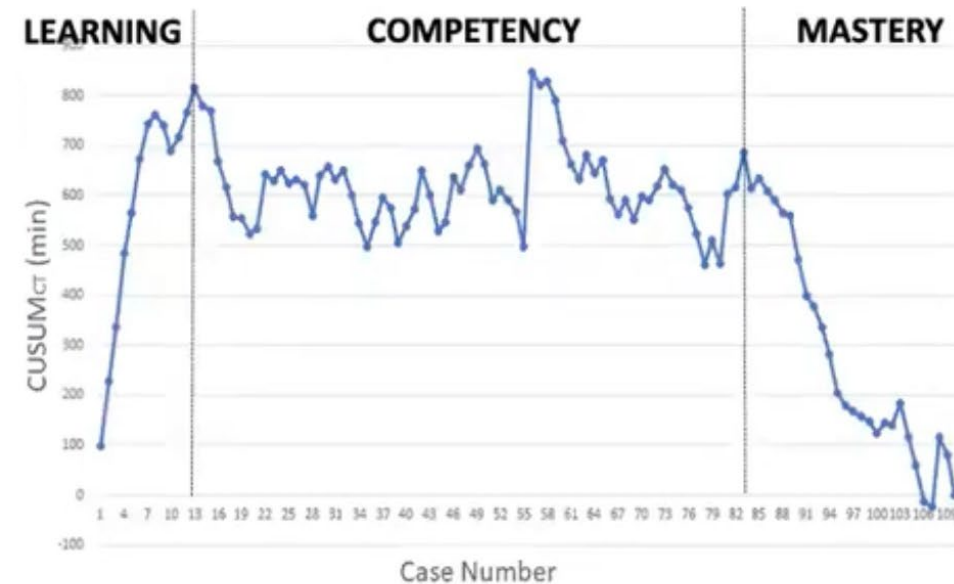
Telesurgery via robotic platform

(Nestor et al., 2019)

The Robotic Surgery Learning Curve is Steep

Learning curve in robotic colorectal surgery

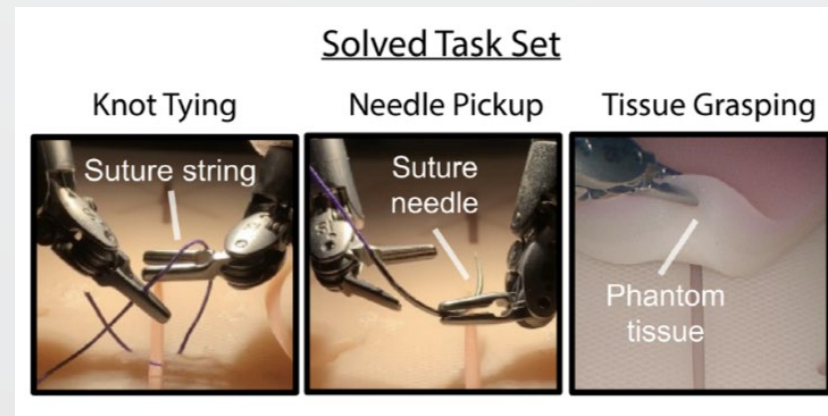
- *Three Phases were Identified:*
 - ▲ *Learning phase (case 1-13)*
 - ▲ *Competency phase (case 14-83)*
 - ▲ *Mastery phase (case 84-111)*



Task Autonomy

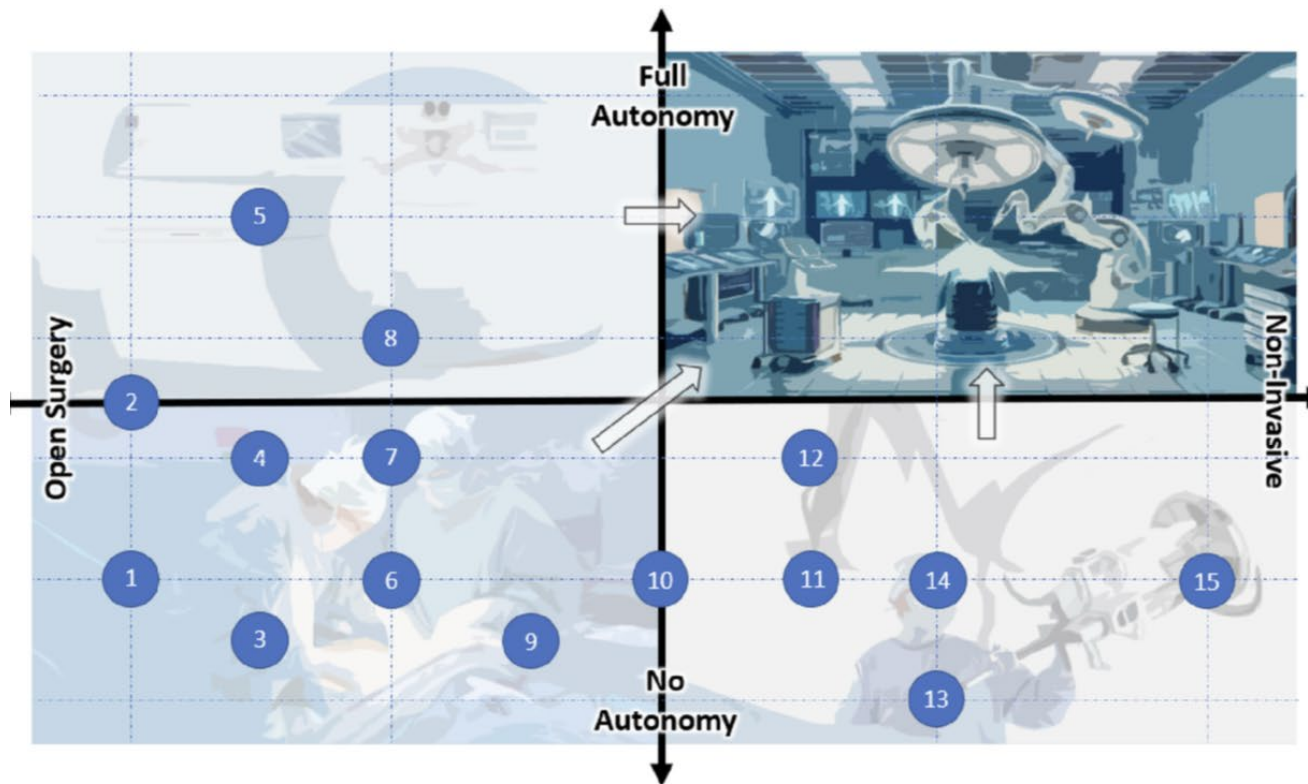
Autonomous
Robotic
Surgery

Telerobotic
Surgery

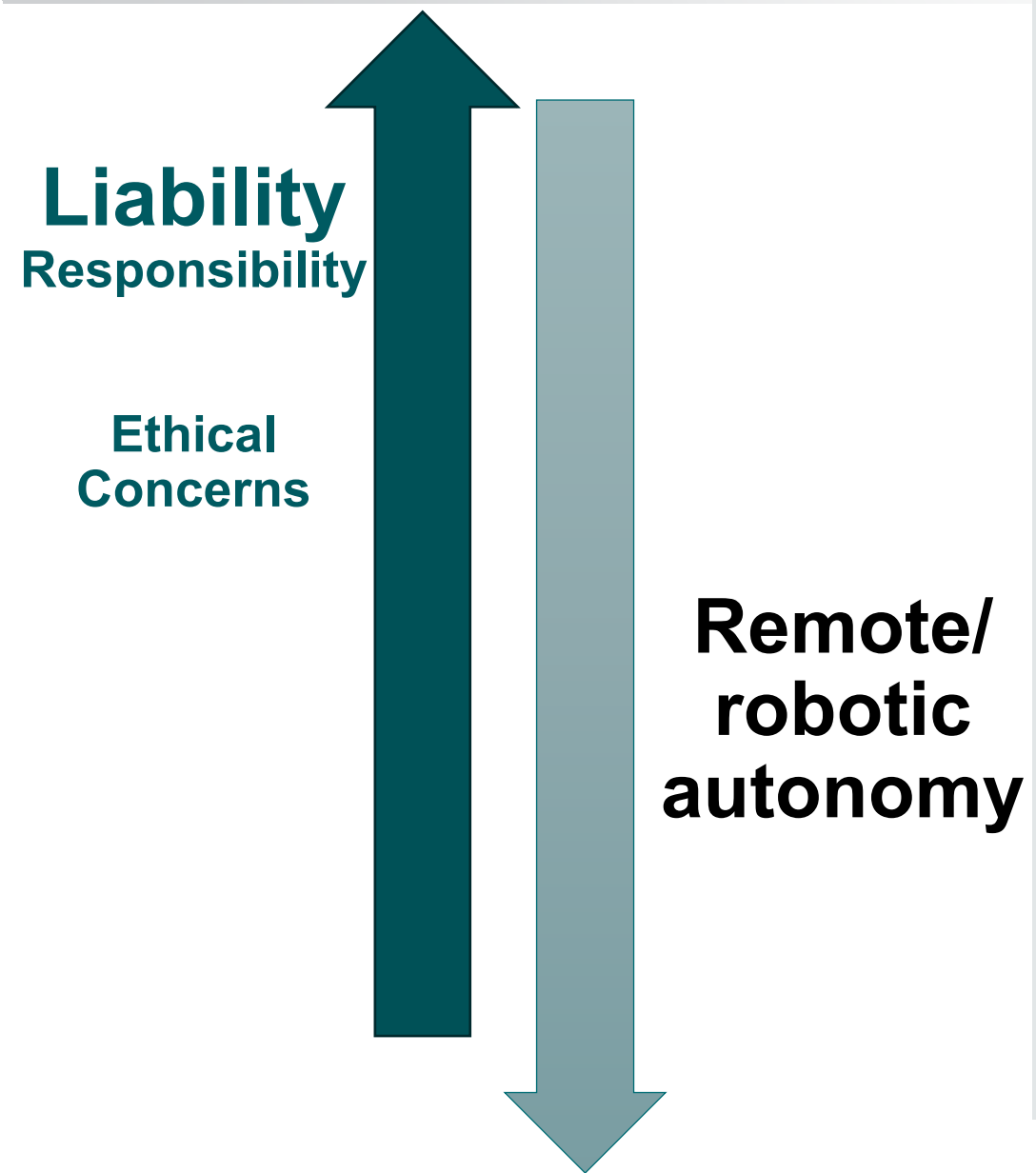


Task Autonomy Research is Active and Promising

The Trend of Autonomy and the Surgical Approach



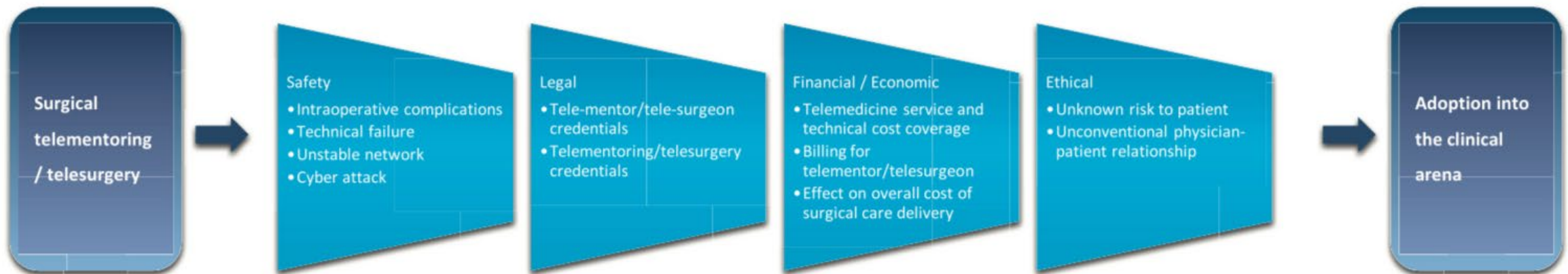
#	Robot
1	MUSA (34)
2	MAKO (43)
3	EndoAssist (36)
4	STAR (2016) (48)
5	VisuMax (53)
6	daVinci Xi (31)
7	DVRK (46, 47)
8	STAR (2022) (58)
9	Jaimy (38)
10	da Vinci SP (32)
11	MagnetoSuture (40)
12	Kuntz/Alterovitz (45)
13	NaviCam (29)
14	Ion (37)
15	Edison (39)



LoA	Description	DoA	Description
0	No autonomy	0	Full manual: There is no robotic interaction during the surgical procedure, and the human is responsible for all surgical planning, decision making, and execution.
1	Teleoperation	1	Teleoperation: The robot assists the human operator during surgery, but the human maintains continuous control of the robot. The robot may perform mechanical tasks to enhance the operator's performance, but it does not perform surgical tasks on the patient.
2	Task autonomy	2	Preprogrammed execution: The human generates and selects the surgical plan to be performed, and the robot executes that plan.
		3	Shared decision: Both the human and robot generate possible surgical plans, but the human has the sole decision to select the surgical plan to be executed. The human and robot share execution of the plan.
		4	Decision support: The robot generates surgical plans that the human may choose to augment. The robot then performs execution of the surgical plan.
3	Supervised autonomy	5	Blended decision: The human and robot share in the generation and selection of the surgical plan. However, the robot makes an initial selection that the human can choose to confirm or modify.
		6	Guided decision: The robot is responsible for generating all of the surgical plans, and the human selects the surgical plan. The robot executes the surgical plan without human assistance.
4	High-level autonomy	7	Autonomous decision: The robot generates, selects, and executes a surgical plan. The surgical plan can be augmented by the human before it is selected or executed.
		8	Operator monitoring: The robot generates, selects, and executes the surgical plan without human assistance. The human can only monitor the task execution and intervene in cases of emergency.
5	Full autonomy	9	Full autonomy: The robot executes all steps of a surgical procedure and does not require monitoring from a human.

(Schmidgall et al., 2025)

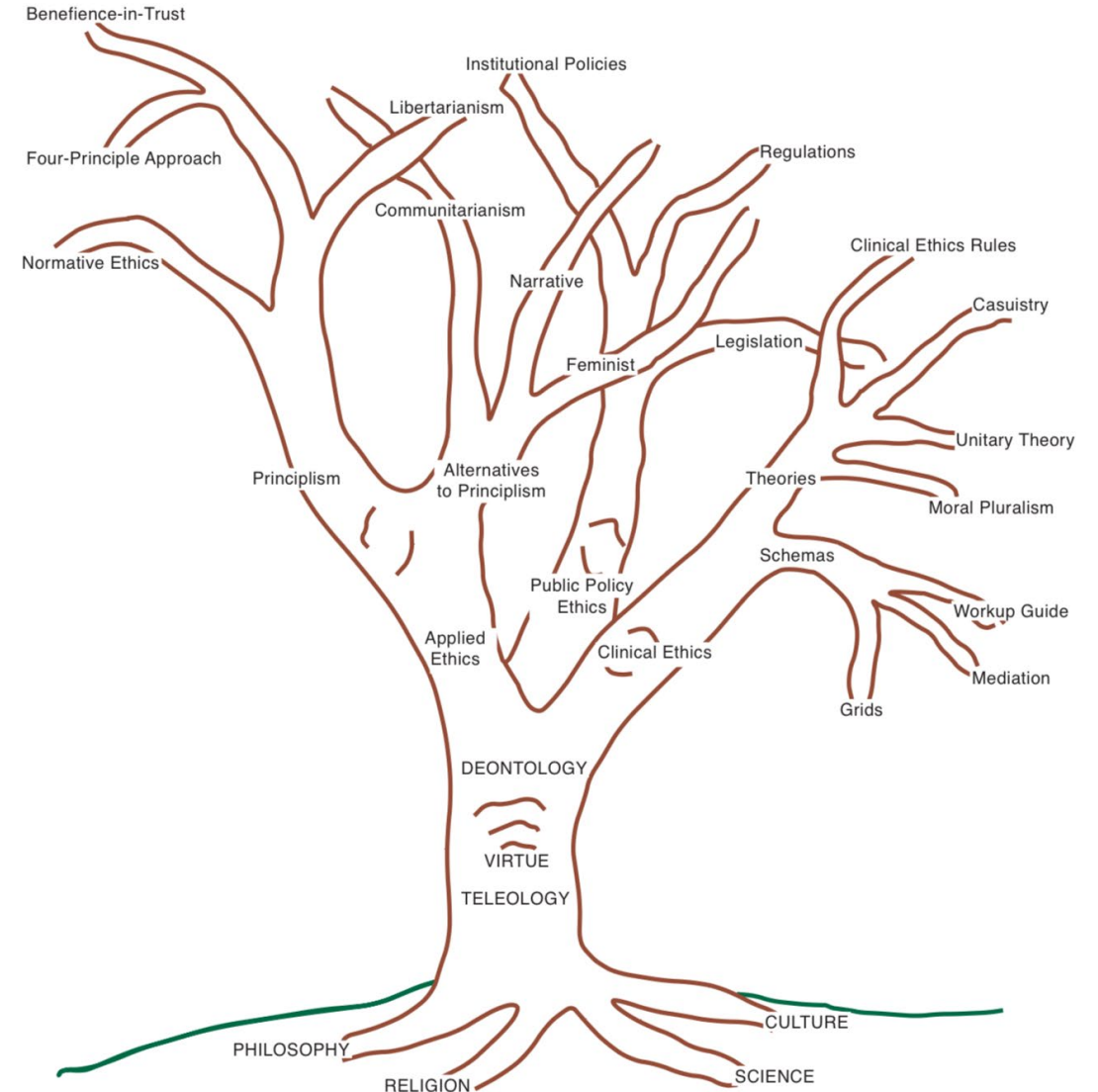
Challenges to Adoption of Telementoring & Telesurgery



Creating an Ethical Framework for Telesurgery

(Thomasma, 2003)

Military Medical Ethics, Volume 1



Telesurgery Ethical Framework

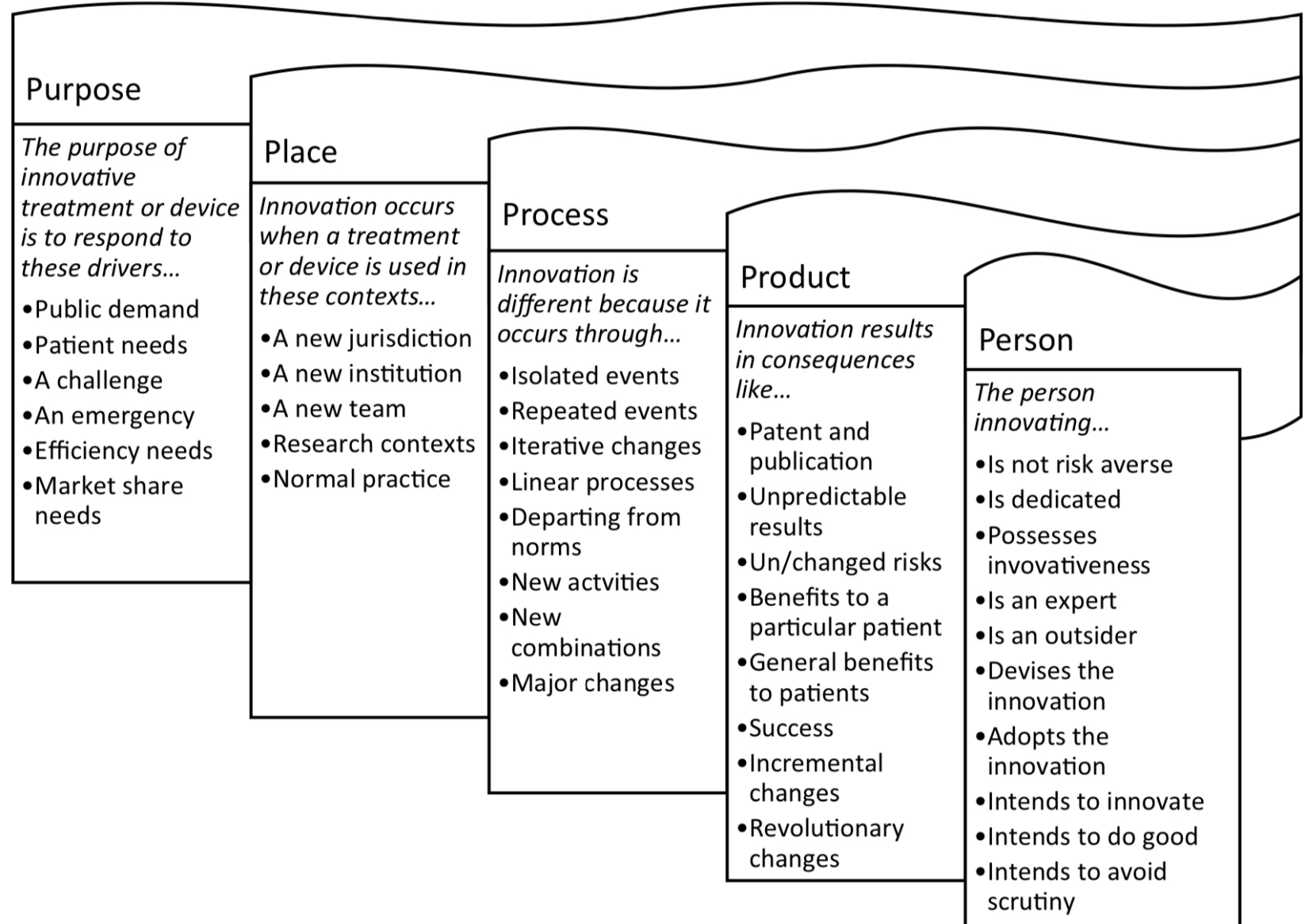
1. Moral Purpose
2. Safety
3. Informed Consent
4. Patient Vulnerability
5. Conflicts of Interest
6. Effective Oversight

“Robotics is currently one of the least equitable healthcare resources, but it has the potential to become the most equitable resource via telesurgery.”

Robotic Surgery Ethics

- Utilitarian – “Greatest good for the greatest number”
- Benefit of this minimally invasive technology generally outweighs its risks
- Surgical robot is an instrument surgeons use at their discretion if (a) credentialed, (b) the device is safe and (c) the practice is within the standard of care
- Surgeon pleasure, welfare, happiness
- Not concerned with distributive social justice

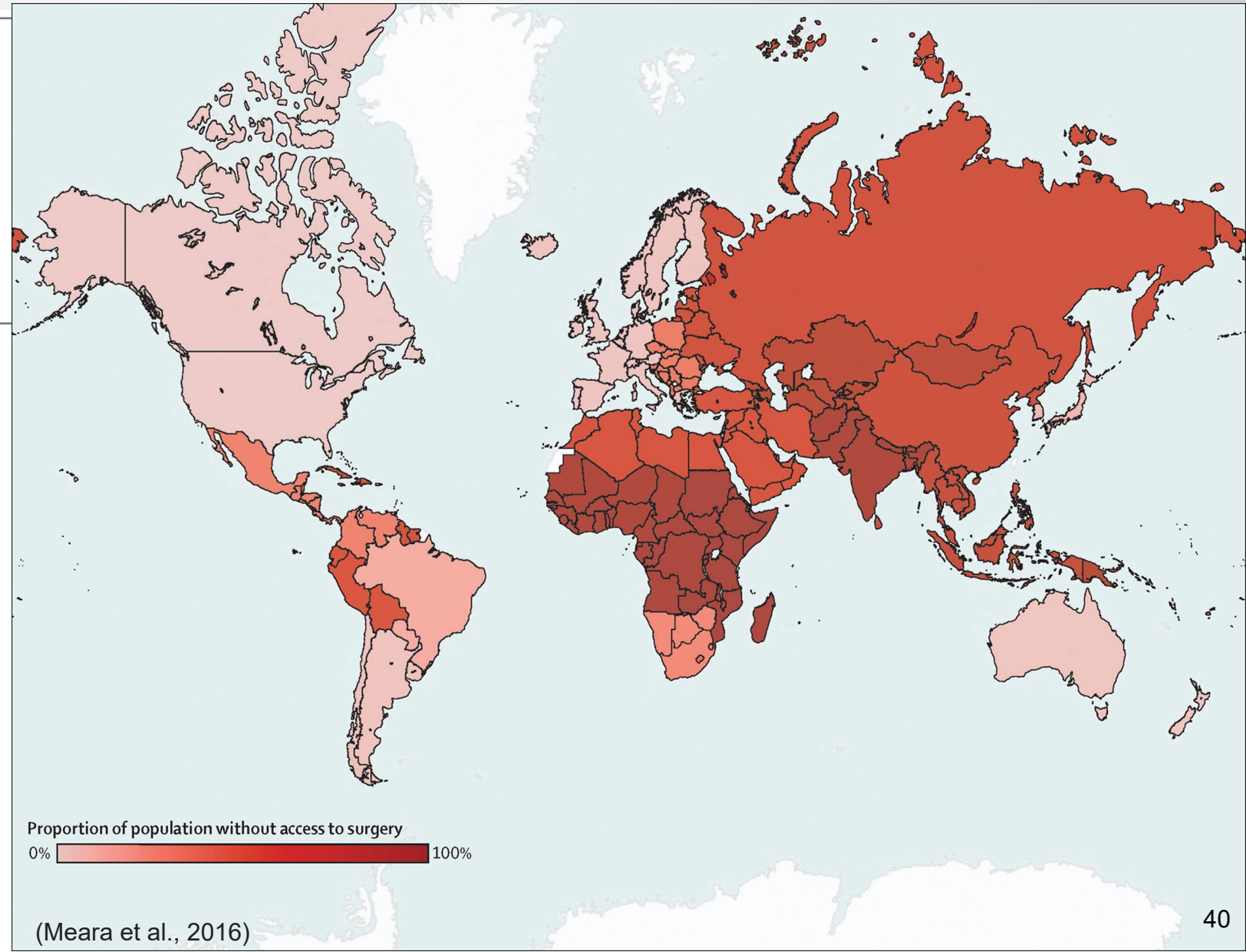
Conceptual Toolkit to Analyze Surgical Innovation



Moral Purpose of Civilian Autonomous Surgery & Telesurgery

Both dependent on robotic systems
*Both technologic solutions to a core
human problem:*

*Limited patient access to high-
quality surgical care*



Telesurgery Ethical Framework

1. Moral Purpose
2. Safety
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4. Patient Vulnerability
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6. Effective Oversight

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Surgical Education is the Most Important Clinical Endpoint of Telesurgery

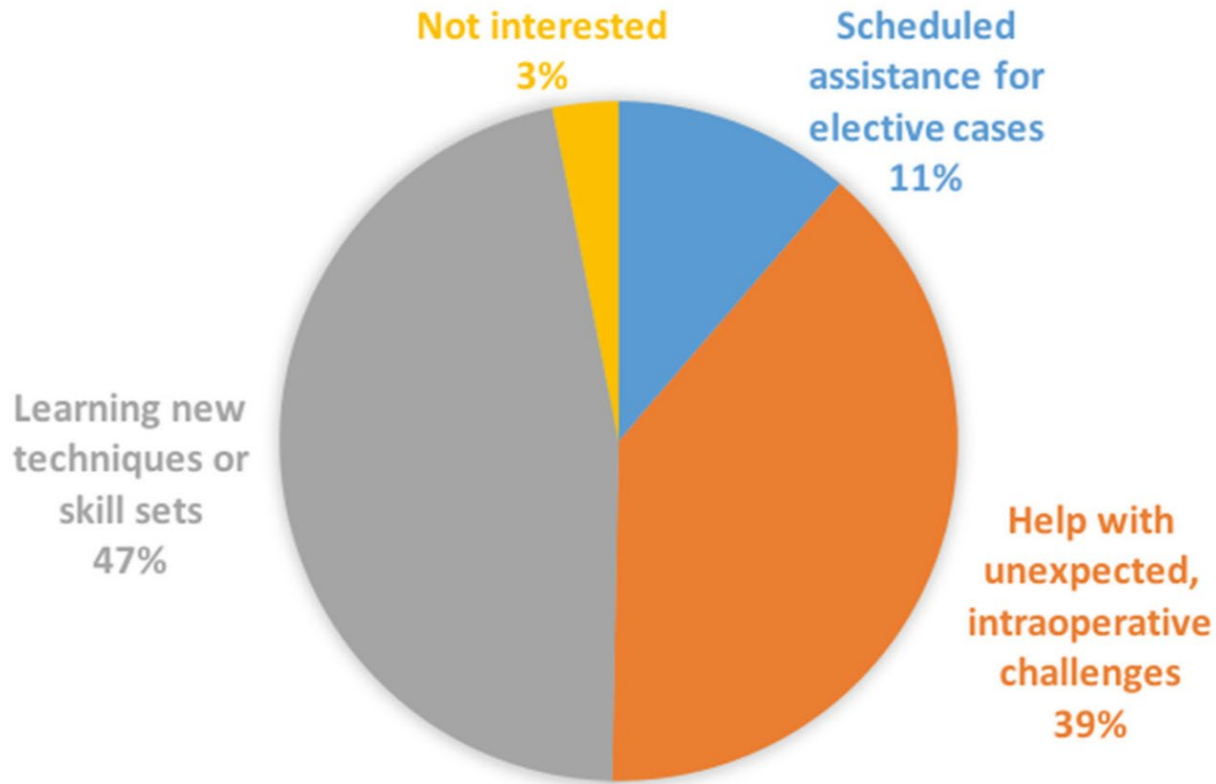
- Driver of long-term health equity
- Not intended to replace local surgeon-patient relationships
- Some role assistance in damage-control situations

Table 3 – Utilisation of telepresence in different settings

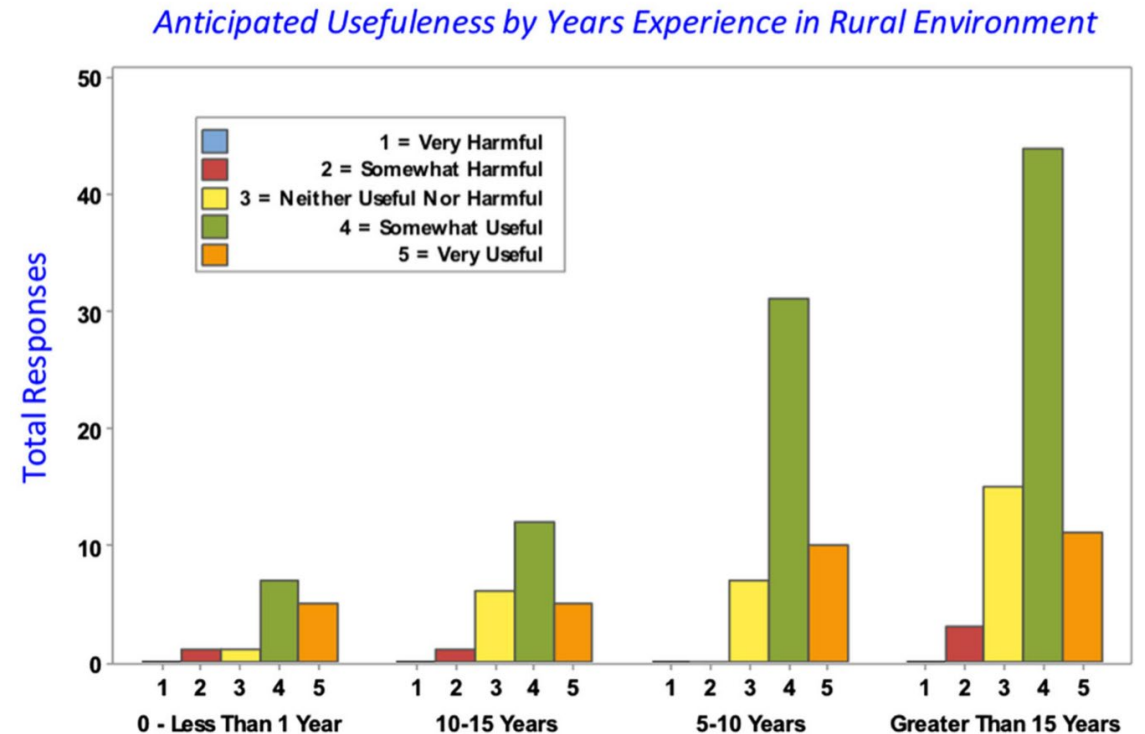
Level of agreement	Do you agree that telepresence has potential to be effective in various settings?
100%	● Elective telementorship ● Self-reflection and assessment, where the trainee reviews his/her own surgical performance
95%	● Elective teleproctorship ● Emergency (unplanned) telementorship, where the patient is stable, but the inexperienced surgeon is presented with an unfamiliar scenario
90%	● Immediate feedback delivered to the trainee, after the surgery has been completed, but not in real time ● Team training video performance analysis (not in real time)
85%	● Team training in real time

American College of Surgeons Survey

Rural Surgeon Perspectives on Telementoring



Safety benefits of telesurgery must be considered along with the risks



Ethical Telesurgery – Implicit Elements

Telepresence set-up, planning and safety checklist

Before installing the service ▶▶▶▶▶▶▶▶ Before patients involved ▶▶▶▶▶▶▶▶▶▶ Before patient leaves operating room

Set-up	Delivery	Audit
☐ Local IT contact confirmed • Sufficient bandwidth (>5MbS) • Good audio-visual links • Secure connection • Stable connection available • Enable firewall traversal, appropriate ports ☐ Equipment required • Laptop • Video converter • External camera(s) • Tele-stration/image overlay/ghost instruments ☐ Telepresence software licence	☐ OR team trained in telepresence ☐ Communication terminology ☐ TTT-certified telementor identified ☐ Telepresence service agreement signed between trainer and trainee	☐ Surgeon records in the notes • Name of the procedure • Length of time of the operation • Whether there were any telepresence problems to be addressed
☐ Test connectivity • Ability to view video streams on laptop • Video resolution for use case – between 720 p at 20 fps to 1080 p at 30 fps • Drops ≤1 drop per hour • RTD <250 ms between centres ☐ Hospital organisation confirms • Protocols for telepresence services • Legal implications/GDPR/HIPAA compliance	☐ Teleconference with trainer ☐ Review: procedural phases, visual cues, tasks and errors ☐ Review: patient Hx, imaging, MDT ☐ Agree op plan and telepresence schedule for the planned operation	☐ Connectivity • Good image quality • Good audio • Drops ≤1 drop per hour
	☐ Informed consent form for patients ☐ Informed consent form for OR team	☐ Telepresence functionality • Telepresence software functioned
		☐ Trainer followed agreed protocols • Trainer and trainee discussed case before the operation • Available for WHO checklist “time out” • Present for port placement • Available for agreed op plan timings
		☐ Trainee followed agreed protocols • Trainee followed agreed operative plan • Satisfactorily followed telementorship guidance during the operation

This checklist is not intended to be comprehensive; additions and modifications to fit local practice are to be encouraged

Protecting Vulnerable Patients in Telesurgery (1 of 4)

Ethical Concerns

- A surgical **skill differential** exists between local and remote surgeons in telesurgery. This skill differential may be wide or narrow.
- **Disclosure** of risks, benefits and alternatives may have qualitative differences when discussed by surgeons with different experience levels.
- Prioritize **patient autonomy**
- Limited opportunity for **persuasion**

Consent must provide patients with a fair understanding of this skill differential



Autonomy

Respecting an individual's freedom to make their own decisions



Beneficence

Acting in the best interest of the individual; providing benefit



Non-maleficence

Avoiding and doing no harm to the individual



Justice

Treating all individuals with fairness, equality, and impartiality

Protecting Vulnerable Patients in Telesurgery (2 of 4)

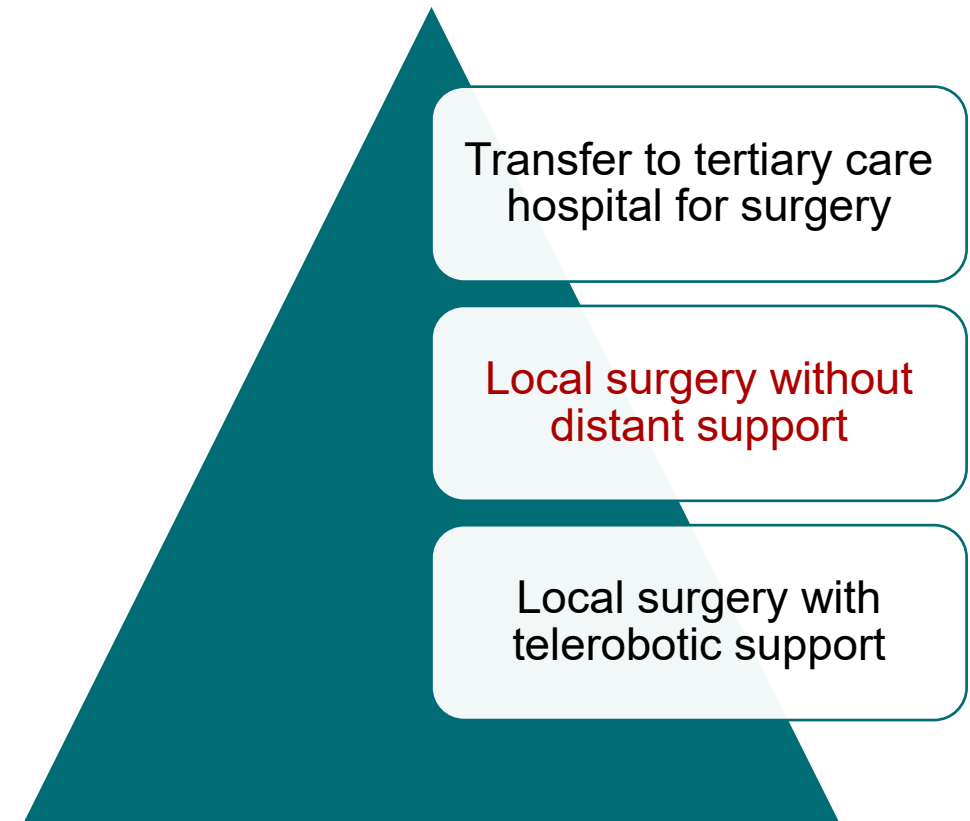
Consent must provide patients with a fair understanding of this skill differential

Possible Solutions:

1. Two-stage informed consent
2. Opportunity for patient teleconsultation with remote surgeon
3. Clear outline of surgical alternatives

(Anvari, 2007)
(Miller et al., 2014)

Canadian Telepresence Paradigm



Protecting Vulnerable Patients in Telesurgery (3 of 4)

Ethical Concerns

The integrity of the patient-surgeon relationship must be preserved

Possible Solutions: None may be needed!

In the Canadian study, no patients chose to pursue laparoscopic surgery at a tertiary referral center over remaining with their local surgeon when they had the benefit of telerobotic expertise.

(<https://neuroethicscanada.wordpress.com/tag/policy/>)



(Photo courtesy of Dr. Frenkel)

Protecting Vulnerable Patients in Telesurgery (4 of 4)

Accountability: What is the remote surgeon's role in perioperative care

Possible Solution:

1. Shared responsibility disclosure
2. International standards that transcend cultural heterogeneity

Japanese Guidelines for Apportionment of Telerobotic Responsibilities



Framework for Ethical Elective Telesurgical Informed Consent

Implicit Elements

- ✓ Safe
- ✓ Efficacious
- ✓ Surgeon credentialed
- ✓ No disqualifying conflicts of interest
- ✓ Procedural elements within standard of care

Situational Disclosure Elements

- 1) Tangible therapeutic benefit⁴
- 2) Procedure elements outside standard of care
- 3) Added risks associated with telesurgery, e.g. surgeon immediately available but not at bedside
- 4) Capabilities of local team
- 5) Contingency plan if telesurgery failure
- 6) Likelihood of telesurgery case completion
- 7) Reasonable alternatives to telesurgery

Surgeon-Specific Disclosure Elements

- 1) Relevant skills
 - 2) Telesurgical experience
 - 3) Limitations
- ❖ Conflicts of interest (COI): Financial, reputational, etc.

Local or Remote

Shared Responsibility Disclosure

- ✓ Default (Local surgeon)
- Divided (Clear documentation)³
- ❖ Obligatory remote surgeon responsibilities



Catherine H Frenkel MD FACS

Conflict of Interest

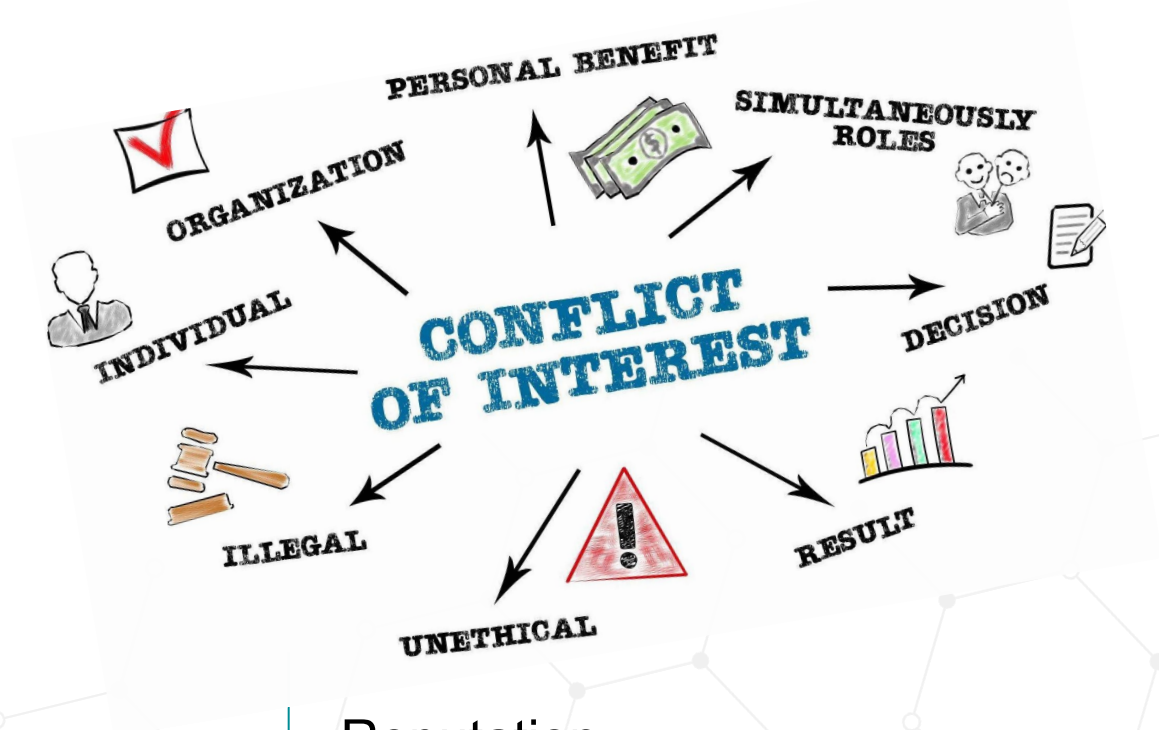
Financial Conflict of Interest (COI)

Payment
Travel
Grants

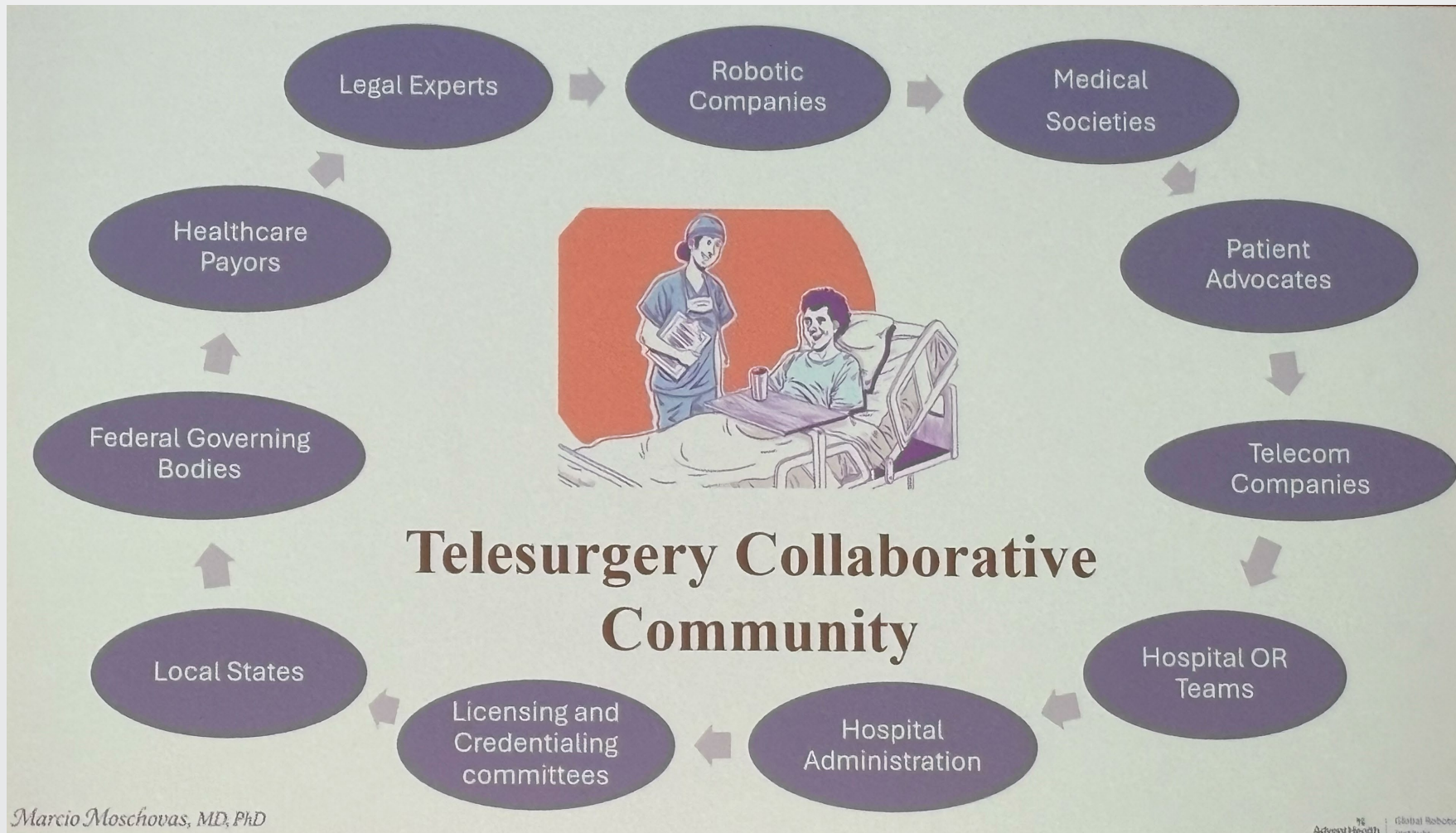
Non-financial COI

Recognition
Awards

Reputation
Excitement



Effective Oversight



Key Takeaways

- Elective telerobotic surgery in the civilian sector is a radical force for surgical healthcare equity, this is its “moral purpose.”
- The primary clinical effector of this moral purpose through telesurgery is surgical education
- The military is likely to drive robotic surgical task automation/semi-autonomy, and the ethical consequences of this force are still unknown
- Know the six key elements of telesurgery’s ethical framework

References (1 of 5)

Anvari M. (2007). Remote telepresence surgery: the Canadian experience. *Surgical endoscopy*, 21(4), 537–541.

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