



# 2nd Health Care Engineering Systems Symposium

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# Resiliency in Cyber-physical Systems for Robot-assisted Surgery

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**HCESC**

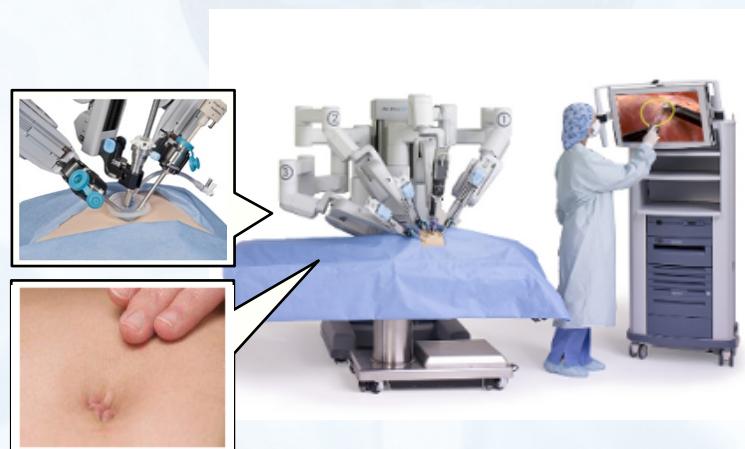
**jump**trading  
SIMULATION &  
EDUCATION CENTER

**ARCHES**

 **JumpLabs**

# Safety Incidents in Robotic Surgery

- More than 1.75 million robotic procedures since 2000
- Various surgical specialties:
  - Gynecology, Urology, General, Cardiothoracic, Head and Neck



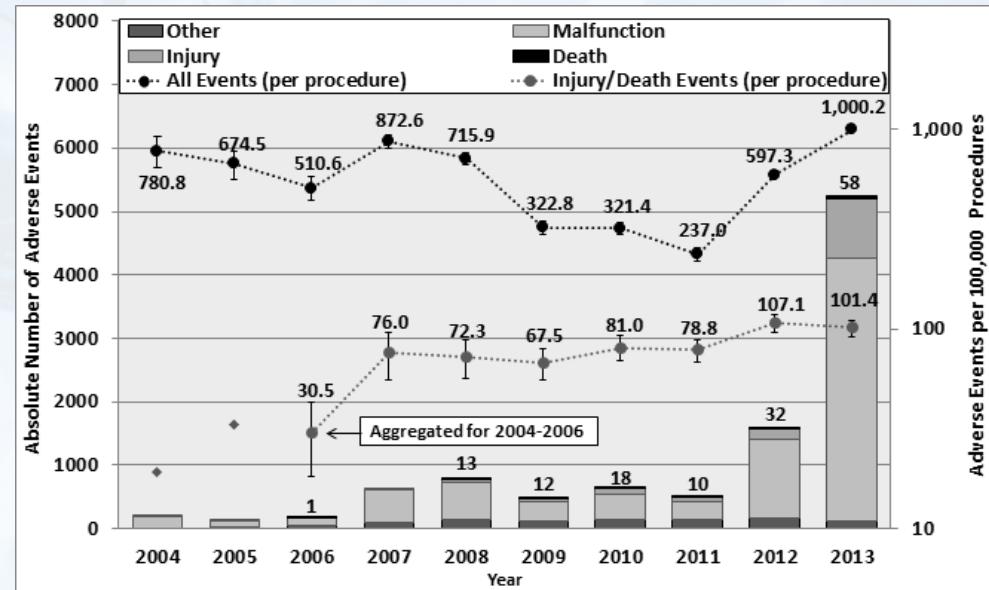
Applied Dexterity, Biorobotics Lab, UW, 2007



Zeus Robot, First Intercontinental Surgery, 2003

# Safety Incidents in Robotic Surgery

- Over 10,600 adverse events reported to the FDA
  - On average, one adverse event per 100 procedures
  - When an adverse events happens, there is a 24% risk of:
    - Injuries and deaths
    - Longer procedure times for troubleshooting problems
    - Conversion to non-robotic methods
    - Rescheduling



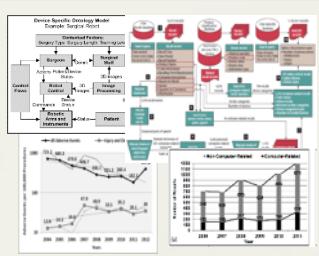
# Safety Challenges

- **Accidents are under-reported and not well studied**
  - Causal analysis of accidents by considering humans in the loop
  - Improved error logging and monitoring mechanisms
- **Monitoring and recovery mechanisms are passive**
  - Assessing system resiliency against safety hazards
  - Considering HW/SW interactions, physical system, and human operators interactions
- **Surgical teams are not well trained for dealing with adverse events**
  - Simulation-based training by creating safety hazard scenarios in virtual environments

# Our Research

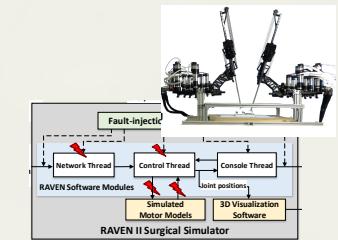
## Analyzing Past Failures and Safety Incidents

- Tools for automated analysis of incident reports
- Systems-theoretic accident models and hazard analysis



## Assessing Resilience to Safety Hazards

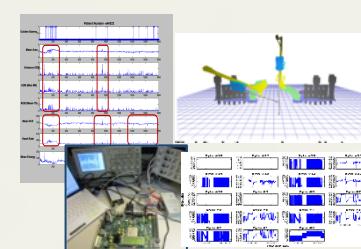
- Software fault-injection to emulate realistic failures
- Simulators to virtually recreate hazard scenarios



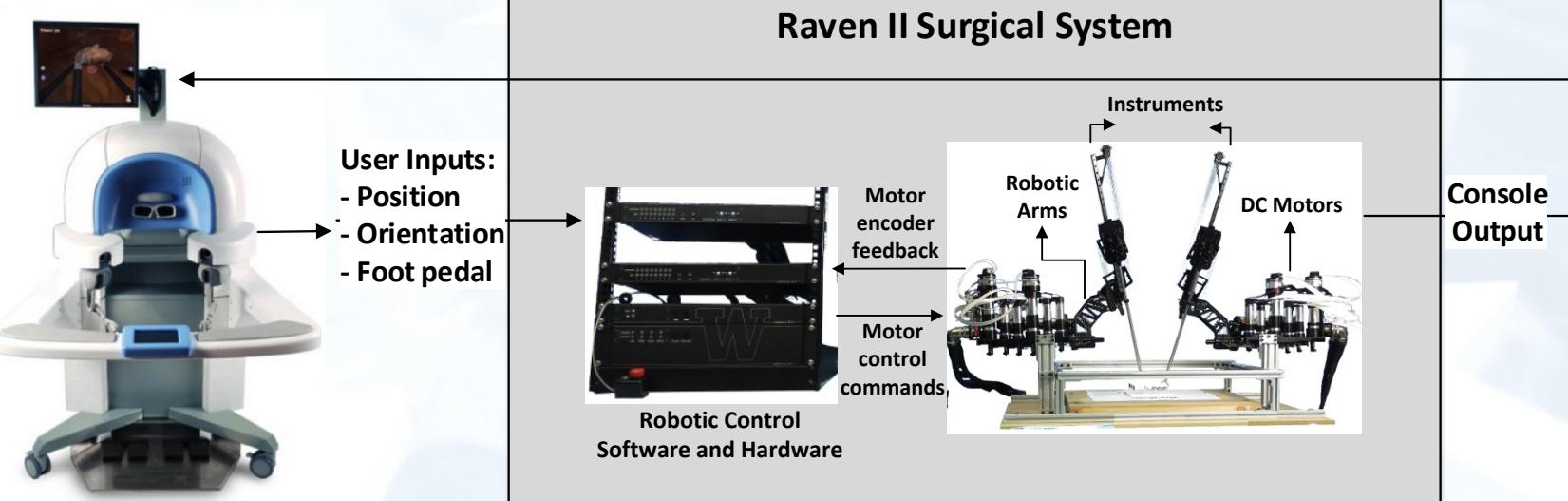
## Resilient Robotic Surgical Systems

## Designing Resilient Surgical Systems & Simulators for Training

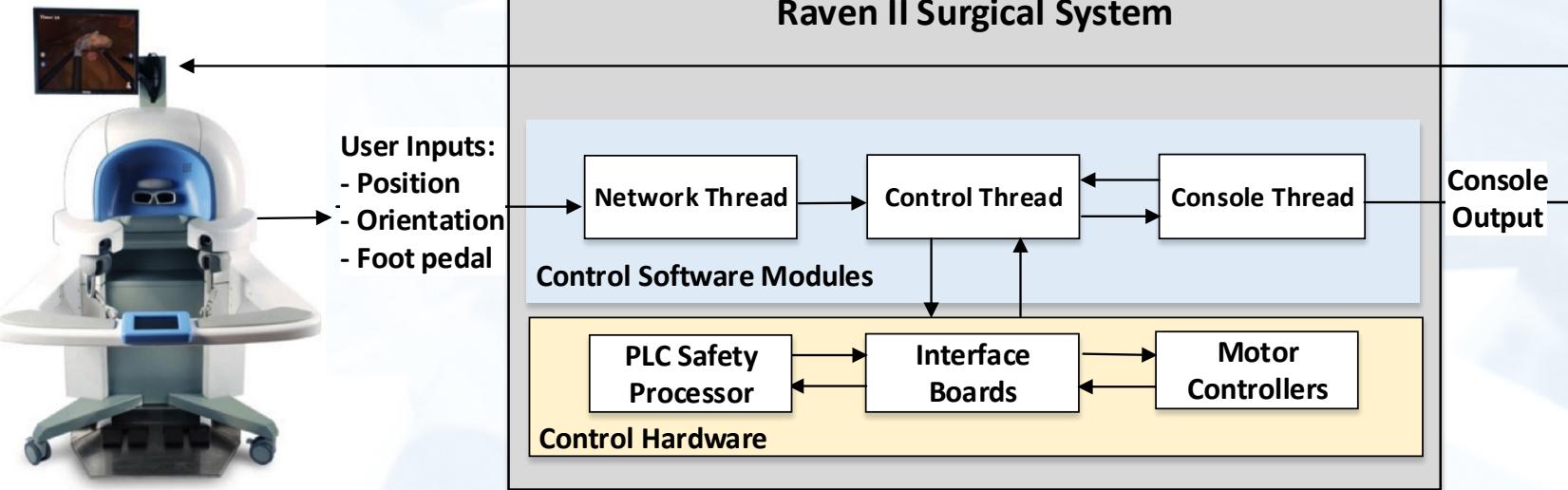
- Safety monitors for early detection/mitigation of safety hazards
- Training modules to expose surgeons to realistic hazard scenarios



# Surgical Simulator Safety Assessment and Training

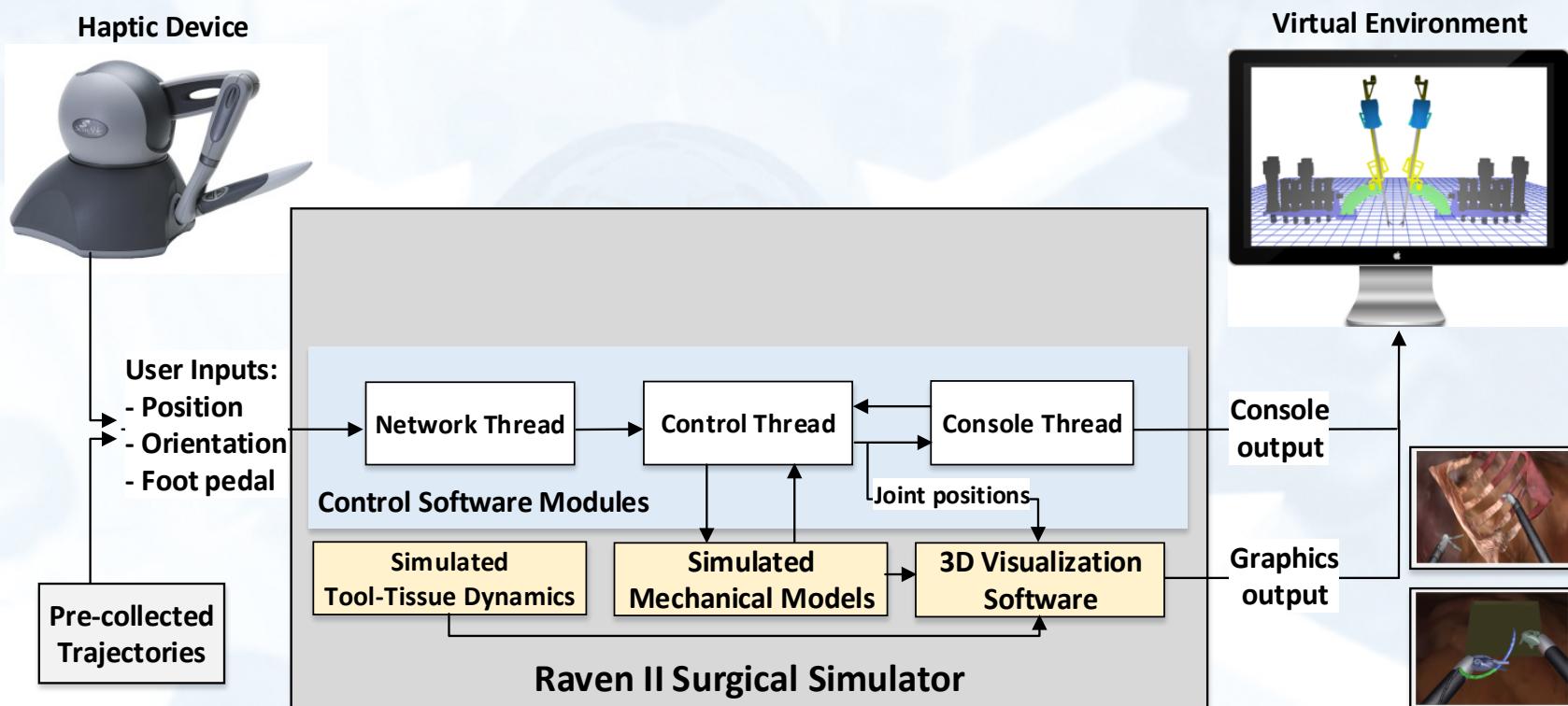


# Surgical Simulator Safety Assessment and Training

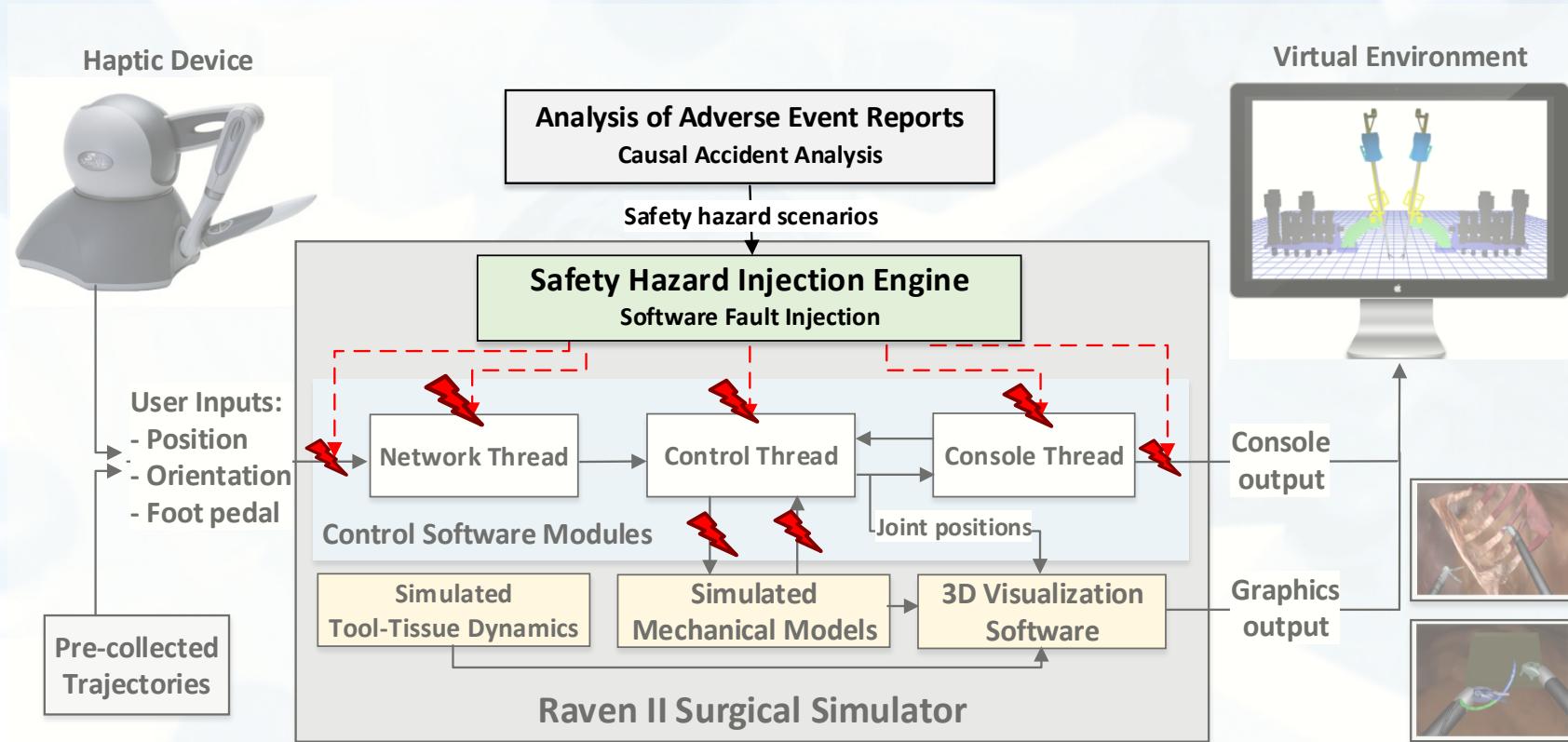


# Surgical Simulator

## Safety Assessment and Training



# Surgical Simulator Safety Assessment and Training

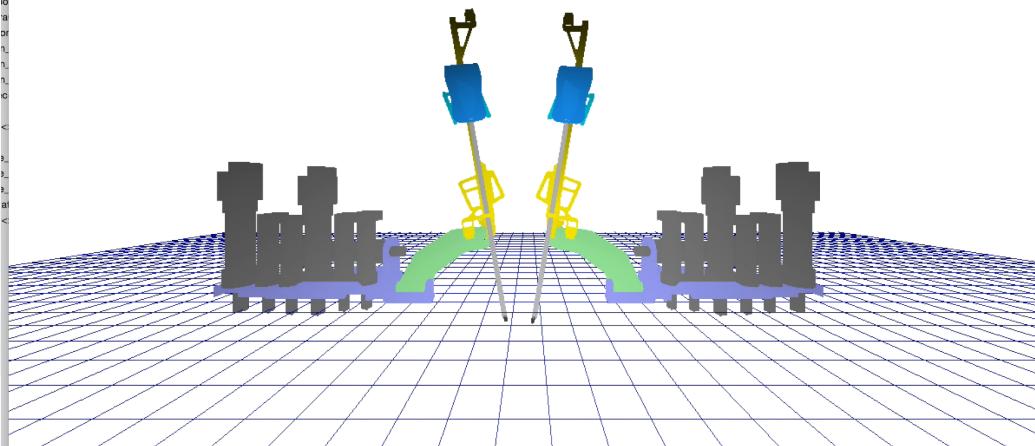
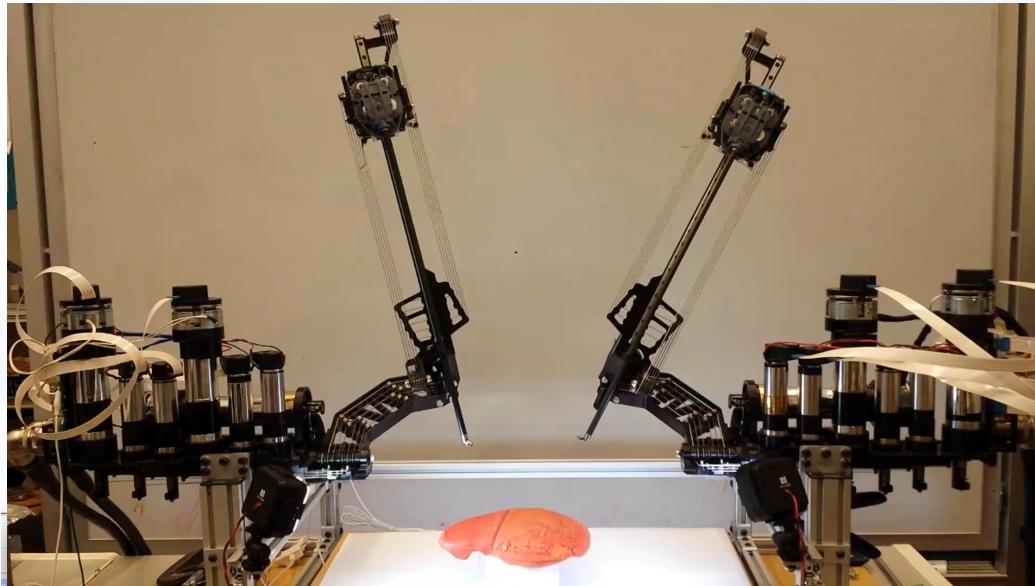


Alemzadeh et al., "A Software Framework for Simulation of Safety Hazards in Robotic Surgical Systems," *Medical Cyber Physical Systems Workshop*, 2015.

Alemzadeh et al., "Systems-theoretic Safety Assesment of Robotic Telesurgical Systems," *International Conference on Computer Safety, Reliability, and Security (SAFECOMP)*, Delft, Netherlands, 2015.

# Simulation of Safety Hazards

Safety  
Assessment

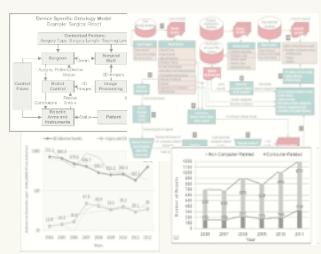


Safety  
Training

# Future Directions

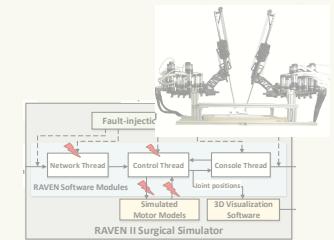
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## Assessing Resilience to Safety Hazards

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Resilient  
Robotic Surgical Systems

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