



Robotically Assisted Cochlear Imaging and Access

Team 1

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- **Mentors:** R. Taylor, I. Iordachita, J. Kang
- **Clinical Mentors:** J. Niparko, W. Chien





- **Motivation**
- **Background and Specific Aims**
 - Ear Anatomy and Implant Structure
 - Standard Cochlear Implant Surgery
 - Optical Coherence Tomography
 - Steady-hand Robot
- **Technical Approach**
- **Organization and Management**
 - Deliverables
 - Validation
 - Dependencies
 - Timeline
 - Management Plan
- **Bibliography and Reading List**





Bad news: More than 36 million Americans have some degree of hearing loss. An estimated 3/1,000 children in the US may be born with hearing loss. Hearing loss can leave you feeling isolated from friends and family.

Good news: We have Cochlear Implants!

External system

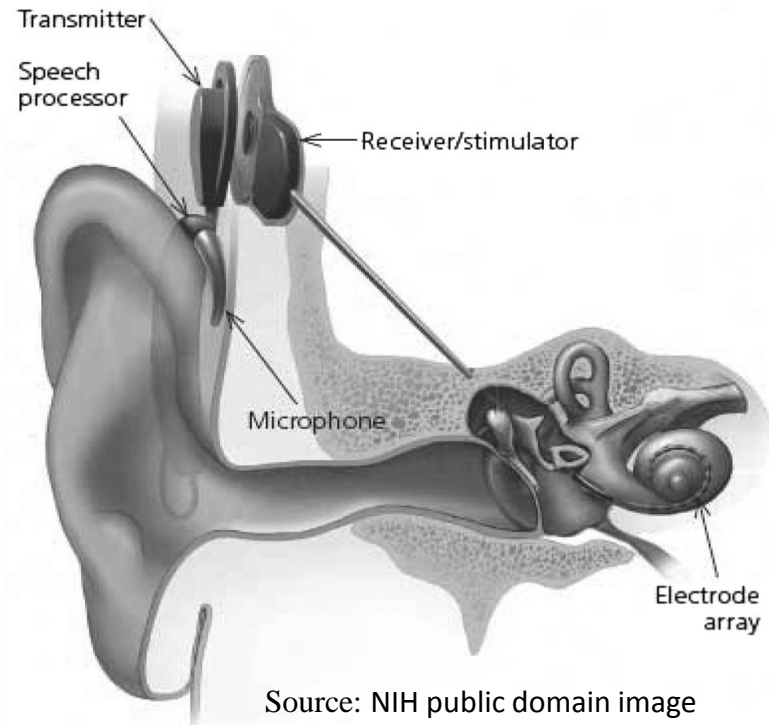
- Microphone
- Speech processor
- Transmitter

Internal system

- Receiver/stimulator
- Electrode array



Surgery required!



Source: NIH public domain image





Motivation

Lack of precise motion and feedback in the implant insertion procedure



Highly dependant on the surgeons skills and experience



Trauma on critical tissues in Cochlear Implant Surgery



Clinical need for visualization and precise implant insertion



Hypothesis



Using robotic system and intra-operative imaging feedback can enhance the outcome of the procedure

Problem

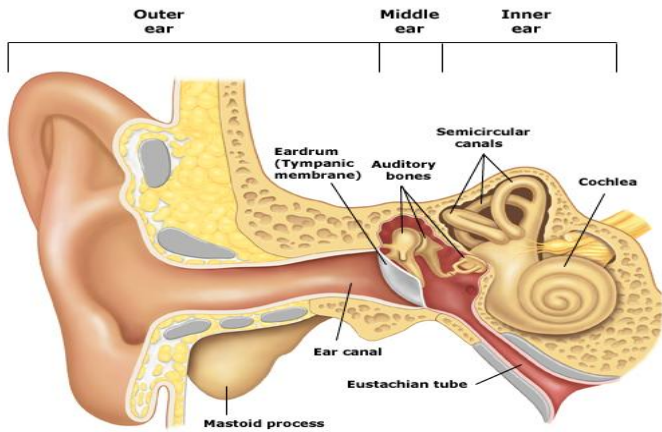


Solution

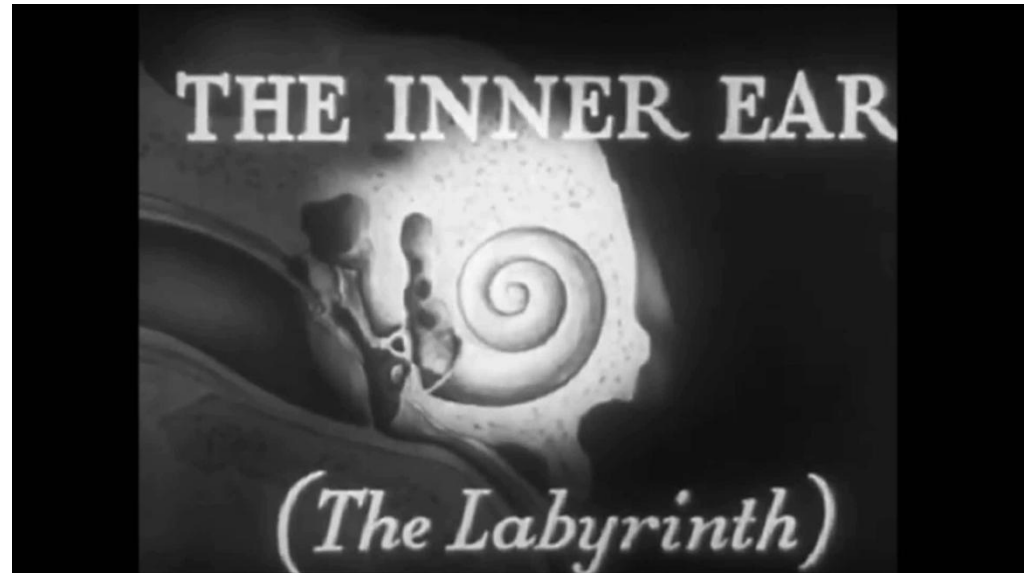




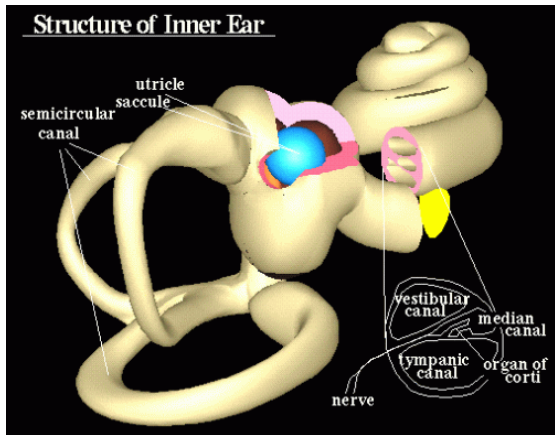
Background & Specific Aims



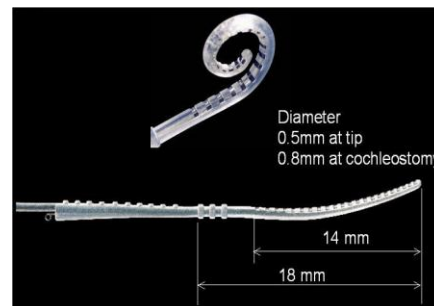
Ear Anatomy (courtesy Adams)



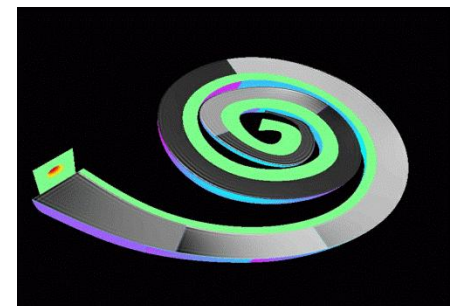
Anatomy of the inner ear (1940 knowledge builders)



Structure of the inner ear (caltech.edu)



Implant Structure Cochlea anatomy (caltech.edu)





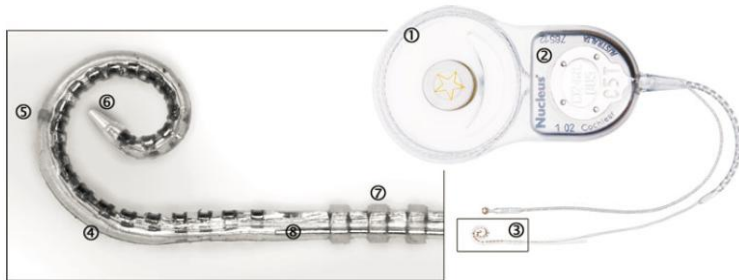
Overview of Standard Cochlear Implant Surgery



OR setup during the Cochlear Implant procedure



Video of the surgery by Dr. Sergio Sztern (CIGNO)



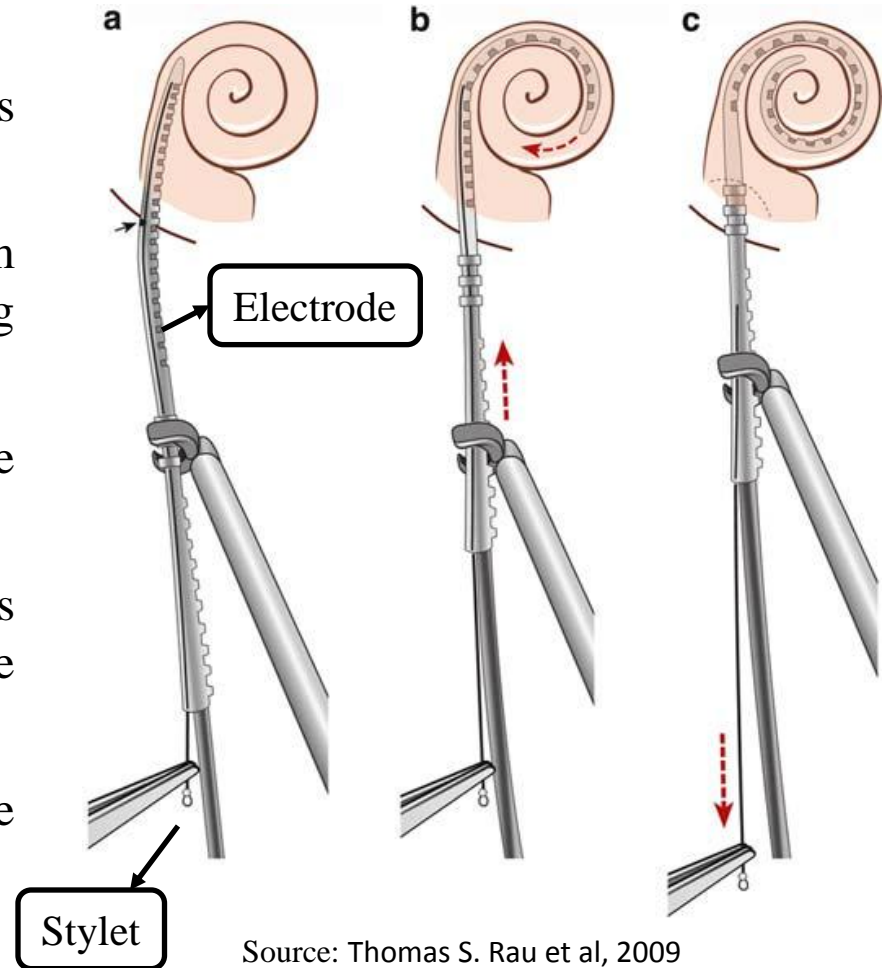
Structure of a cochlear implant





What is happening inside?

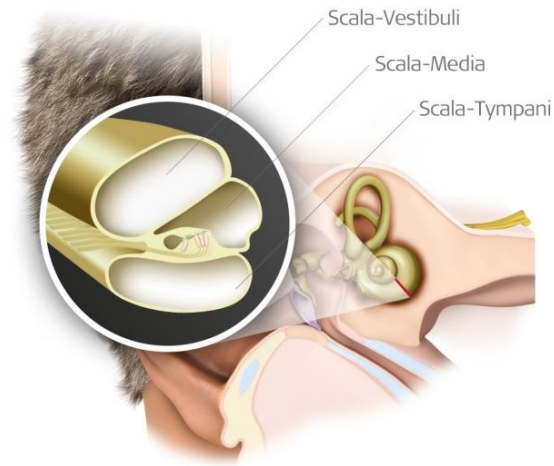
- Advance Off-Stylet insertion technique is used.
- Flexible curved electrode array (1 mm diameter) is advanced into 15-20 mm long channel.
- The whole electrode is inserted until the white marker reaches cochleostomy site.
- The stylet is held stationary, electrode is deployed off the stylet to give the electrode its naturally curved shape.
- After the ribs reach the cochleostomy site, the stylet is removed.
- Timing of these steps is very critical!



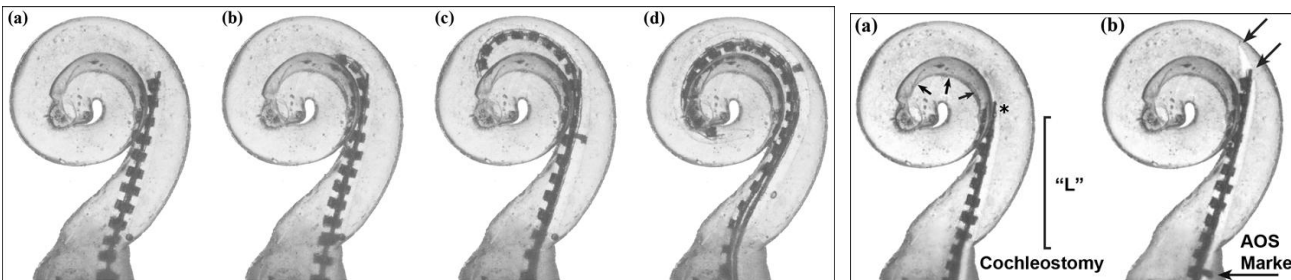


Background & Specific Aims

- During insertion, the electrode should travel in Scala-Tympani with no damage to the basilar membrane.
- For this, there is a critical location to begin off-stylet technique.



Source: <http://www.medel.com>

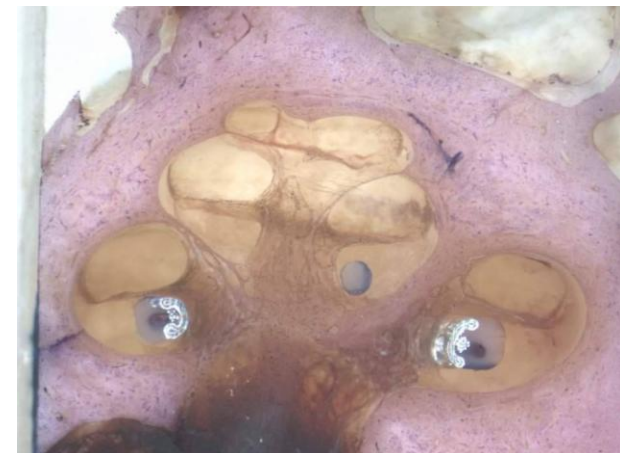


Source: Stephen J. Rebscher et al, 2008

- Electrodes should be located as close to modiolus as possible (perimodiolar position).



Source: www.utsouthwestern.edu



Source: professionals.cochlearamericas.com



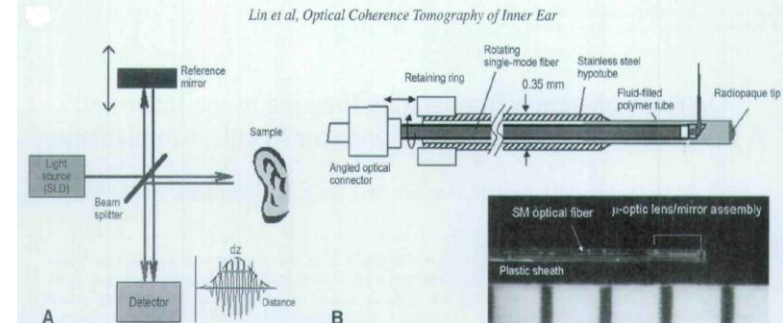
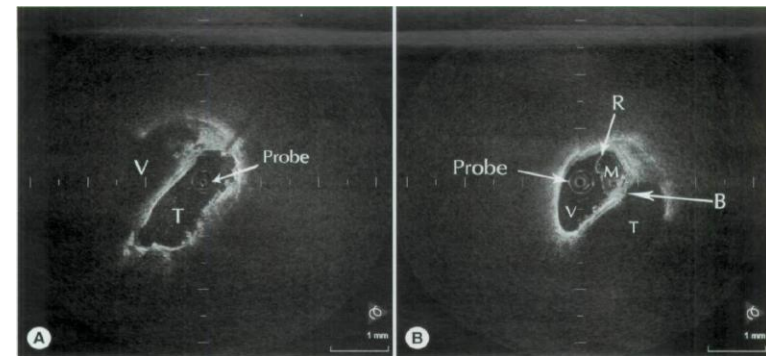
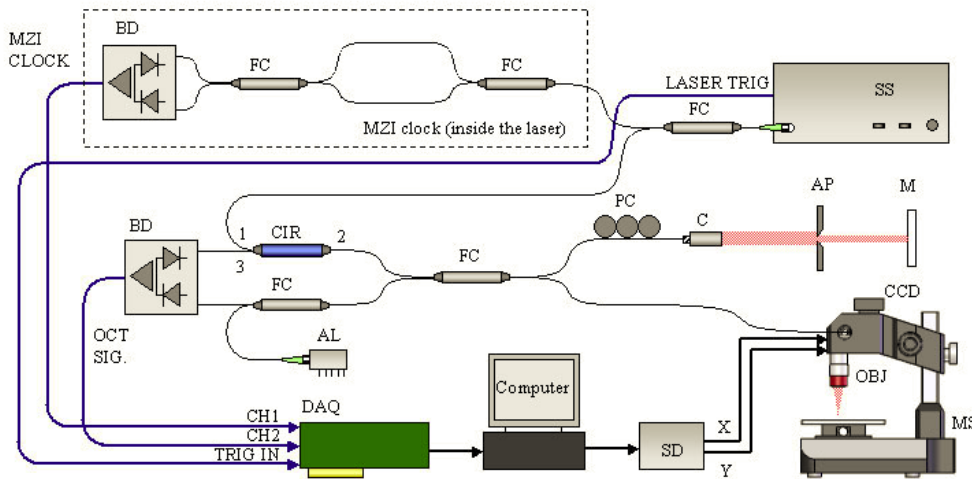


Background & Specific Aims

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Optical Coherence Tomography (OCT)

- Up to 25 times higher resolution than anything used in clinical medicine
- Small Catheters Suitable candidate for intraoperative procedures (Fiber Optics)
- Noninvasive imaging modality
- Realtime display
- Compact and portable



Source: James Lin et al., 2008



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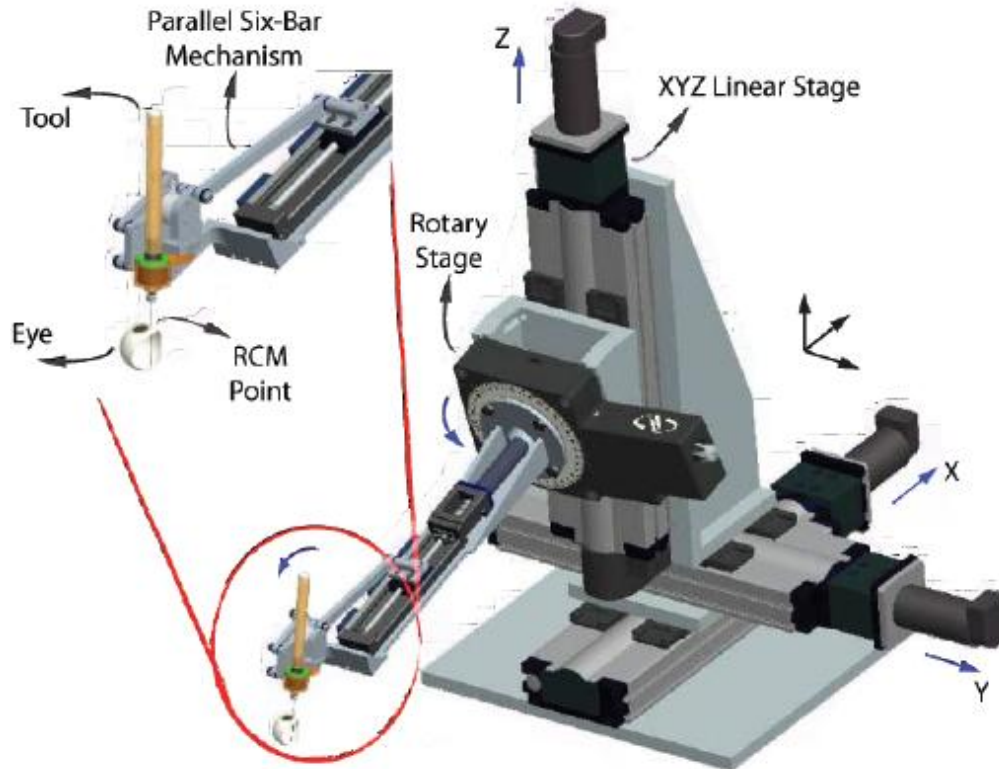
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Steady-hand Robot



Source: Uneri et al, 2010

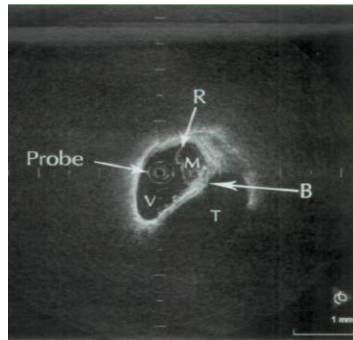
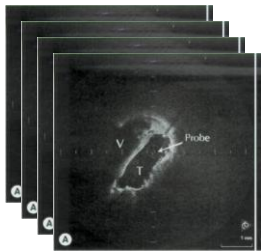
- Designed for sub-mm manipulation tasks.
- Provides smooth, tremor-free, precise position control.
- Combines manipulative transparency and immediacy of hand-held tools with precision and sensitivity of a machine.
- Successful tests and improvements in retinal microsurgery.





OCT

➤ 2-D OCT images



Source: James Lin et al., 2008



Steady-hand Robot

➤ Drive OCT probe inside the cochlea.

- Eliminate hand tremor during insertion.
- Limit tool motion and prevent intra-cochlear trauma.



➤ 3-D Cochlear Model

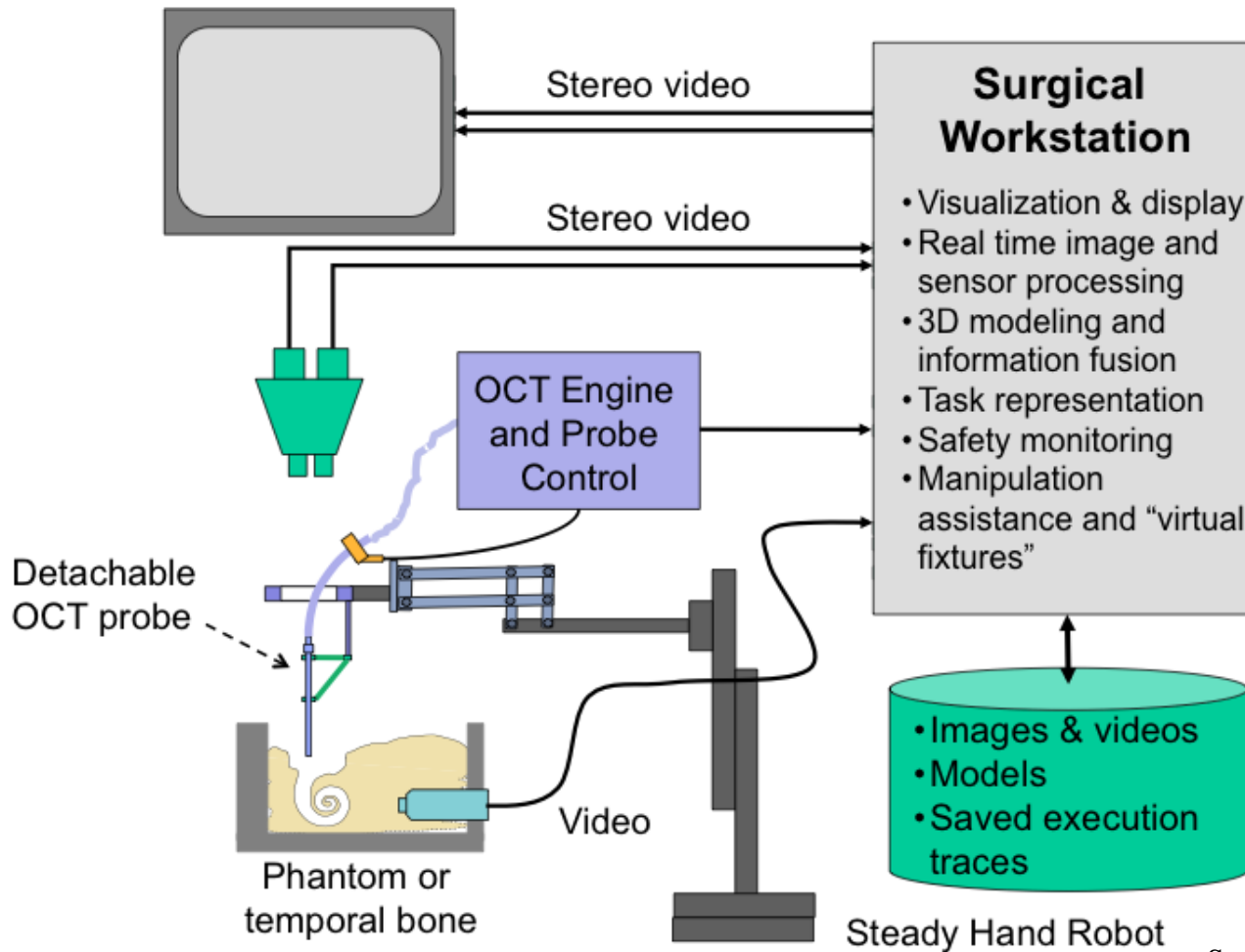


Source: archive3d.net





Technical Approach



Source: Prof. Taylor





Organization & Management

<u>Deliverables</u>	
Minimal	1. OCT-adapter design and fabrication for the steady-hand robot
	2. Tooling design and fabrication for electrode insertion with the steady-hand robot
	3. Procedure workflow for robotically assisted implantation
Expected	1. Software for controlling the motion of OCT probe inside the cochlear canal
	2. 3-D reconstruction software for building cochlear canal model from OCT images
	3. OCT scanning videos and images
	4. Implant insertion videos and images
Maximal	1. OCT system demonstration
	2. Implant insertion demonstration





Validation

- Most evaluation experiments will be performed on our artificial cochlea phantom.
- The surgeons will be asked to evaluate the robotically assisted procedure based on:
 1. Intracochlear damage (number of hits and forces on Scala-Tympani walls.
 2. Operation time
 3. Final electrode position.





Organization & Management

	<u>Dependency</u>	<u>Plan/Source</u>	<u>Status/Comments</u>
1	OCT imaging system	Schedule with Dr. Kang's lab	Scheduled
2	CI procedure observation	Schedule with Dr. Niparko's assistant	Done
3	Engineering and clinical mentors	Schedule weekly meeting with the team	Scheduled
4	Advance Electrode Arrays	Cochlear	We have 3; will probably need more eventually
5	Biohazard and blood pathogen training	Register/ take online class	Done/In progress
6	Temporal bones	Ask Drs. Niparko & Chien	Received
7	Cochlear phantom with video capture capability	Buy/build/borrow	Building will require a video camera (\$\$)
8	CISST libraries	Training	Training acquired
9	3D anatomical model of the inner ear with relevant structures	Order from Amazon	Received





Organization & Management

Period	Task	2/13	2/20	2/27	3/05	3/12	3/19	3/26	4/02	4/09	4/16	4/23	4/30	5/07	
Planning Period	Literature Survey	█	█				Spring Break								
	OR visit		█												
	Detailed Problem Definition and Conceptual Designs		█	█											
	Evaluation of Concepts			█											
	Project Proposal Presentation			█											
Design and Fabrication Period	Design of OCT Adapter (CAD Model) and Ordering Materials				█	█									
	Design of Implant Manipulating Adapter (CAD Model) and Ordering Materials				█	█									
	Development of OCT Control Software				█	█			█						
	Development of 3-D Reconstruction Software								█	█					
	Fabrication of the First Prototype								█	█					
OCT Testing Period	OCT Tests on Temporal Bone Model										█	█	█		
	Modifications and Debugging										█	█	█		
	OCT System Demonstration												█		
Robot Testing Period	Electrode Insertion Tests on Temporal Bone Model												█	█	█
	Modifications and Debugging												█	█	█
	Electrode Insertion Demonstration													█	
Final Presentation														█	





Management Plan

1. Weekly meeting with mentors for establishing goals under engineering and medical experience.
2. Weekly team meeting on Wednesdays and Saturdays for sharing updates, discussion, further planning, and revising plans.
3. We are planning to spend a total of 50 hrs per week on this project.





Bibliography & Reading List

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- [8] Stöver T, Issing P, Graurock G et al (2005) Evaluation of the advance off-stylet insertion technique and the cochlear insertion tool in temporal bones.
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- [11] Hussong A, Rau T, Ortmaier T et al (2010) An automated insertion tool for cochlear implants: another step towards atraumatic cochlear implant surgery.



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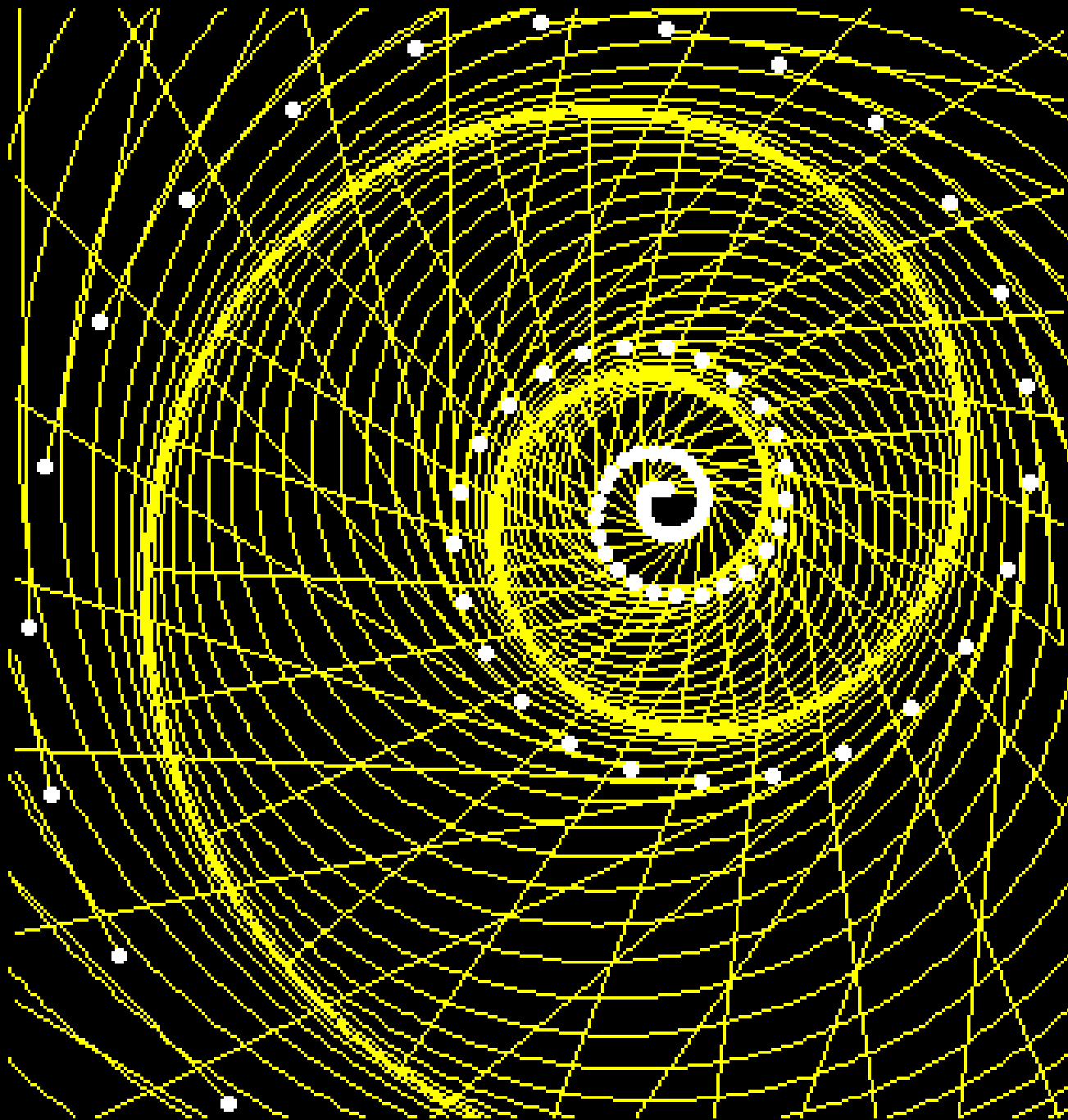
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**Questions
&
Comments**