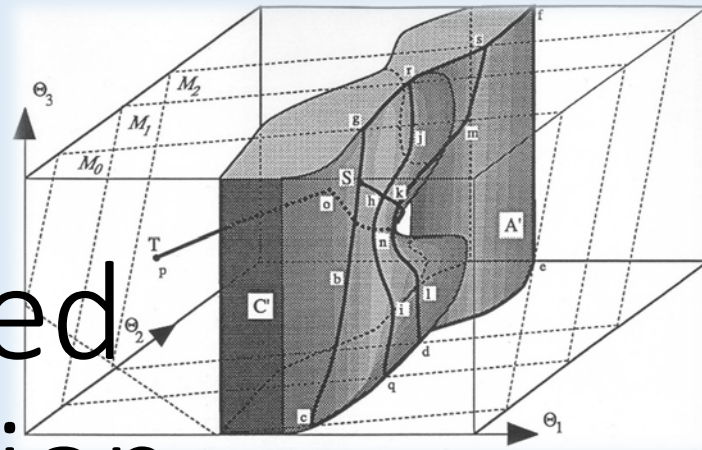
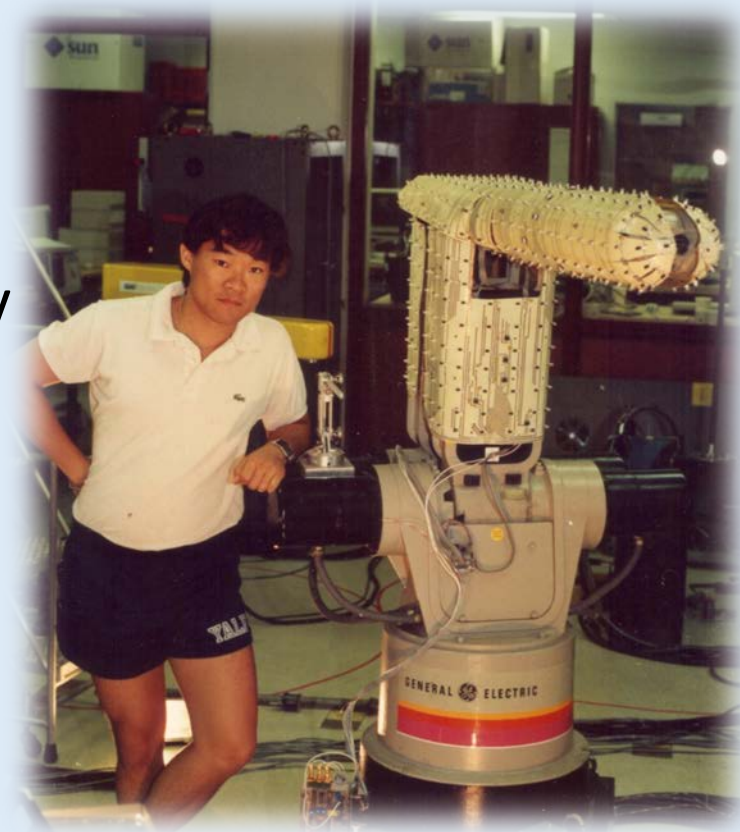
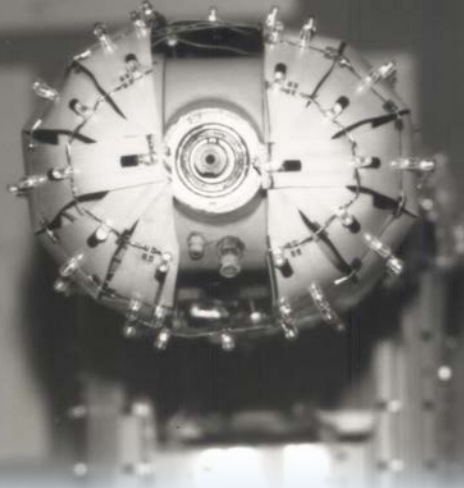




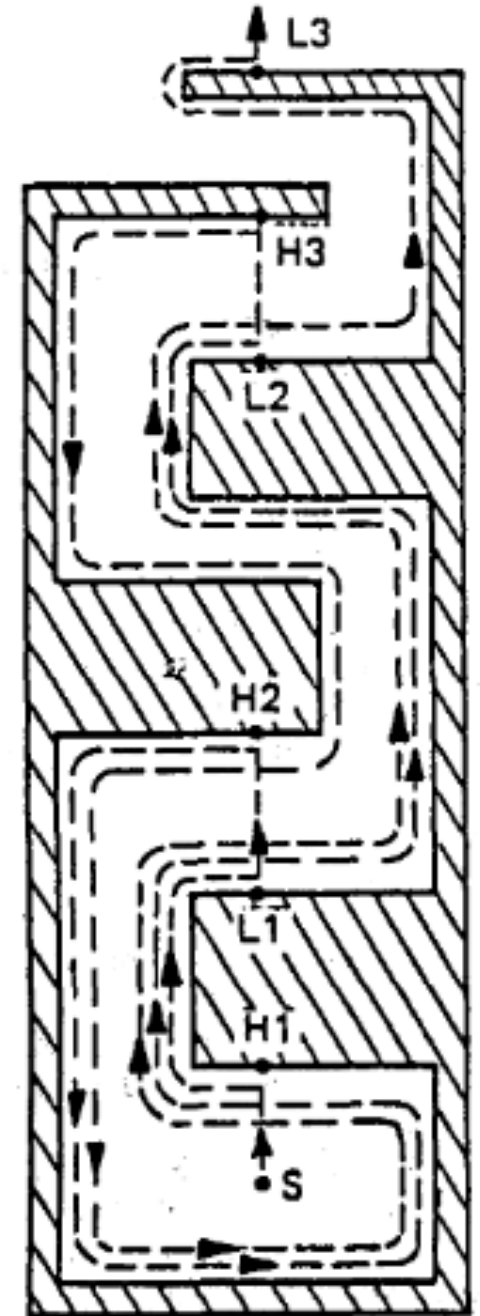
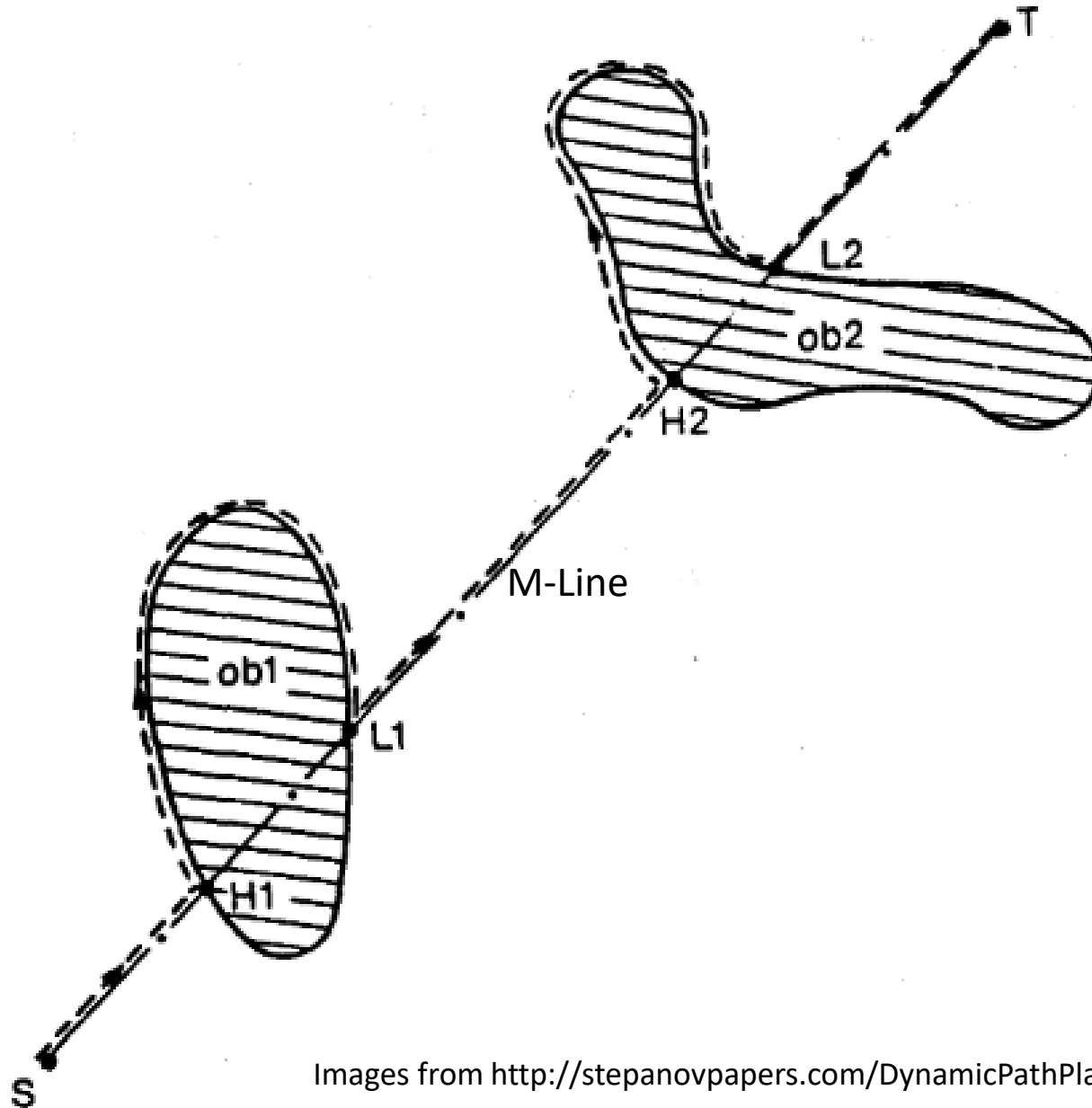
# A Look at Sensor-Based Arm Manipulator Motion Planning in 1980s



Edward Cheung  
edward.b.Cheung@nasa.gov  
IROS 2020  
Las Vegas (remote)

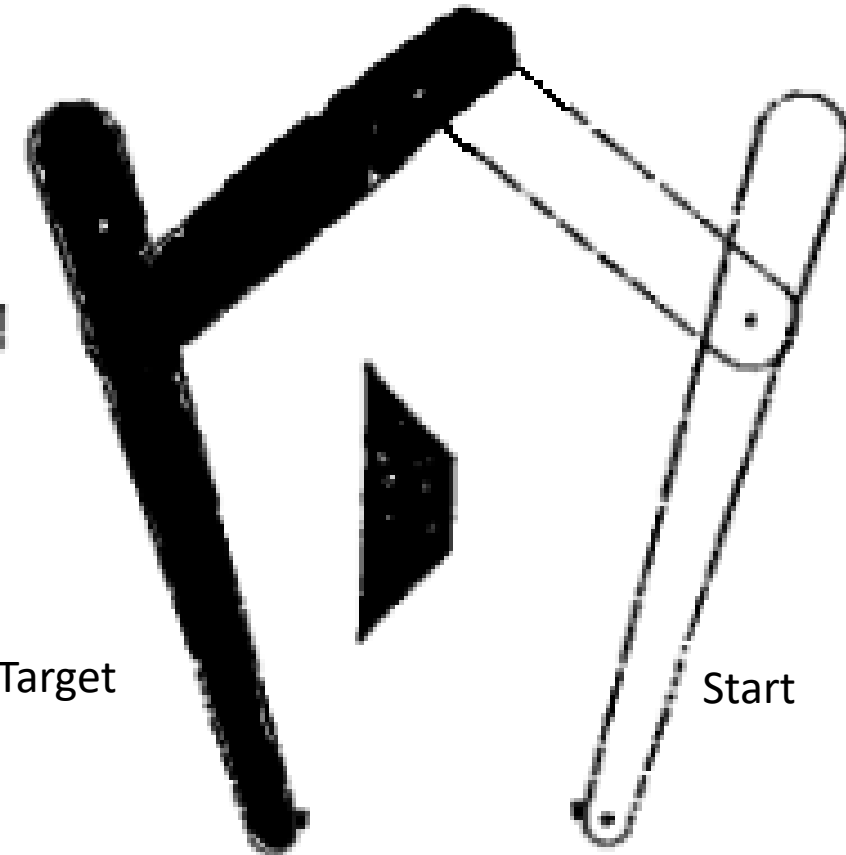
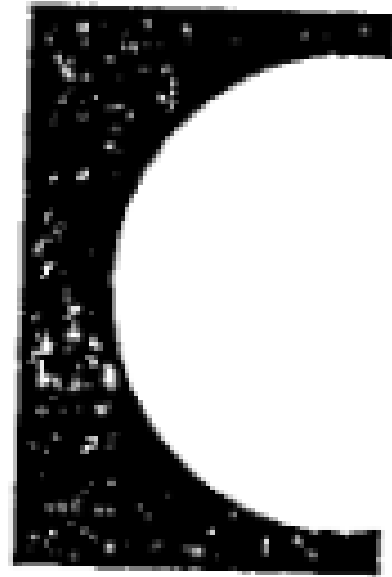


# Lumelsky – Stepanov (early 1980s)





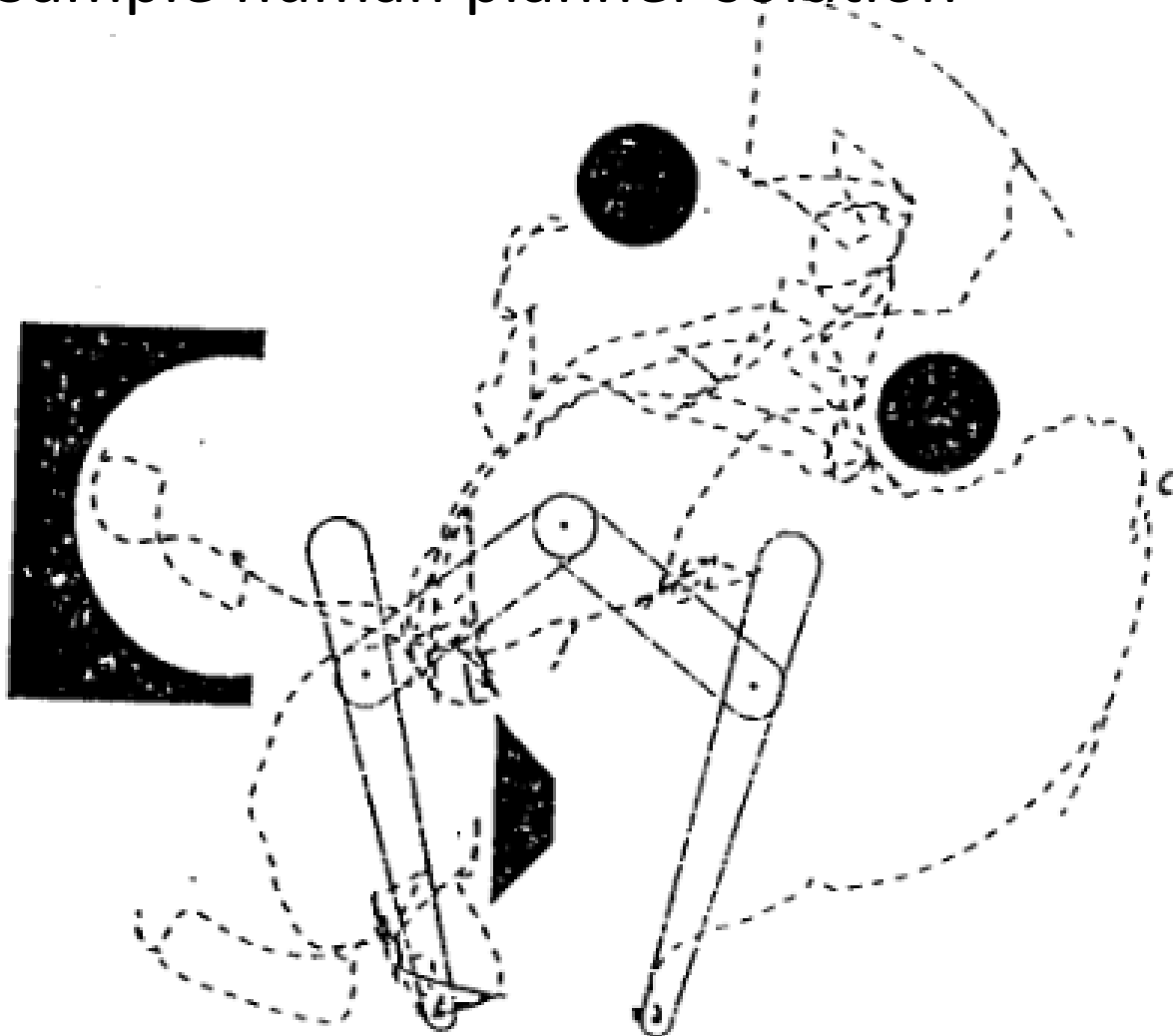
# Lumelsky – Skewis (mid 80s)



From Lumelsky & Skewis. On Human Performance In  
Teleoperation. IEEE International Workshop on Intelligent Robots  
and Systems IROS 1990

# Lumelsky – Skewis (page 2)

- Sample human planner solution



Path length = 71.95

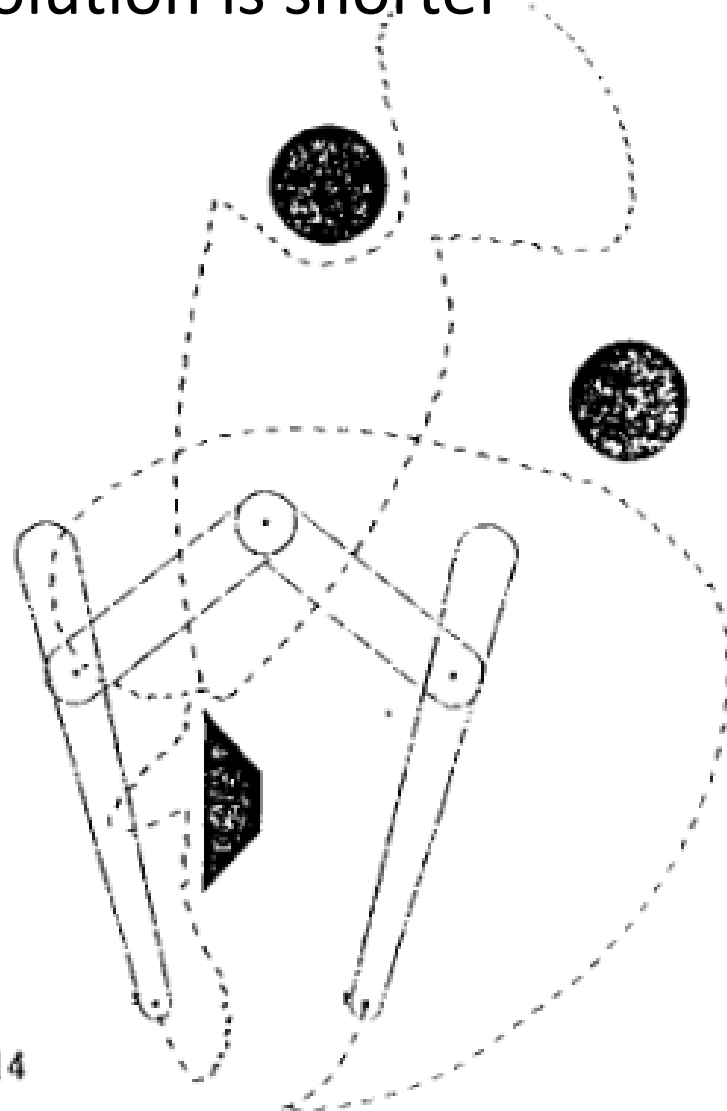
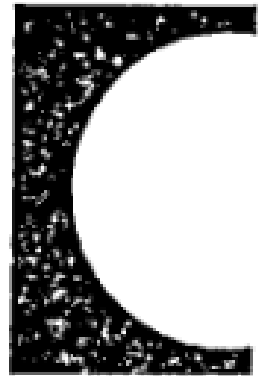


b)

Figure 4. Experiment 1. The test is done in Mode 1 - the subject cannot see obstacles and relies on tactile sensing only. Note that the subject prefers to control both links simultaneously. a) work space, b) configuration space.

# Lumelsky – Skewis (page 3)

- Automatic “Bug” solution is shorter
  - 21.14 vs 71.95



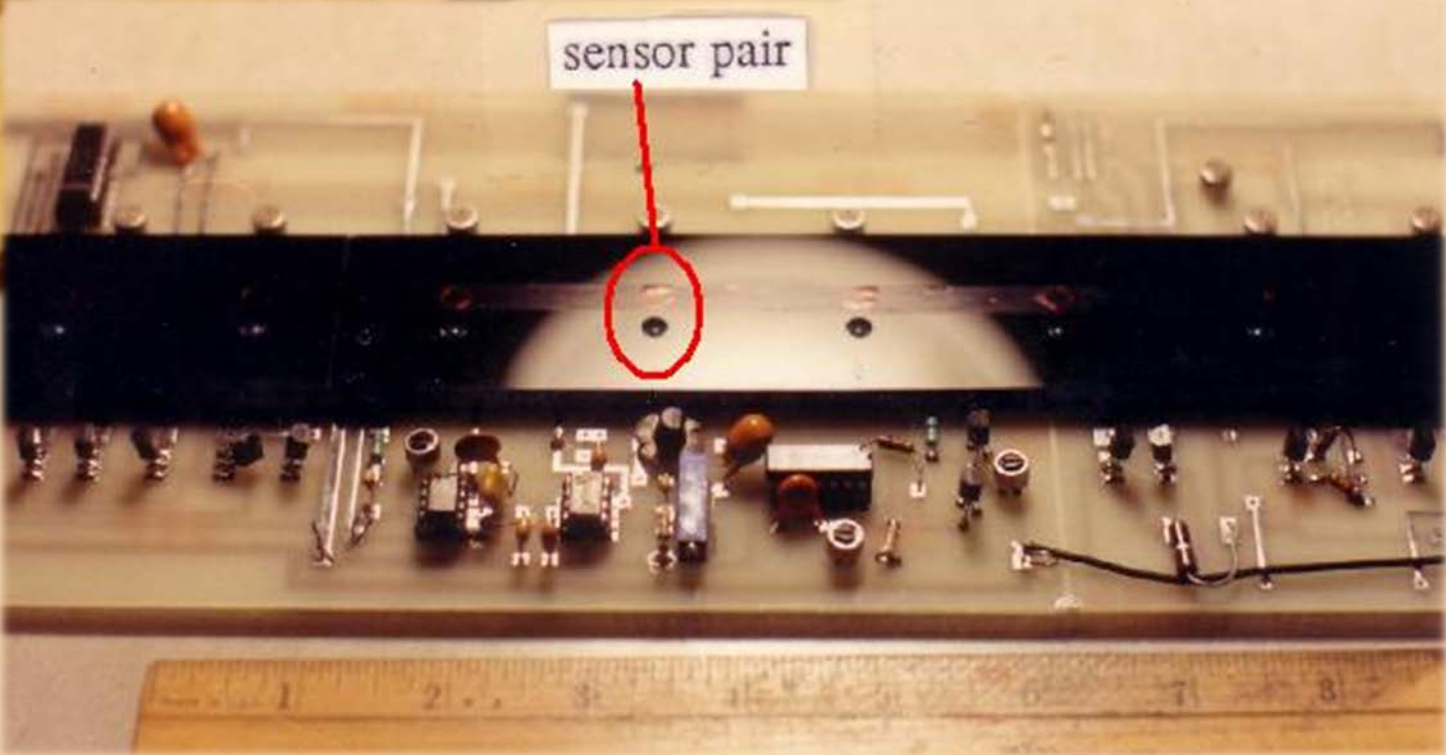
Path length = 21.14



b)

Figure 2. Trajectory of the arm endpoint produced by the algorithm [7]. S and T are start and target positions. a) work space and b) configuration space presentation; point A - arm position in Figure 1, point B - arm position in Figure 3.

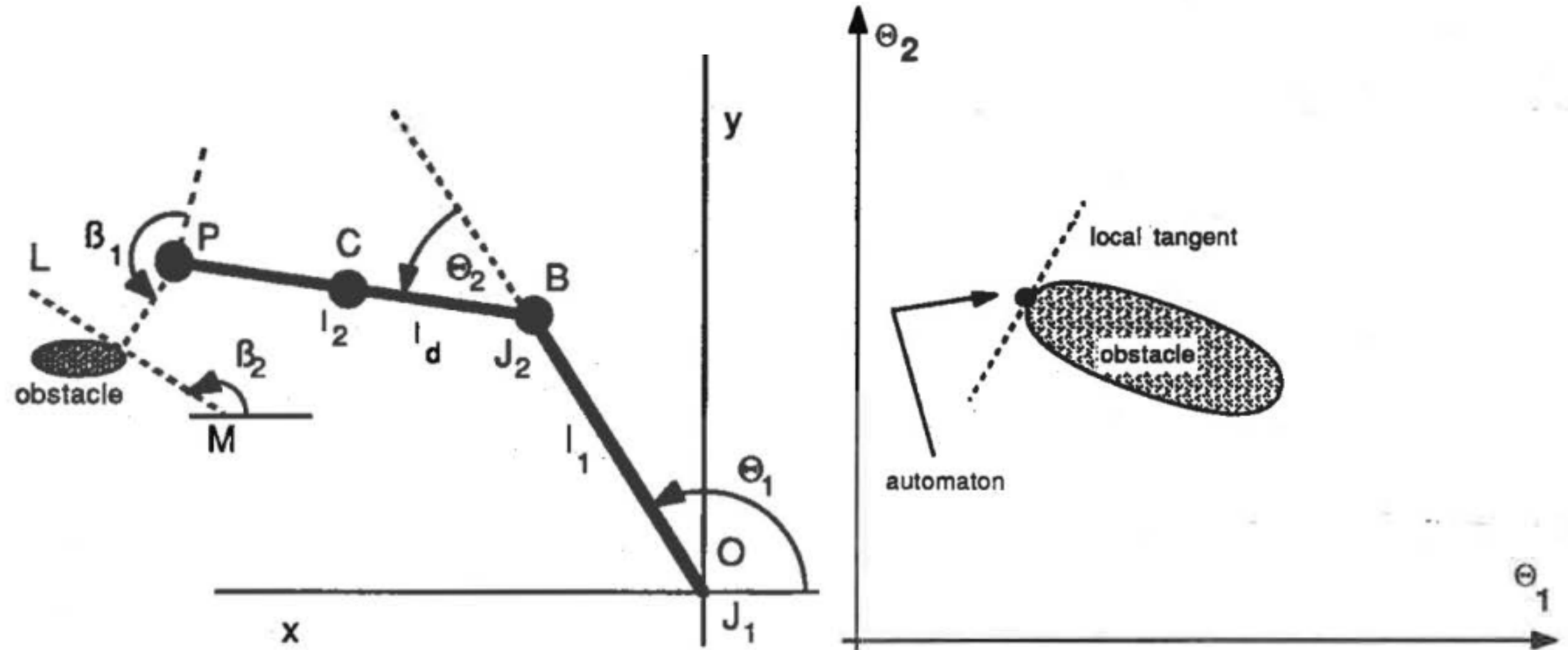
# Lumelsky – Cheung : Hardware Approach



Placement on PUMA Arm to form 2D “skin”



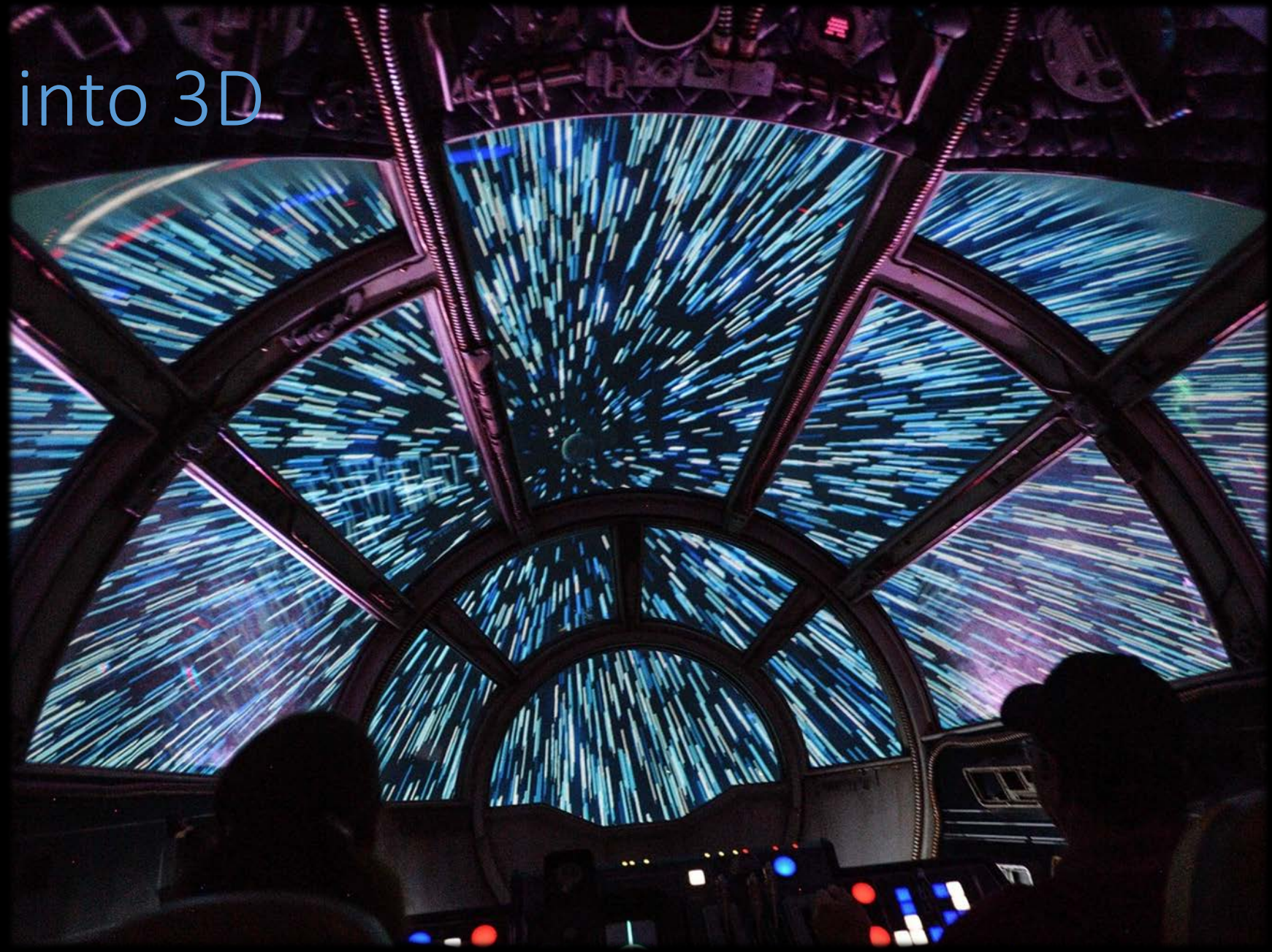
Problem: How to process sensor skin data?



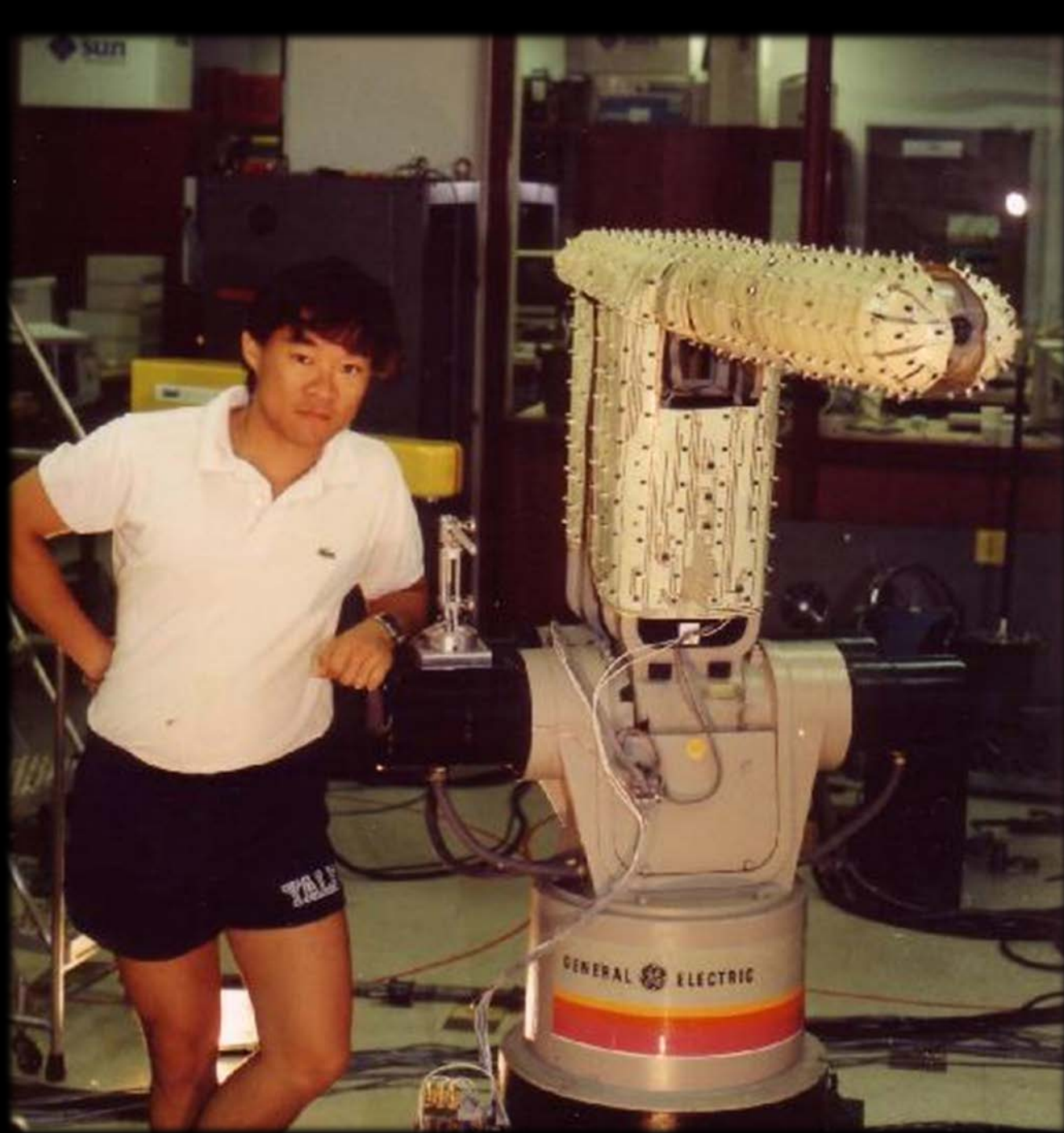
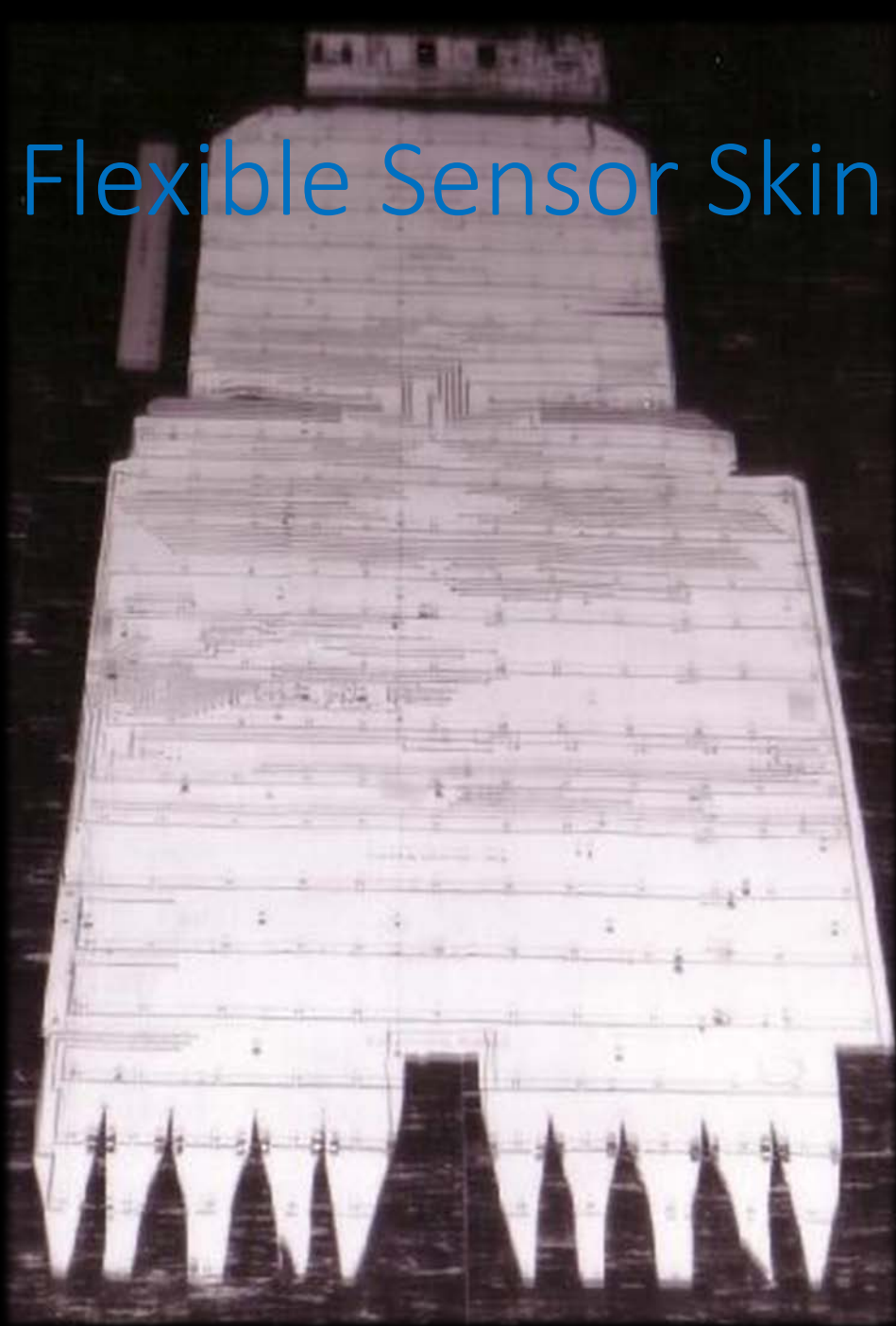
Assembled  
2D system



Jump into 3D



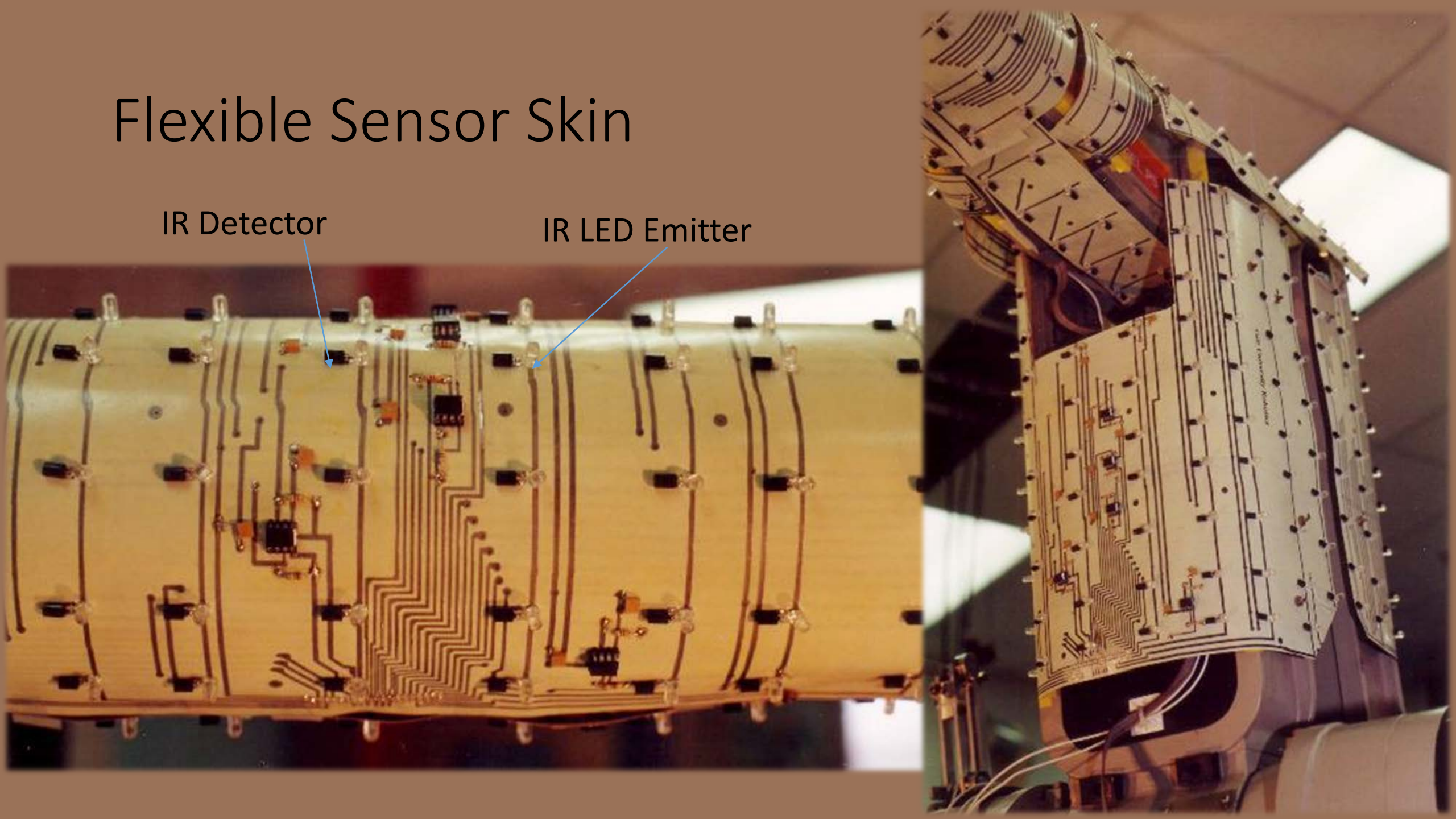
# Flexible Sensor Skin



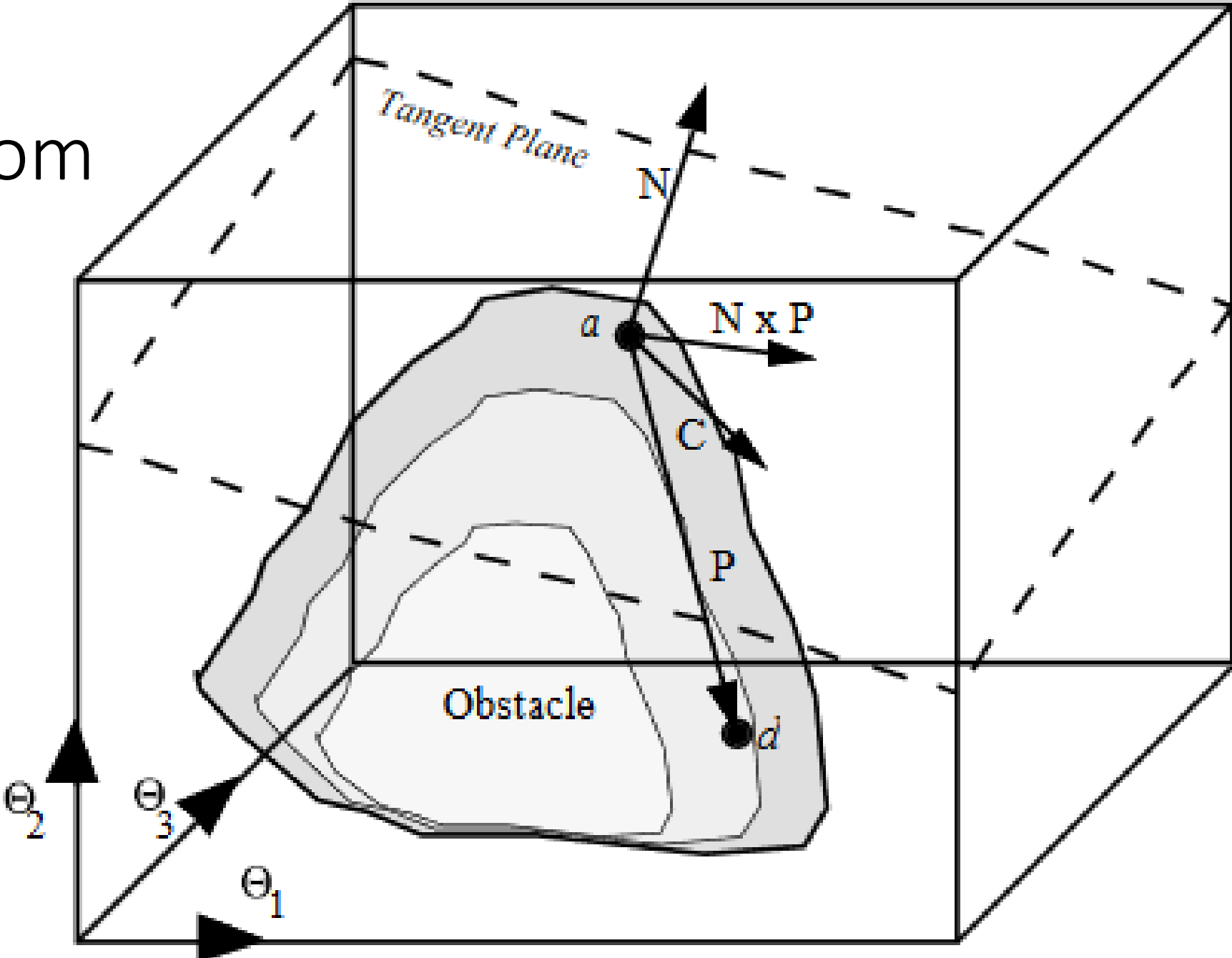
# Flexible Sensor Skin

IR Detector

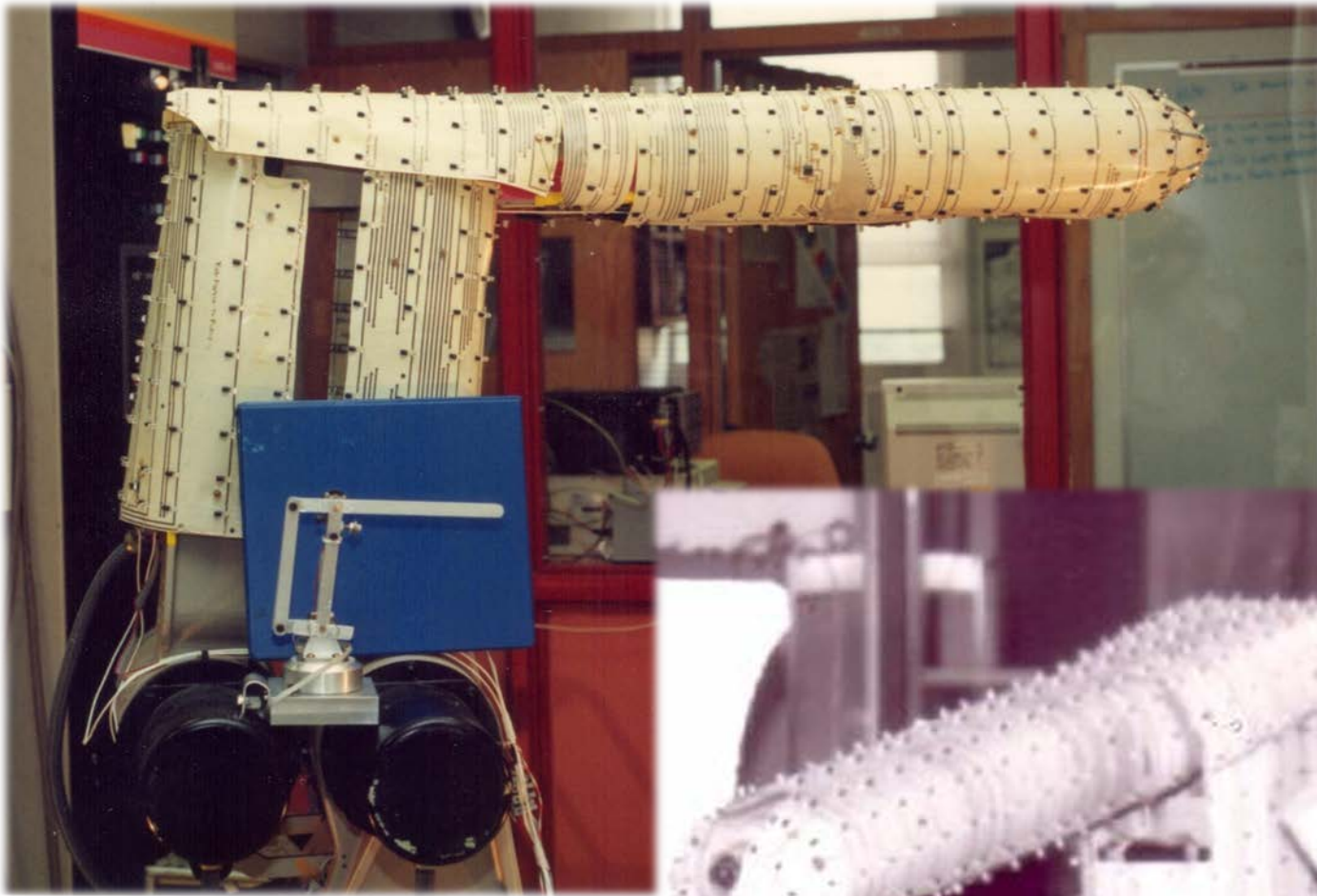
IR LED Emitter



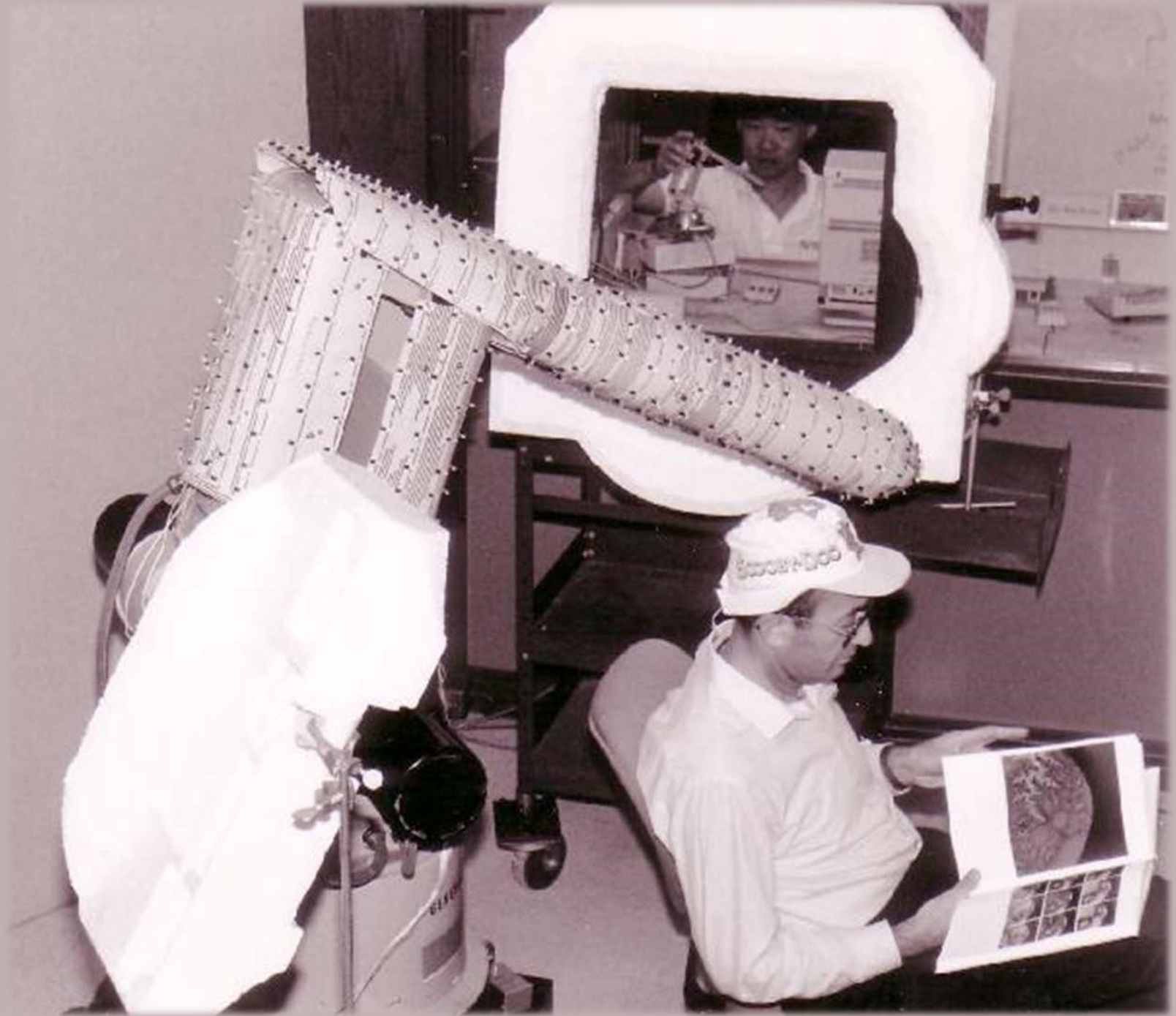
Processing  
sensor data from  
a 3D skin



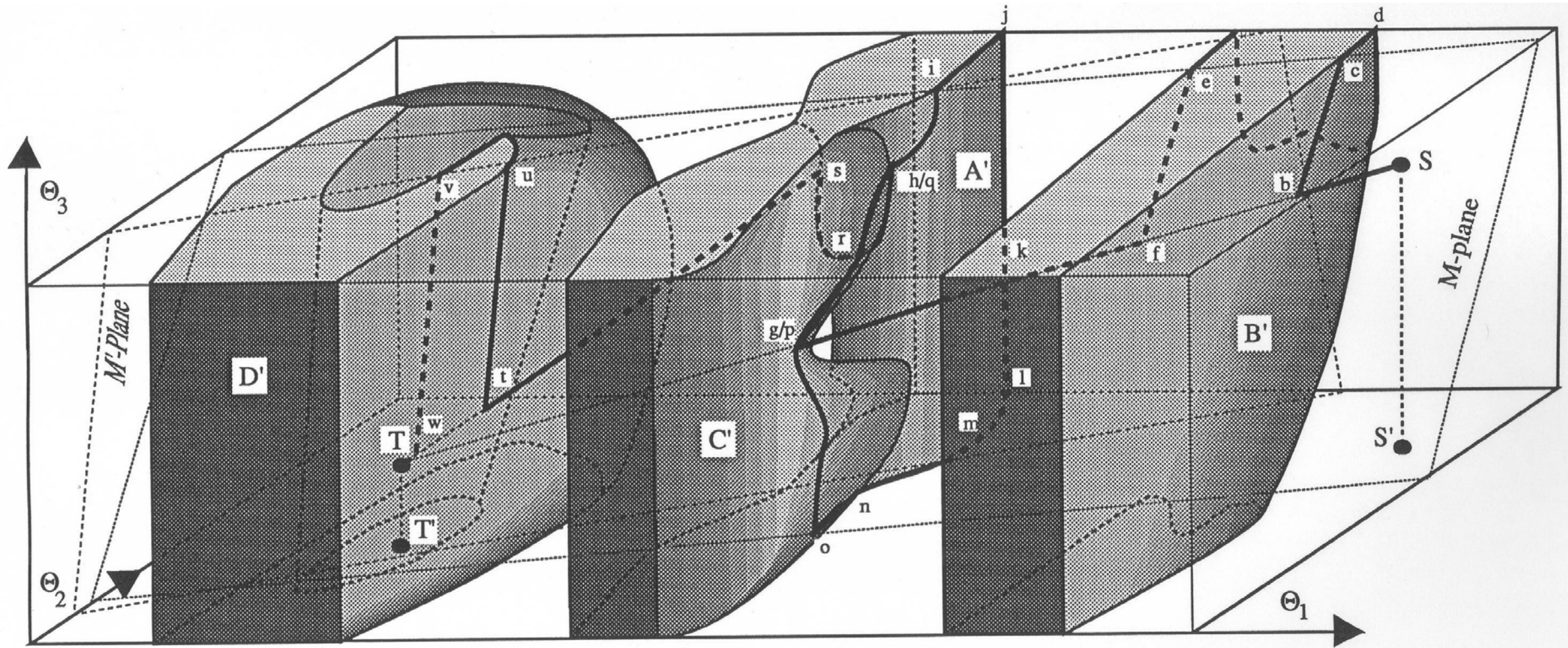
# Mini-Master Arm Control



# Safe Teleoperation



# Another Mode: Full Autonomous Motion Planning



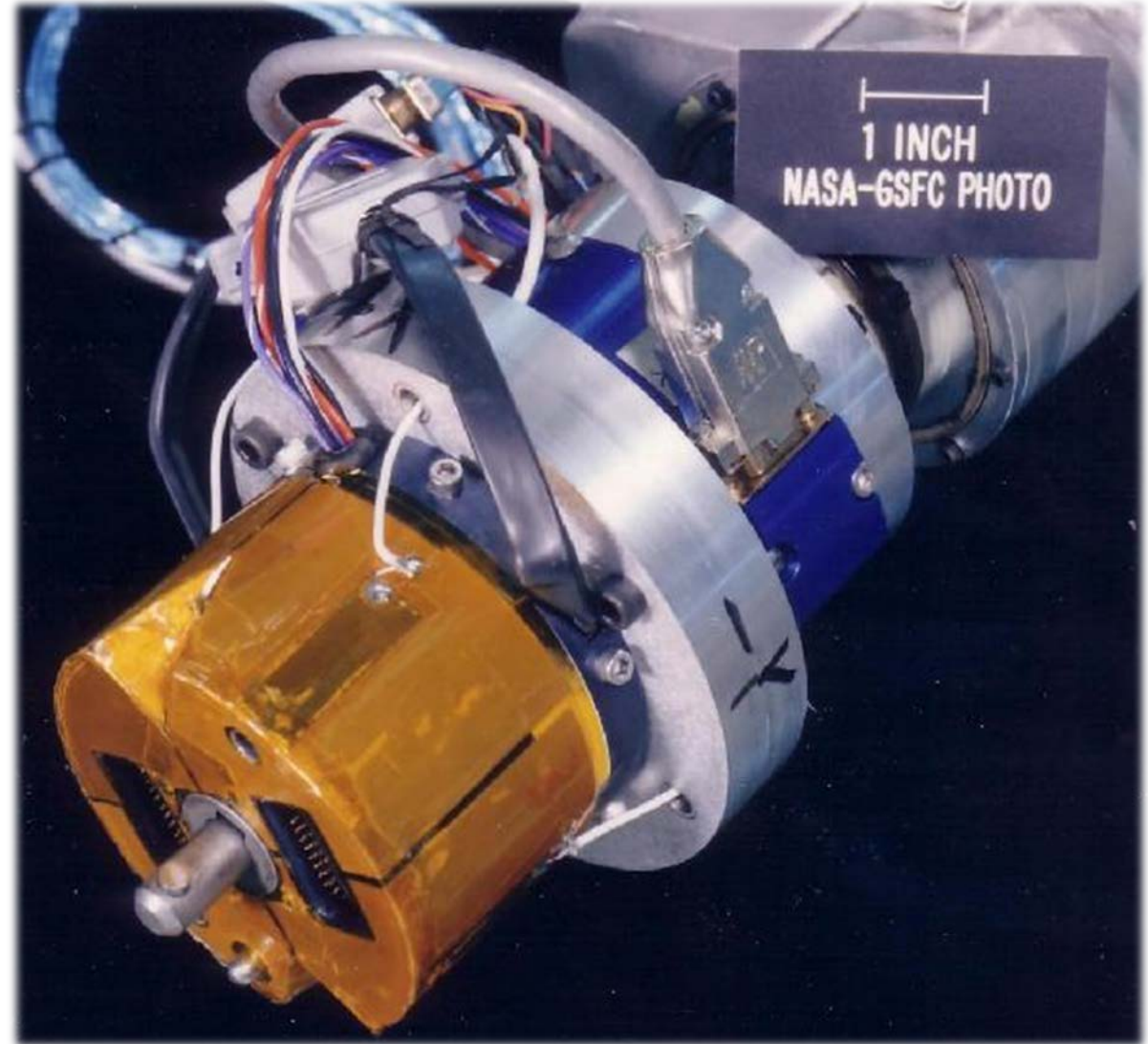
# Video

- <https://www.youtube.com/watch?v=5mweu4Kd4mg>

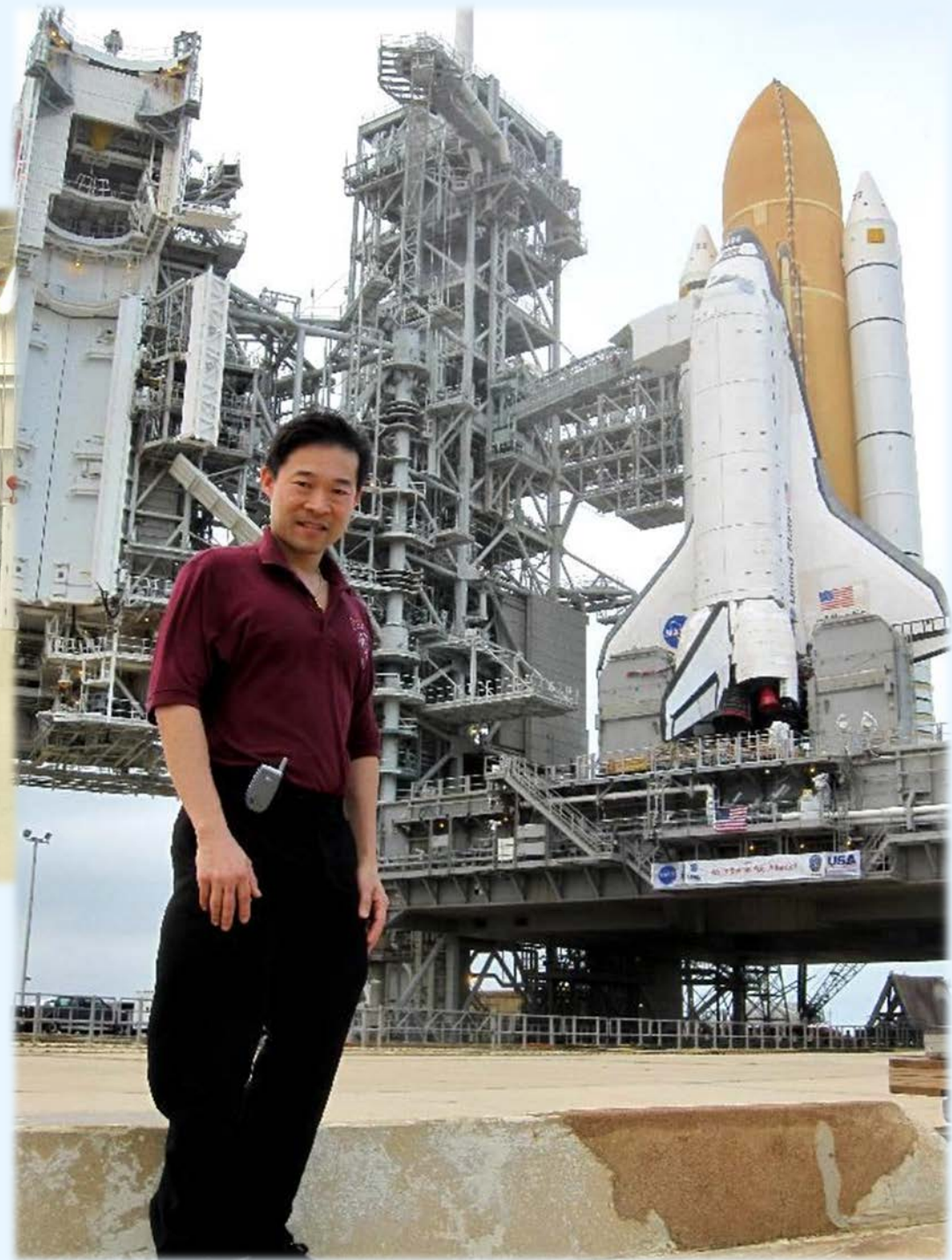
or

- <https://tinyurl.com/cheung-skin>

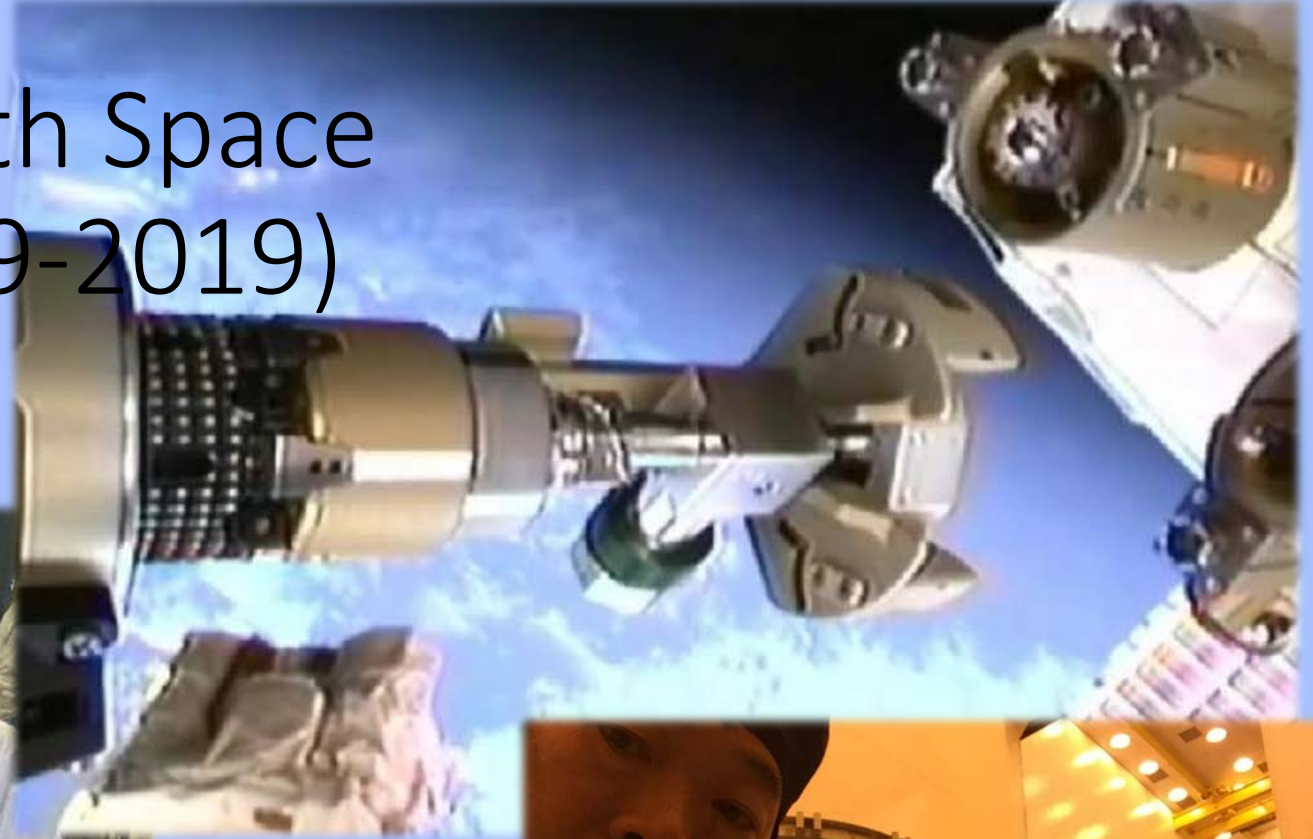
# Work at NASA-GSFC (1991 – 1997)

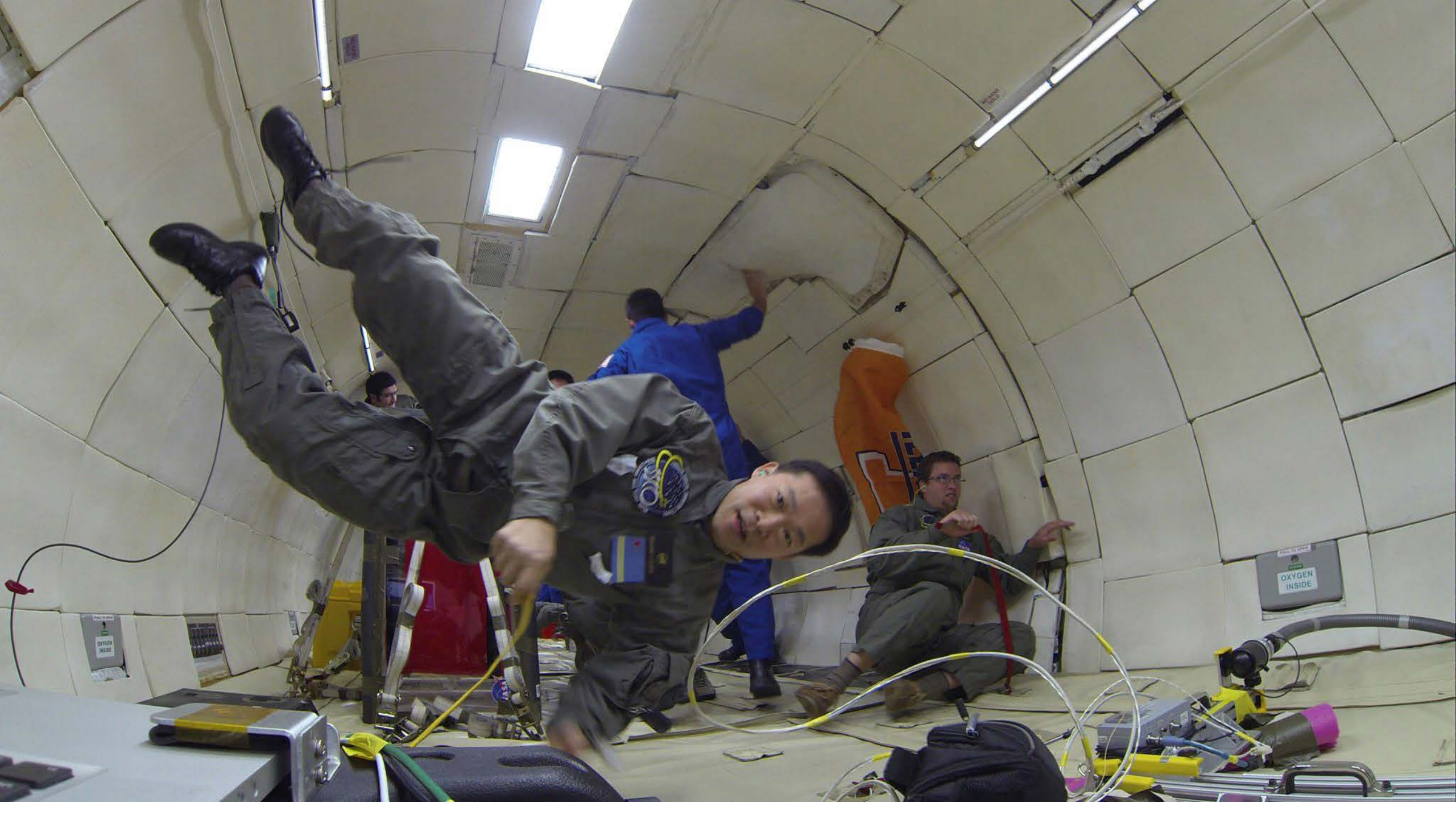


# Hubble years 1997 to 2009



# Satellite Servicing with Space Station Robots (2009-2019)





# Servicing with Robots: OSAM-1

- On-Orbit Servicing, Assembly and Manufacturing Mission
- Launch is 2025

<https://nexis.gsfc.nasa.gov/OSAM-1.html>

