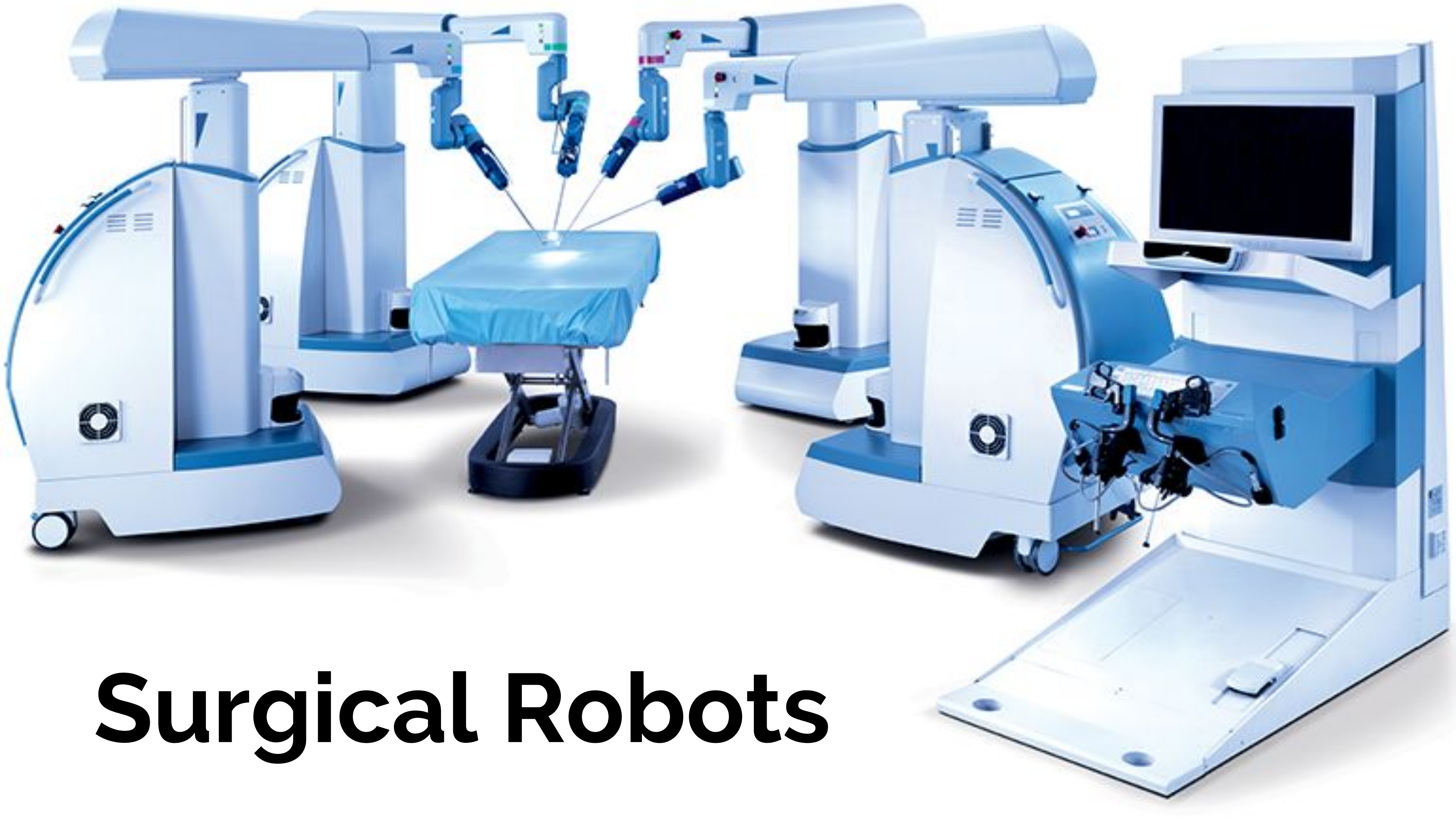


Surgical Robots

To Be Discussed

Introduction

Introduction

- Surgical robots are robots, that are used to improve the outcome of surgery.
- A Robotic surgery, or robot-assisted surgery, allows doctors to perform many types of complex procedures with more precision, flexibility and control than is possible with conventional techniques

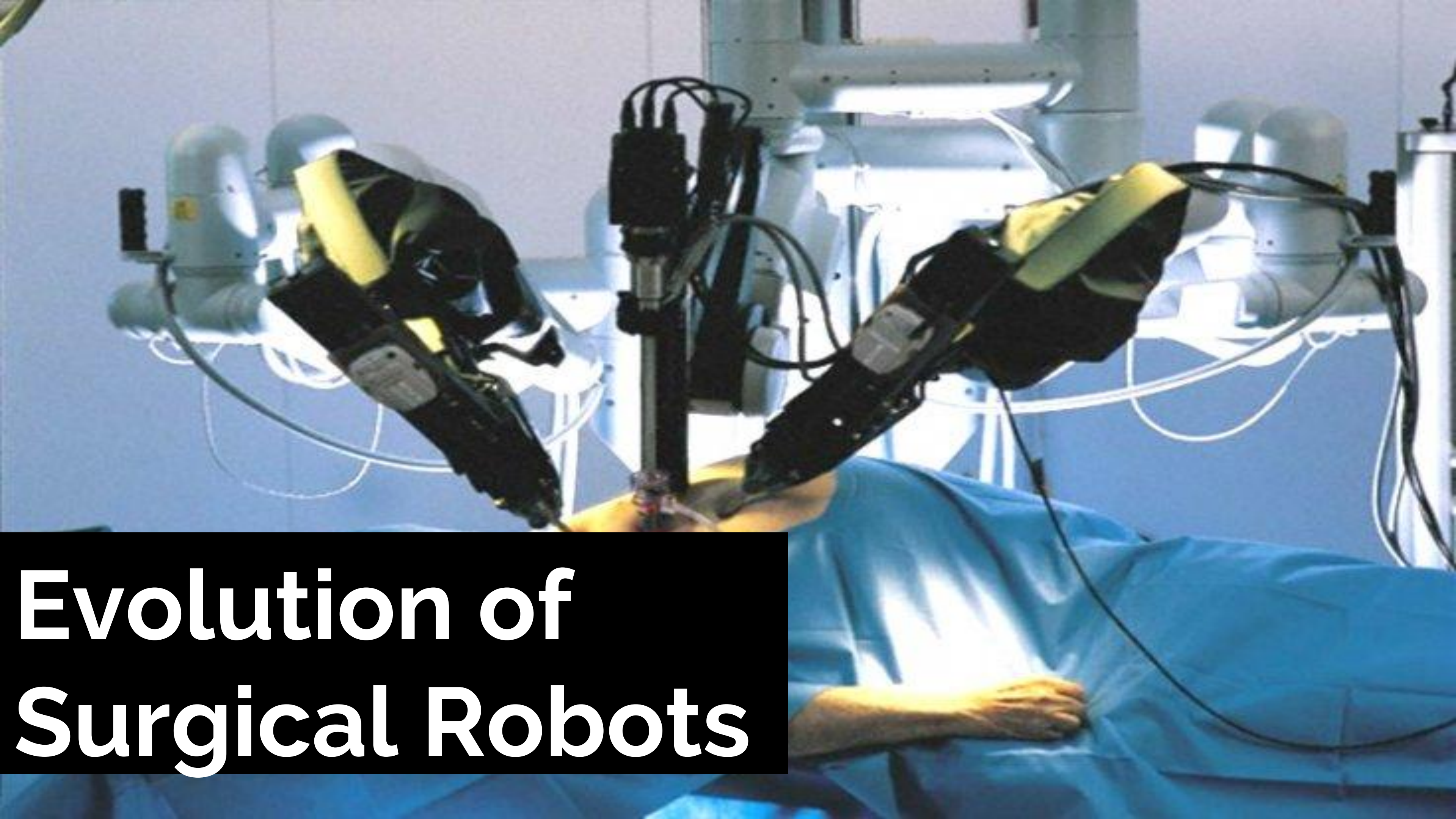
The areas of usage of these :

1. Cardio Thoracic
2. Orthopedic Surgery
3. Neurosurgery
4. General Surgery
5. Urology
6. Ophthalmology

And the robots are mainly used for

1. MIS
2. Reproducibility
3. Mechanical Stiffness
4. Guideways

Evolution of Surgical Robots



Evolution

1

PAST, THE FIRST COHORT:

- Surgical robotic systems based on an industrial active robot or with an autonomous approach make up a first cohort of surgical robots.
- Examples:
  PUMA 200, Probot, CASPAR

2

PRESENT, THE SECOND COHORT:

- Robotic devices that are able to move autonomously but are not programmed to do so. Instead, they are programmed to reproduce the surgeon's motions in a master/slave configuration
- Examples:
  DaVinci, Acrobot Sculptor, Sensei Robotic Catheter System

3

POSSIBLE FUTURE, THE THIRD COHORT:

- The characteristics of a third cohort of surgical robots are still to be defined but is anticipated these intelligent new tools will be smaller, special purpose, lower cost, possibly disposable robots, providing alternatives to the current large, versatile and expensive systems

Advantages

1. Incisions made are smaller, so less recovery time, less blood loss.

2. Gives better view of the surgical site, easier access to hard to reach places and tighter control over smaller and more precise surgical instruments attached to robot arms.

3. The robot’s computer software filters out naturally occurring human tremors that increase the risk factor in very intricate surgeries.

4. Surgeons perform robotic assisted surgery while sitting down, so they can work longer hours tirelessly, which lowers the risk factor caused by fatigue and hence more surgeries can be carried out in the same time as compared to conventional surgeries.

Present Limitations

1. Higher cost of robot as well as the disposable supplies. High annual maintenance cost.

2. The learning curve for surgeons who adopt use of the system is too long.

3. Also, the Setup time is very high for some of the robots

4. Other issues - The da Vinci system uses proprietary software which cannot be modified by physicians, thereby limiting the freedom to modify the operation system.

5. Injuries caused by stray electrical currents released from inappropriate parts of the surgical tips

6. If there’s some complication because human body in completely unpredictable, the intervention by a human surgeon is very important and the time of reaction is also a very crucial factor.

IN VIVO SURGICAL ROBOTS

- Miniature robots that can be completely inserted inside the body.
- Minimally Invasive Surgery (MIS) is replacing open procedures, thereby providing patients with significant benefits including reduced trauma and costs along with faster recovery times, improved cosmetics, and decreased mortality rates

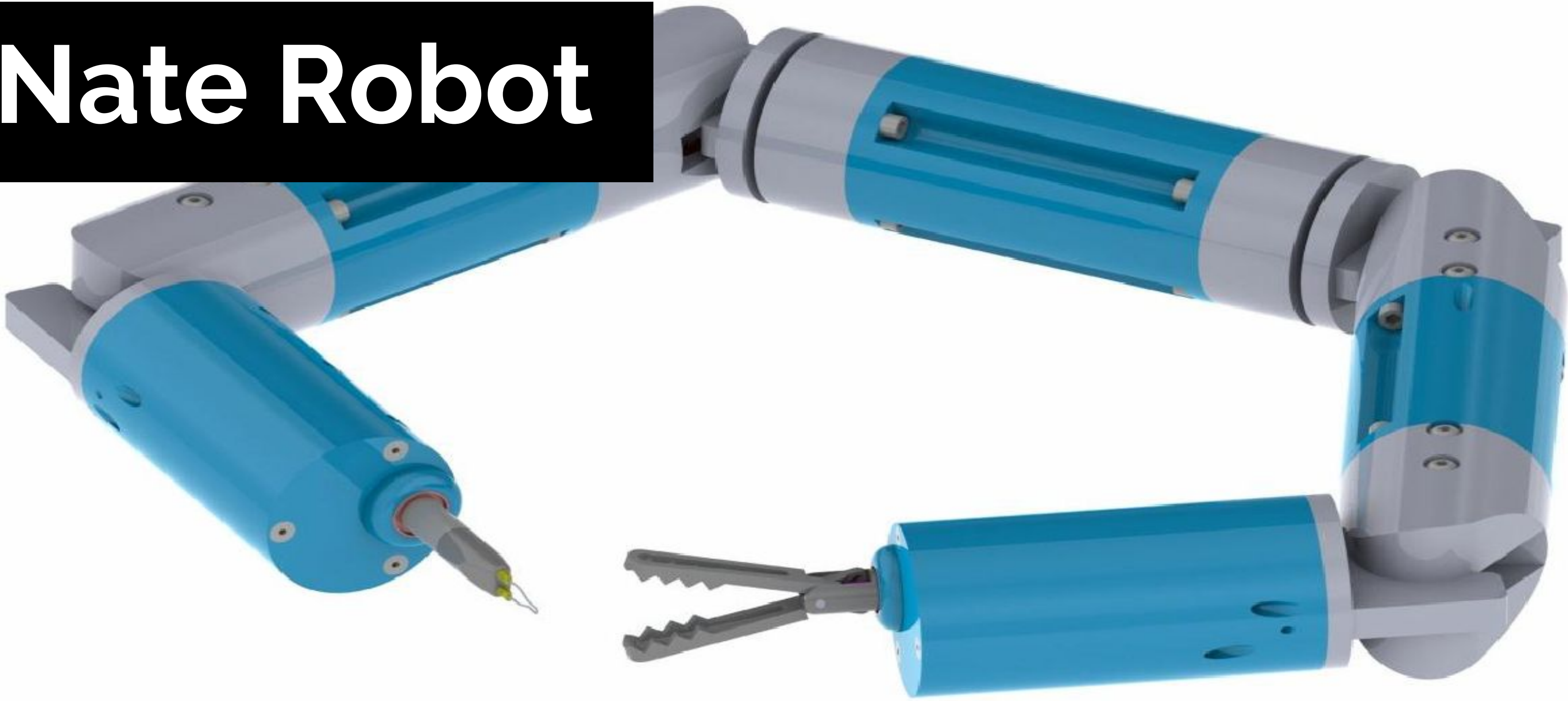
➢ Natural Orifice Translumenal Endoscopic Surgery (NOTES) is the ultimate MIS goal. NOTES completely eliminates all external incisions by accessing the peritoneal cavity through a natural orifice, leaving no external scars and further reducing the risk of infection to the patient. NOTES offers additional advantages to MIS, but is limited by the size of the natural orifice and the requirement that instruments be flexible enough to traverse the natural lumen.

➢ Laparoendoscopic Single-Site Surgery (LESS) has been viewed as an important step, and possibly a bridge to NOTES. LESS surgery is performed by utilizing multiple articulating, bent, or flexible laparoscopic tools inserted through a single specialized port in the abdominal wall

Design Concepts

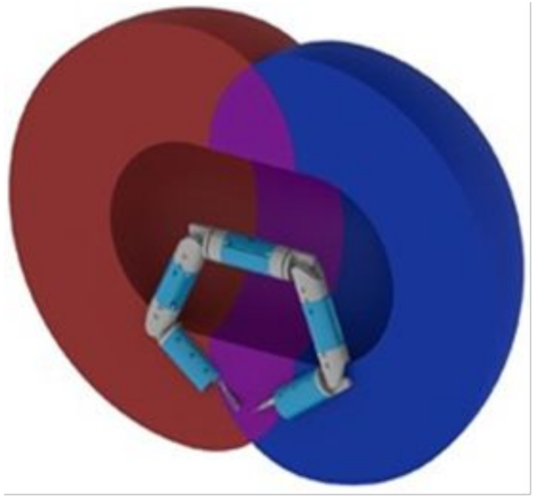
- With single incision surgery, there are many constraints with instrument placement, visualization, and tissue manipulation.
- Dexterous in vivo robots aim to replace standard laparoscopic tools in general MIS.
- The basic robot design consists of two arms that can be separated and inserted individually through a single small incision.
- After the robot is completely inserted within the abdominal cavity, both arms are positioned and mated together using a central assembly rod.
- This assembly rod protrudes out through the incision and allows the robot to be supported and grossly positioned, if needed.

Nate Robot



Design

- Both arms could be straightened so they were aligned with the body segment. This allowed the robot to be inserted through an overtube in the esophagus, where it could successfully navigate the upper gastrointestinal tract to enter the abdominal cavity.
- For better LESS capabilities a support rod attachment was added to the main body.
- Each arm includes a 2-DOF shoulder joint that provided yaw and pitch, as well as an elbow joint that provided yaw. This robot also had interchangeable end effectors. End effectors could now be quickly bolted on and off to create new combinations for different surgical tasks. Typical end effectors for this prototype included graspers and DC eye cautery. Each end effector has a rotational degree of freedom, along with open/close actuation if necessary.



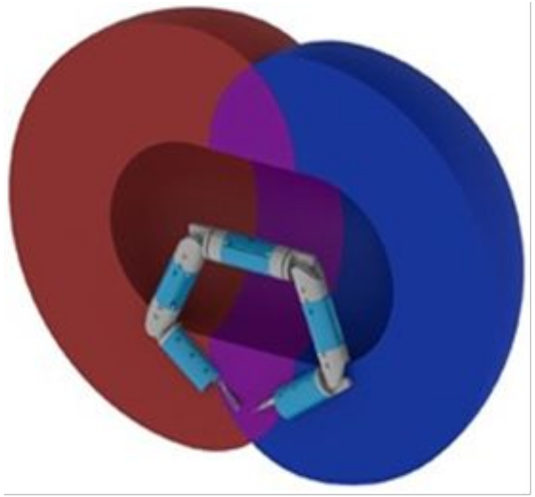
Design

- The Denavit-Hartenberg parameters defining the kinematics of this robot are shown in Table 6.1. These parameters can be used to describe the robotic arms. Parameters L1 and L2 are constants defining the link lengths. L1(upper arm) = 88.4 mm. L2 (the forearm) = 123 mm. Shoulder pitch (θ1), shoulder yaw (θ2), elbow yaw (θ3), and end effector rotation (θ4) define rotations of the robot with respect to intermediate frames of reference.

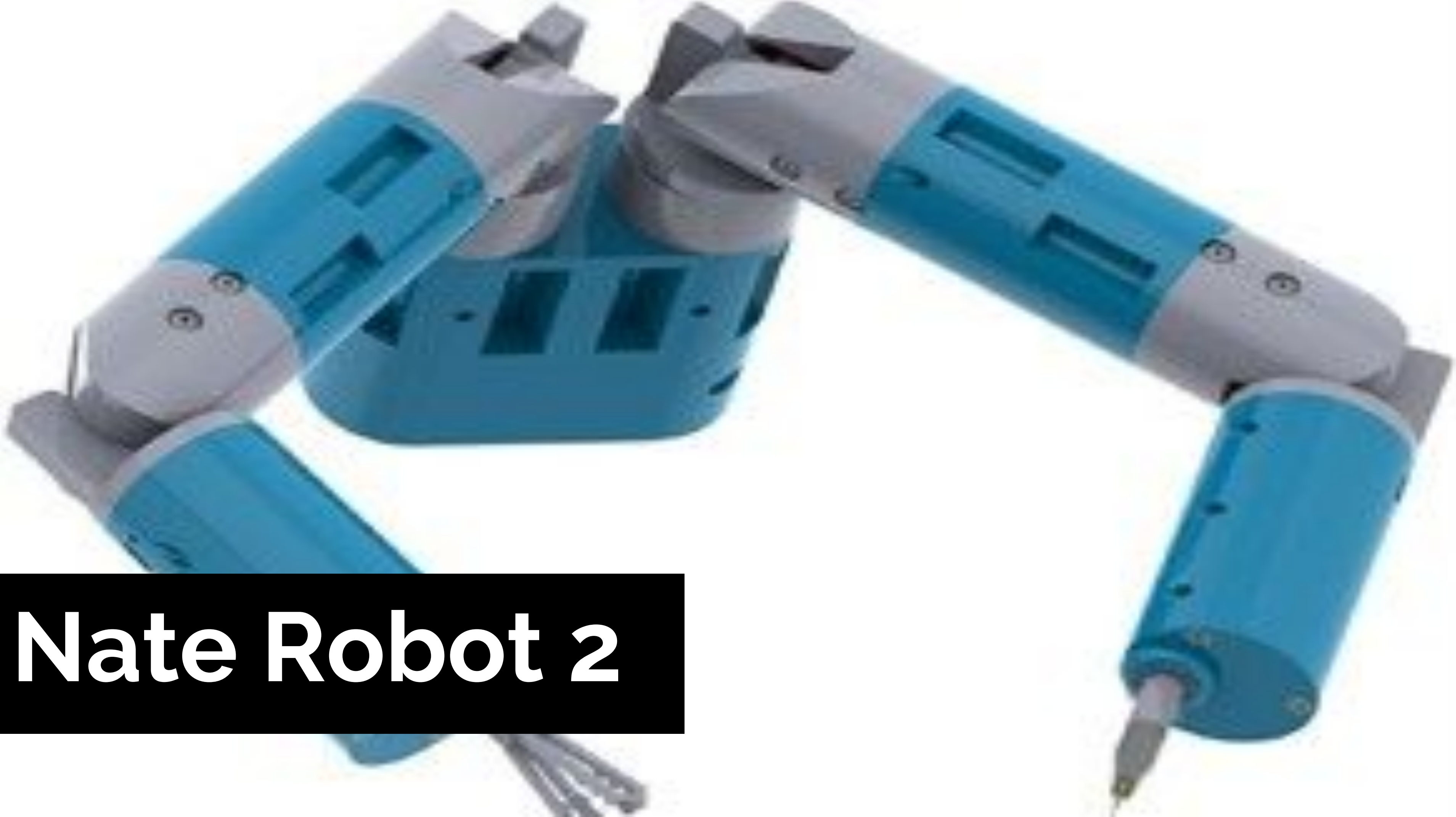
i	α_{i-1}	a_{i-1}	d_i	θ_i	θ Limits
1	0	0	0	θ_1	-45° to +135°
2	90°	0	0	θ_2	0° to +90°
3	-90°	L_1	0	θ_3	0° to +90°
4	-90°	0	L_2	θ_4	-180° to +180°

ISSUES

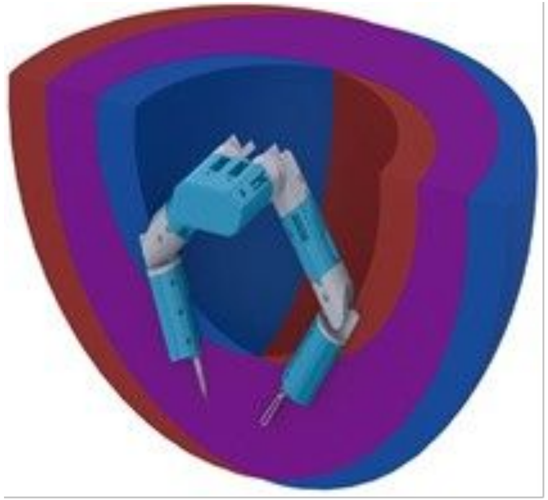
- The red, blue, and purple volumes represent the left arm, right arm, and intersecting workspaces, respectively.
- During benchtop tests and in vivo surgical tests, surgeons commented on the **lack of the robot's** ability to cooperatively use the arms. The purple volume, or intersecting workspace, is a very small portion of the overall workspace. Because of this, the robot had to be continually repositioned to perform simple surgical tasks.
- The reason for this lack of intersecting workspace is due to the robot's poor joint limits with respect to its kinematics. The robot's shoulder joints were too far apart to create an efficient intersecting workspace. This led to further development on the kinematics of this robotic prototype.



Nate Robot 2



- This robot was very similar to NB 1 in almost all design aspects except for the kinematic change. The modified Denavit-Hartenberg parameters defining NB 2 are shown in Table 6.2.
- Again, parameters L1 and L2 are constants defining the link lengths and θ1, θ2, θ3, and θ4 define rotations of the robot joints. The distance between the shoulders was reduced from 108.4 mm in NB1 to 36.7 mm in NB2.



i	α_{i-1}	a_{i-1}	d_i	θ_i	θ Limits
1	0	0	0	θ_1	0° to +90°
2	90°	0	0	θ_2	0° to +90°
3	-180°	L_1	0	θ_3	0° to +90°
4	-90°	0	L_2	θ_4	-180° to +180°

- One beneficial side effect of splitting the two arms was the ability to now individually insert each arm for LESS surgery.
- Due to the limited space within the abdominal cavity, the task of inserting a complete robot proved to be quite difficult.
- Separating the arm modules simplified the insertion procedure.
- Once the arms were individually inserted, they could be brought back together and mated to the support rod.

END EFFECTOR ATTACHMENTS: MONOPOLAR CAUTERY

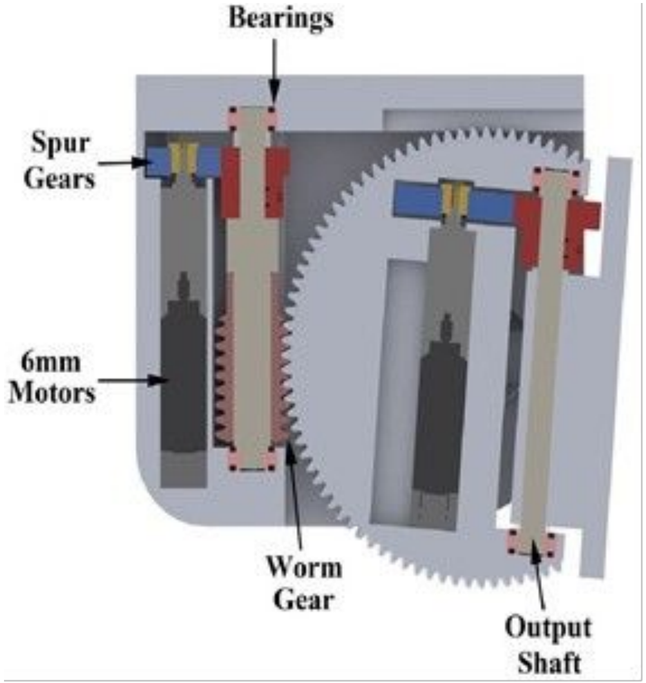
- The DC eye cautery is a wire resistor that heats up when current is applied. This heated wire is then use to cut through tissue.
- While simple to implement, this method is very inefficient and can break downuite easily.
- During monopolar cauterizing, a grounding pad is attached to the patient and AC current is applied to the cautery tip. When the cautery tip touches the patient a circuit is completed and the electricity flow heats up the tissue at the point of contact and thus can be used to cut and coagulate. Implementing the monopolar cautery on NB2 was simple. A hook connected to an electrosurgical generator was added as an end effector to the robot.
- Initially, problems occurred because the generator created a very electrically noisy environment around the robot. This caused problems with the accuracy of the motor encoder readings. To compensate, double-shielded wire and filter boards were used to keep the signal clean.

NEEDLE GRASPER:

- ➢ Another design was needle drivers to be used with the interchangeable end effectors.
- ➢ Suturing of tissue is a common surgical task. Tissue manipulation graspers are typically serrated with teeth to grasp tissue more effectively.
- ➢ These teeth are not ideally suited to grasp a needle used for suturing.
- ➢ Small modifications were made so that the graspers resembled traditional needle drivers.
- ➢ These changes included shortening the graspers and replacing the teeth with a knurled face.

ON-BOARD CAMERA:

- An onboard camera prevents the need for an external laparoscope to be introduced for visualization.
- This camera was designed as a third module that could be mated between the two arm modules.
- The camera has 2-DOF.
- The actuated panning and tilting of the camera allows the entire robotic workspace to be visualized. A monoscopic or stereoscopic imager set-up allows for 2-D or 3-D viewing.
- The tilting of the camera is achieved by a 6mm motor attached to a worm gear that rotates the housing of the pan mechanism and the imager. Panning is accomplished by a 6mm motor attached to a spur gear output that rotates the imager. While this design was bulky, it provided excellent visualization capabilities.



Soft Robotic Device for the Failing Heart:

1. Implantable soft robotic system for heart failure whereby soft actuators wrapped around the ventricles are programmed to contract and relax in synchrony with the beating heart.
2. Improved synchronization with the biological system is achieved by incorporating the native ventricular pressure into the control system to trigger assistance and synchronize the device with the heart.
3. A three-state electro-pneumatic valve configuration allows the actuators to contract at different rates to vary contraction patterns

Why to use this robotic device?

In Heart Failure, the heart cannot pump a sufficient blood flow to meet the metabolic demands of the body. Heart Failure prevalence in the United States is around 5.7 million people and around half of those diagnosed will die within 5 years of diagnosis. The total financial cost of HF in the United States is estimated at $30.7 billion per year. For patients with advanced HF, transplantation is widely accepted as an effective treatment, but limited donor availability means that many patients will die waiting for a donor heart.

Advantages:

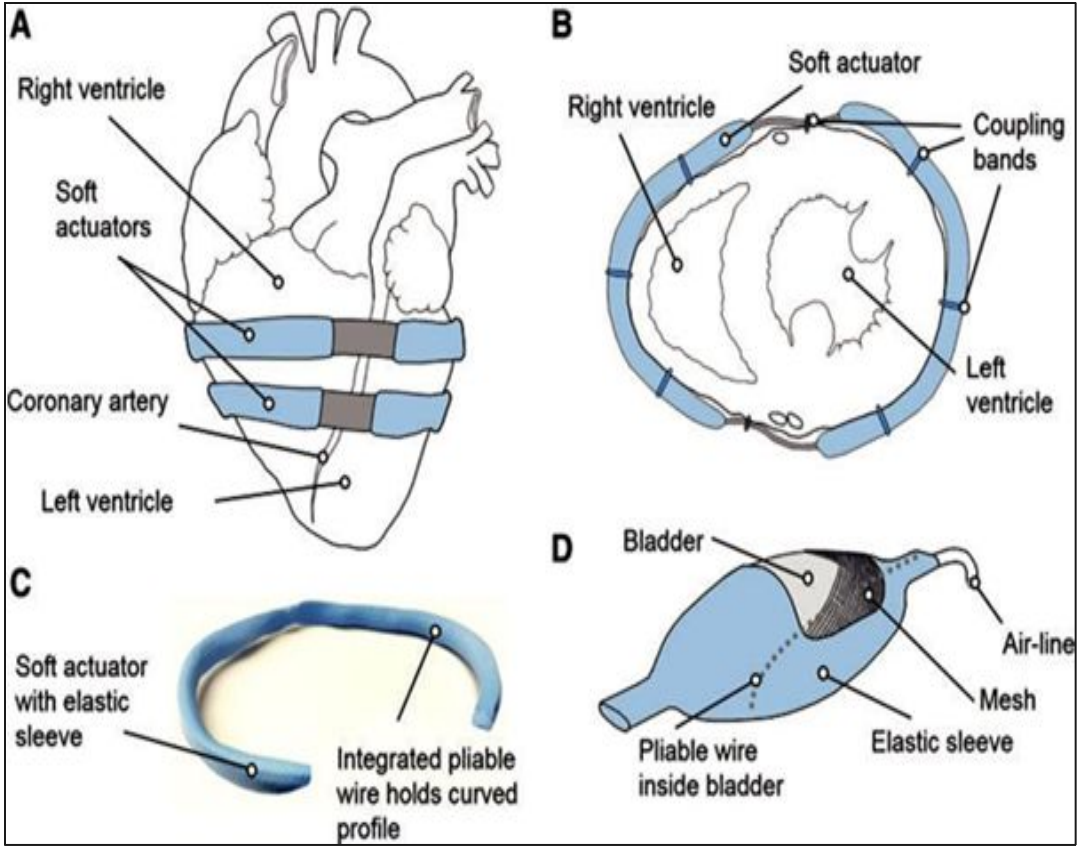
(1) Recoiling ability to refill the heart.

(2) A method of device adhesion to the ventricles to enable diastolic assistance.

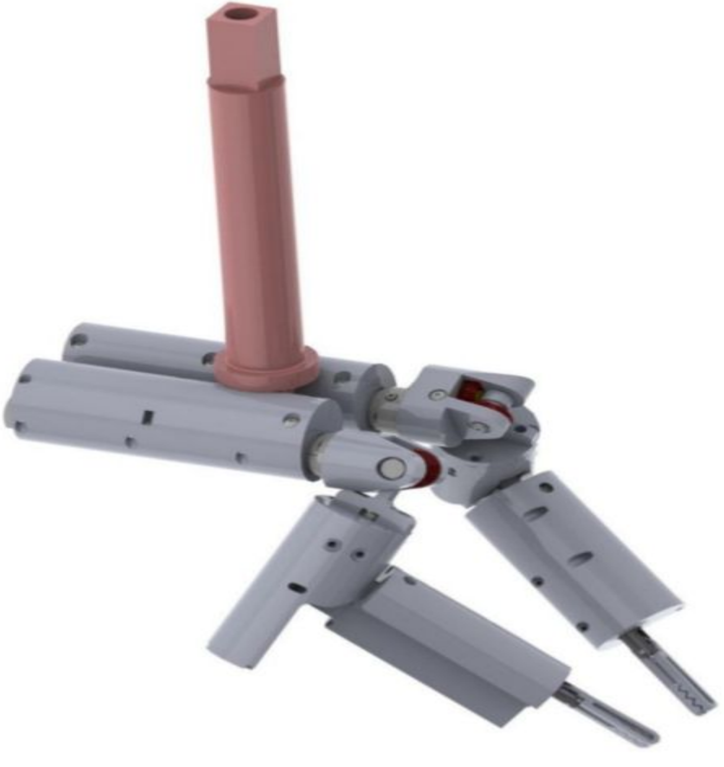
(3) A control system based on real-time hemodynamics for synchronization with the native heart.

(4) Configurable actuators that can be formed in situ to fit the ventricle.

(5) A control system that allows different rates of actuator contraction to optimize system performance.



TYLER ROBOT FAMILY



TYLER BOTS

- Since the NB was tool large to perform the surgery a new kind of robot family, Tyler bot was created- TB1 and the advanced version TB2.
- TB1 - focused on Drive train and link design, aim was to reduce the size and make it less than NB2, to improve insertion. TB2 had a better motor placement and minimalistic approach.
- Though improved TB1 was not reliable and the size was too large.
- TB2 was made after improvements from the previous versions and was made simple, durable, contact and insertable.

DESIGN ISSUES

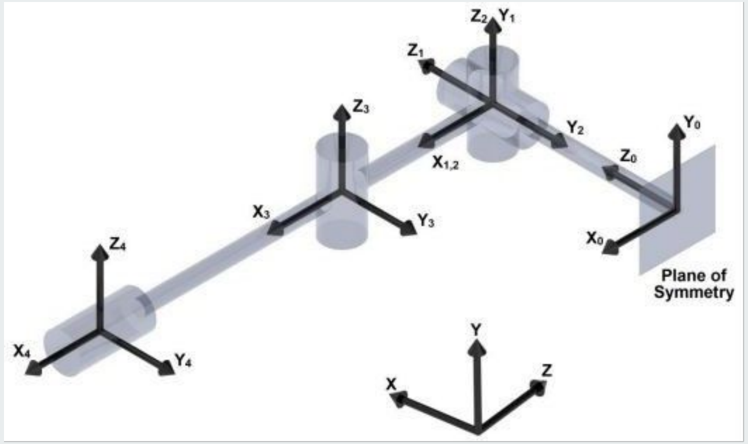
1.This robotic prototype had a very short lifespan and had reliability problems.

2.The size was still too large even after the motor placement.

3. Motors were prone to overheating because of poor heat sink design.

4. The motors were long with small diameter and not very space efficient

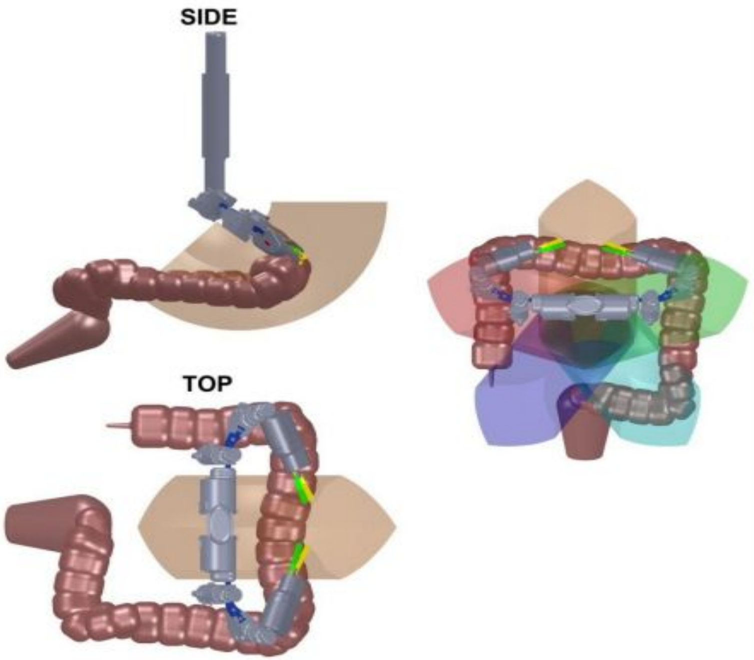
TYLER BOT 2



Tyler- Bot 2 (TB2) was designed based on the knowledge gained from the previous surgical robotic prototypes. The robot was simple, durable, compact and insertable.

Work space, forces and manipulability

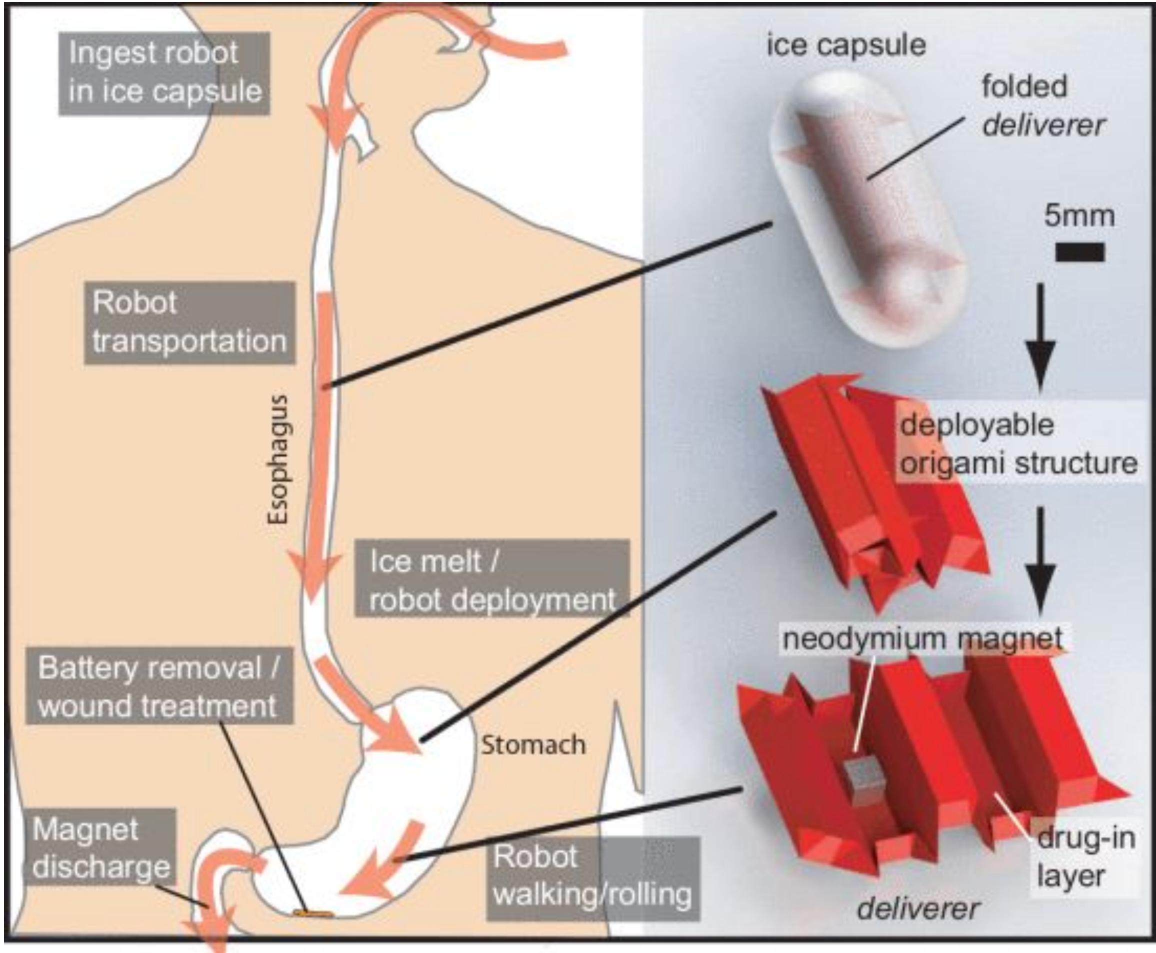
- The workspace of the Tyler Bot is almost equal to the large intestine and allows it to operate easily.
- The torques of the motors are known and this allowed the calculation of the forces on each link and the force applied by the end effector.



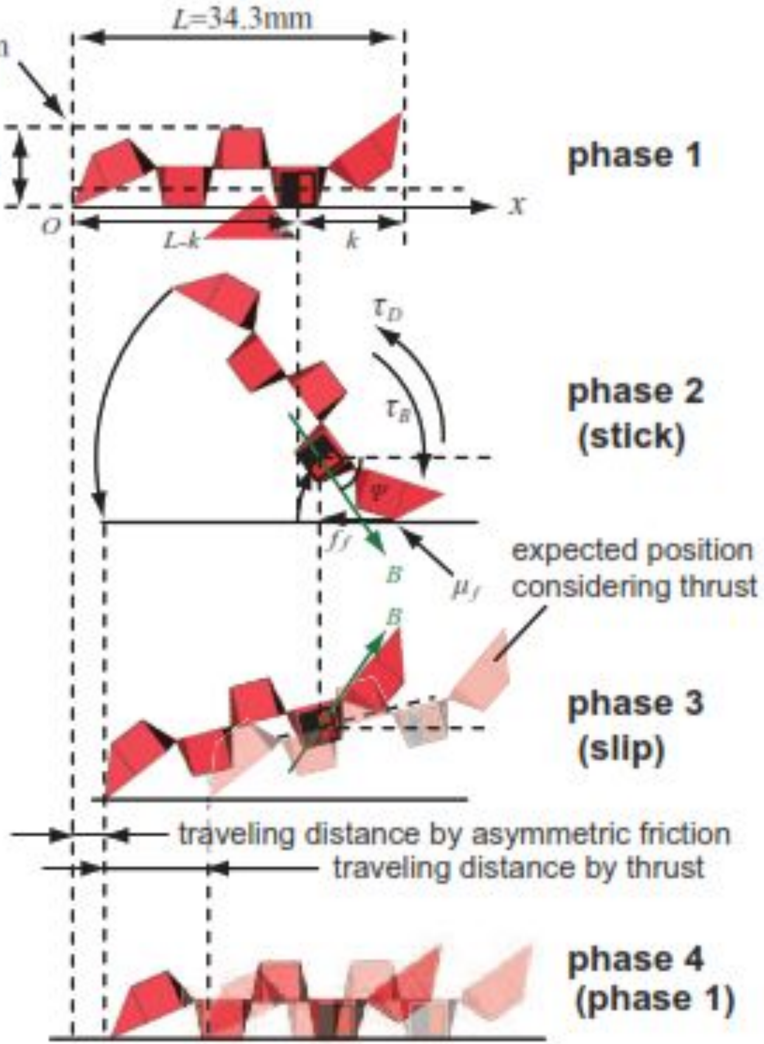
Healthcare Robots

Robot for Patching Stomach Wounds

Ice capsule transportation



WALKING MOTION DELIVERER



LUCAS System

LUCAS System

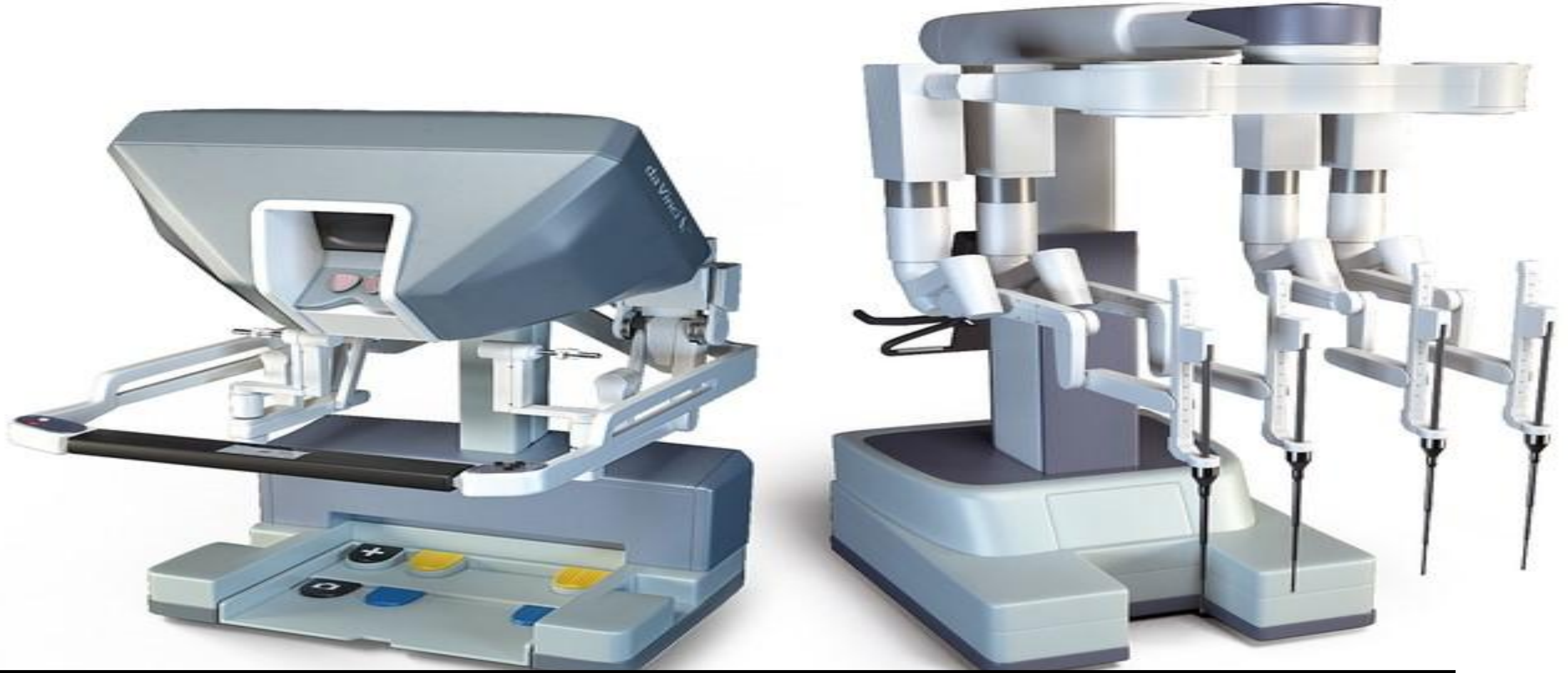
- The LUCAS chest compression system has improved features to facilitate maintenance and handling and allows for new insights through easy, wireless access to device data

- CPR is difficult to do well. Manual CPR training can help and it's expensive and cumbersome to schedule and track. LUCAS is simple and easy to use with minimal training, keeping the cost of ownership low.

SMART WHEELCHAIR

SMART WHEELCHAIRS

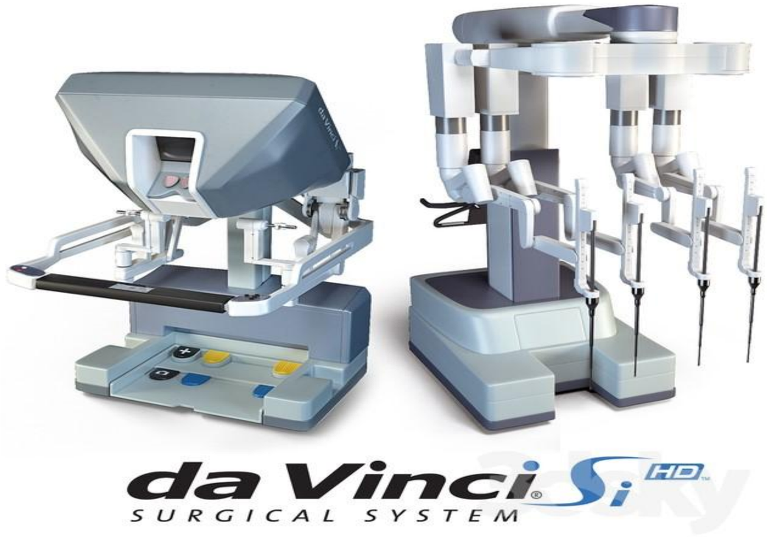
- The machines can also be used in old age homes where the old age persons have difficulty in their movements.
- Different types of smart wheelchair have been developed in the past but the new generations of wheelchairs are being developed and used which features the use of artificial intelligence and hence leaves a little to tinker about to the user who uses the wheel chair.
- The project also aims to build a similar wheel chair which would have a sort of intelligence and hence helps the user on his/her movement.



Da Vinci Surgical System

The Da Vinci surgical System

- The da Vinci Surgical System is a robotic surgical system made by the American company Intuitive Surgical.
- Approved by the Food and Drug Administration in 2000,
- it is designed to facilitate complex surgery using a minimally invasive approach, and is controlled by a surgeon from a console.



Usage of Da Vinci in Different Procedure

- Hysterectomies involving cancerous and benign uterus conditions
- Kidney surgeries in the treatment of kidney cancer including nephrectomy, partial nephrectomy,
- nephroureterectomy that involves removal of the uterer and kidney
- Prostatectomy to treat urinary obstruction and prostate cancer
- Lung surgeries
- Cardiac surgeries involving robotic mitral valve repair
- Urologic reconstruction surgeries involving ureteral reconstruction, ureteral obstruction, pyeloplasty, sacrocolpopexy (uterine prolapse repair), uterine fibroids removal (myomectomy), and gender confirmation surgical procedures
- Endometriosis treatment
- Neck and head surgeries

Da Vinci Robotic Surgical Issues

- Increased risks associated with longer anesthesia and operating time.
- Temporary tissue swelling caused by gas used during the procedure
- Short-term nerve damage because of operating table positioning
- Injuries or complications to the patient’s vision, larynx, or face when the patient is placed in an inverted position with the feet are higher than the head
- Injuries to blood vessels and organs caused by the surgical equipment or instruments
- blood pressure issues caused by gas absorption used during the procedure
- Fluctuating heart rates
- Post-surgical procedure shoulder pain
- Temporary discomfort and/or pain caused by the gas or air used during the surgical procedure

Thank you