

Dynamic Simulation of a Pacemaker Lead Using MSC Adams (2006-19)

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Abstract

Dynamic Simulation of a Pacemaker Lead Using MSC.ADAMS

2006-19

A model of a pacemaker lead with an extendable/retractable fixation helix was constructed using MSC Adams in order to study the forces and motions associated with the implant of such a device into a human patient. The lead body components were modeled as a series of cylindrical parts connected with MS Adams beam elements. A custom contact routine was used to avoid false forces created by the interaction of the edges of these cylinders. A custom menu system was created using macros to facilitate construction of the model. Heart and vein geometry can be loaded into MSC Adams to provide the environment in which the lead operates. Early validation studies have shown promising results.

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The Problem Statement

- A pacemaker lead is the insulated wire that is threaded into a patient's heart to deliver energy from a pacemaker.
- One type of lead contains a retractable helix that provides fixation into the tissue and acts as an electrode.
- The dynamics of the implant of this type of lead are subtle and very difficult to study experimentally:
 - Small forces
 - Small parts
 - Challenging environment (the body)





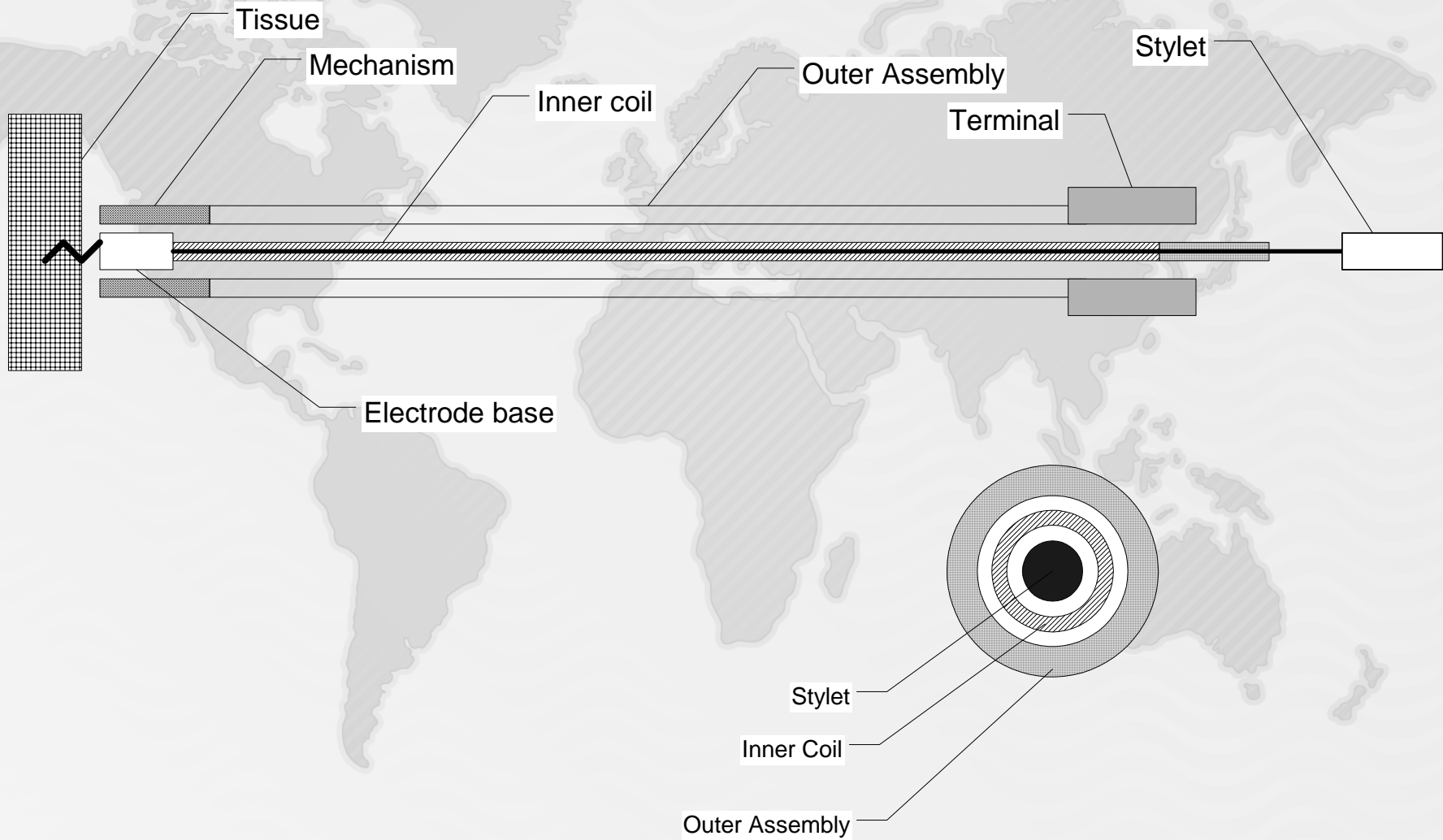
The Problem Statement

Does this behavior really happen *in vivo*?





The System



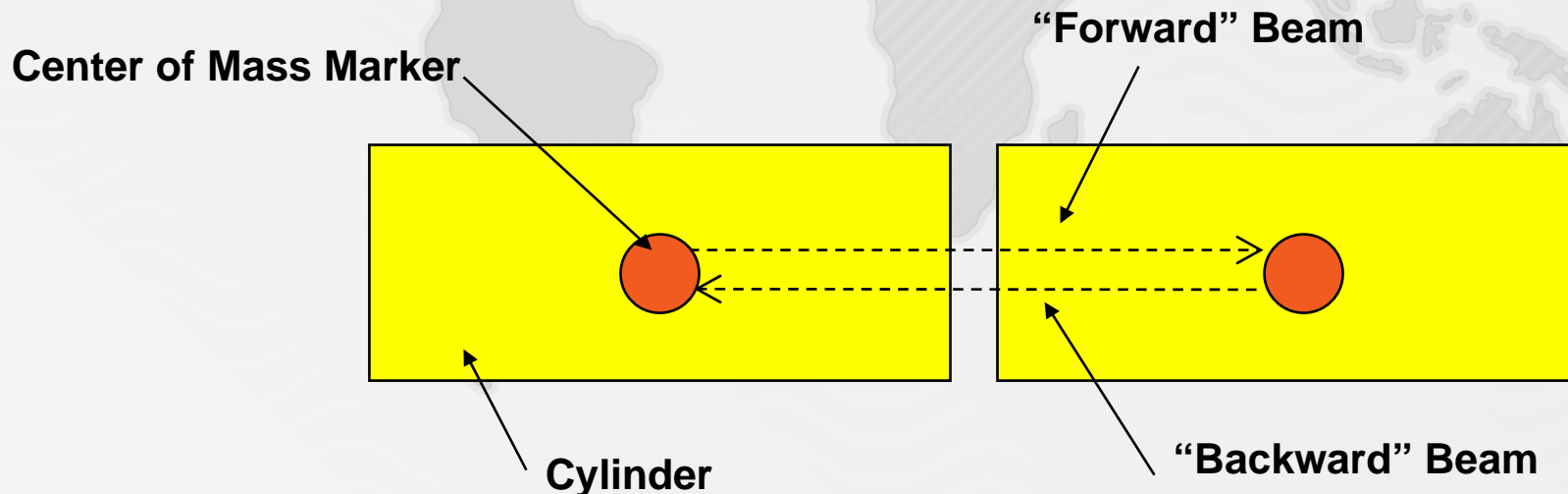


Analysis

- **FEA techniques have been used to study the performance of pacemaker leads.**
- **Modeling the screw mechanism is difficult in FEA.**
- **In MSC Adams, mechanisms are modeled easily, but a flexible lead body is not.**
- **MSC Adams has been used to predict the trajectory of (static) engine hoses. [ref 1 and 2]**
- **Adams has also been used to model tractor and tank treads.**
- **Why not pacemaker leads?**

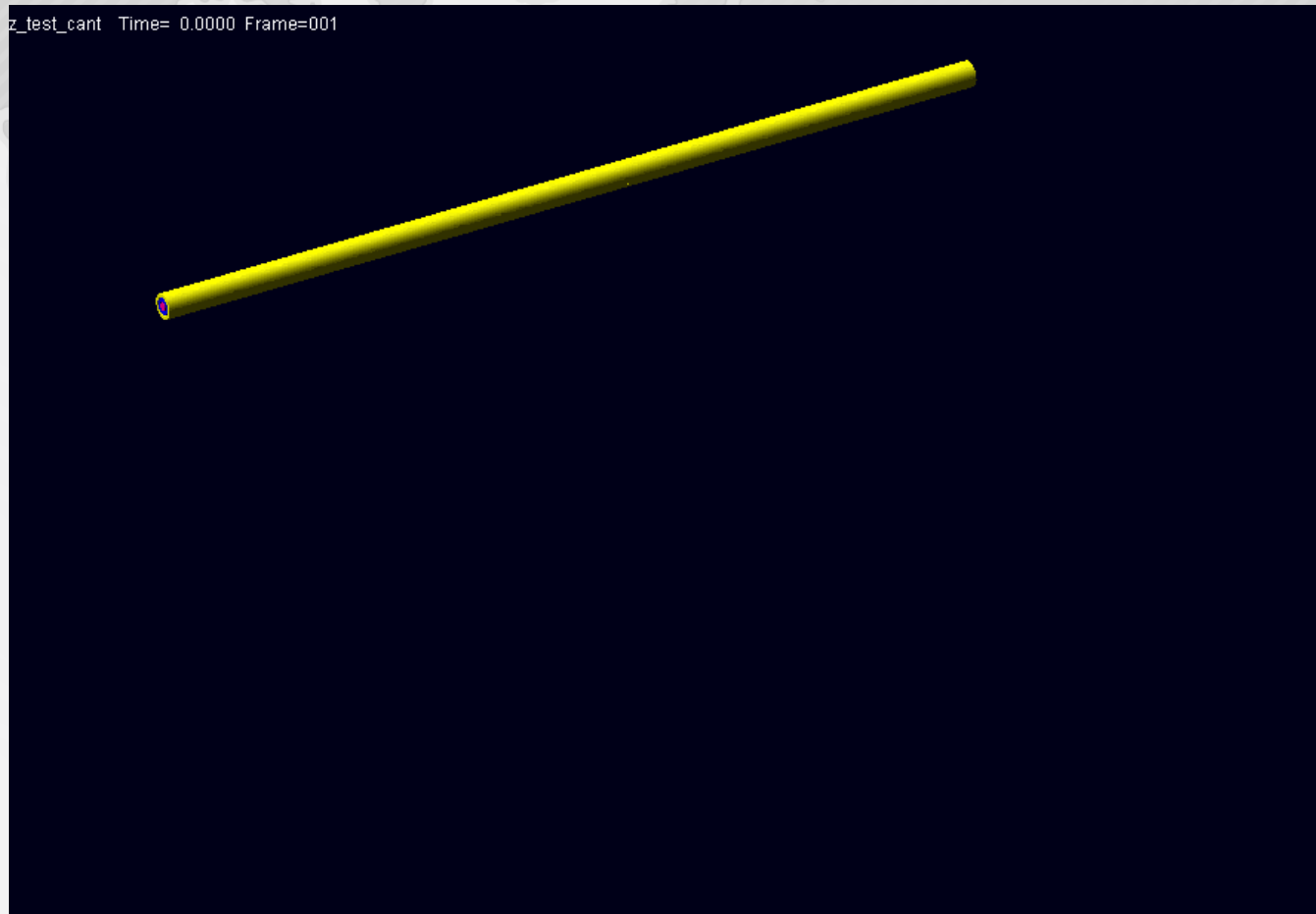
Analysis

- The lead was modeled as a series of cylinders coupled with beam elements.
 - The beams are mass-less .
 - The mass is distributed amongst the cylinder parts.
- This is essentially a FEA methodology.



Analysis: Proof-of-Concept

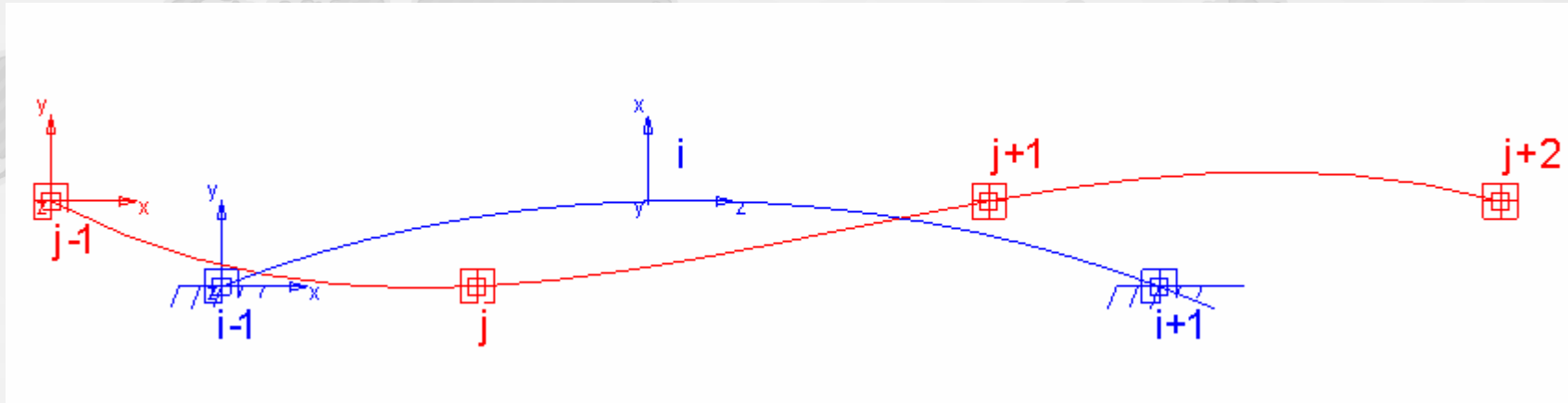
- This early proof-of-concept model showed that the technique resulted in “realistic” behavior.



Analysis: Contacts

- A special FORTRAN routine was developed to address the problem that the edges of the cylinders from the co-axial layers of the lead would interact with each other, creating unrealistic behavior.
- We developed a unique contact macro that fits piece-wise splines between successive cylinder markers.
- The macro uses this continuous curvature to calculate the contact forces between the inner and outer cylinders of the lead.
- Thus, the contact routine does not use the part geometry and thus doesn't "see" any corners.

Analysis: Contact Logic



- For example, if we want to find the force on the inner coil markers (blue) caused by the outer coil (red)...
 - Fit a spline between the red markers.
 - Interpolate to find the location in space for the red curve near the blue marker.
 - Use that data and the known coil radius to determine whether contact occurs.
- Normal Adams contacts are used between the outer assembly and the heart/vein environment.

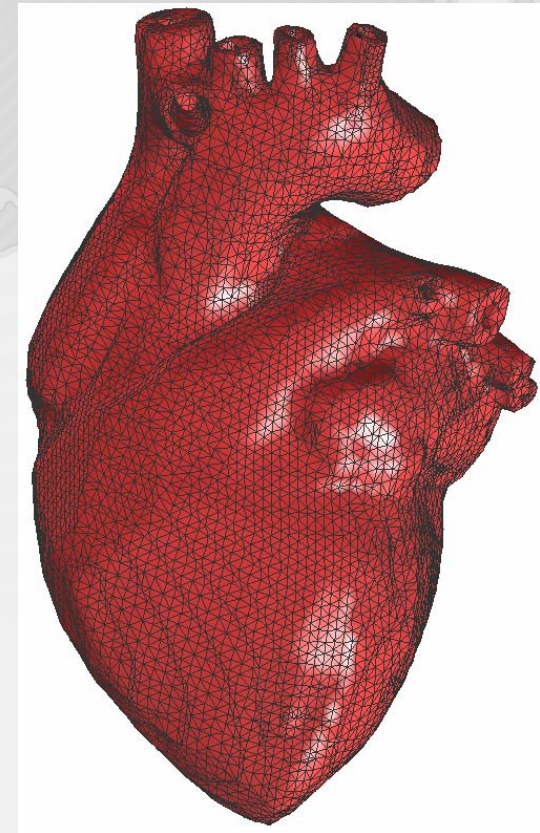
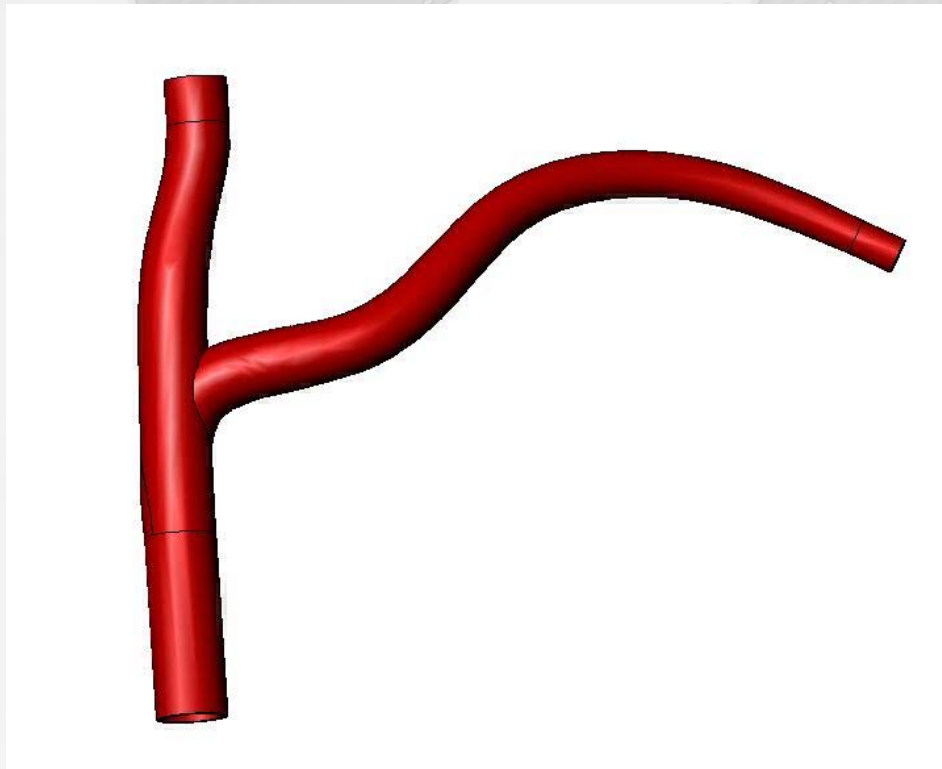
Analysis: Other Features

Other features of this initial version of the model:

- A menu system was developed using macros to facilitate the construction of the model.
 - An entire model can be built in about 10 minutes.
- Helix-tissue interaction can be included by downloading experimental data.
 - We track the furthest penetration of the helix into tissue
- The stylet wire that is used to steer the lead can be given a curved shape.

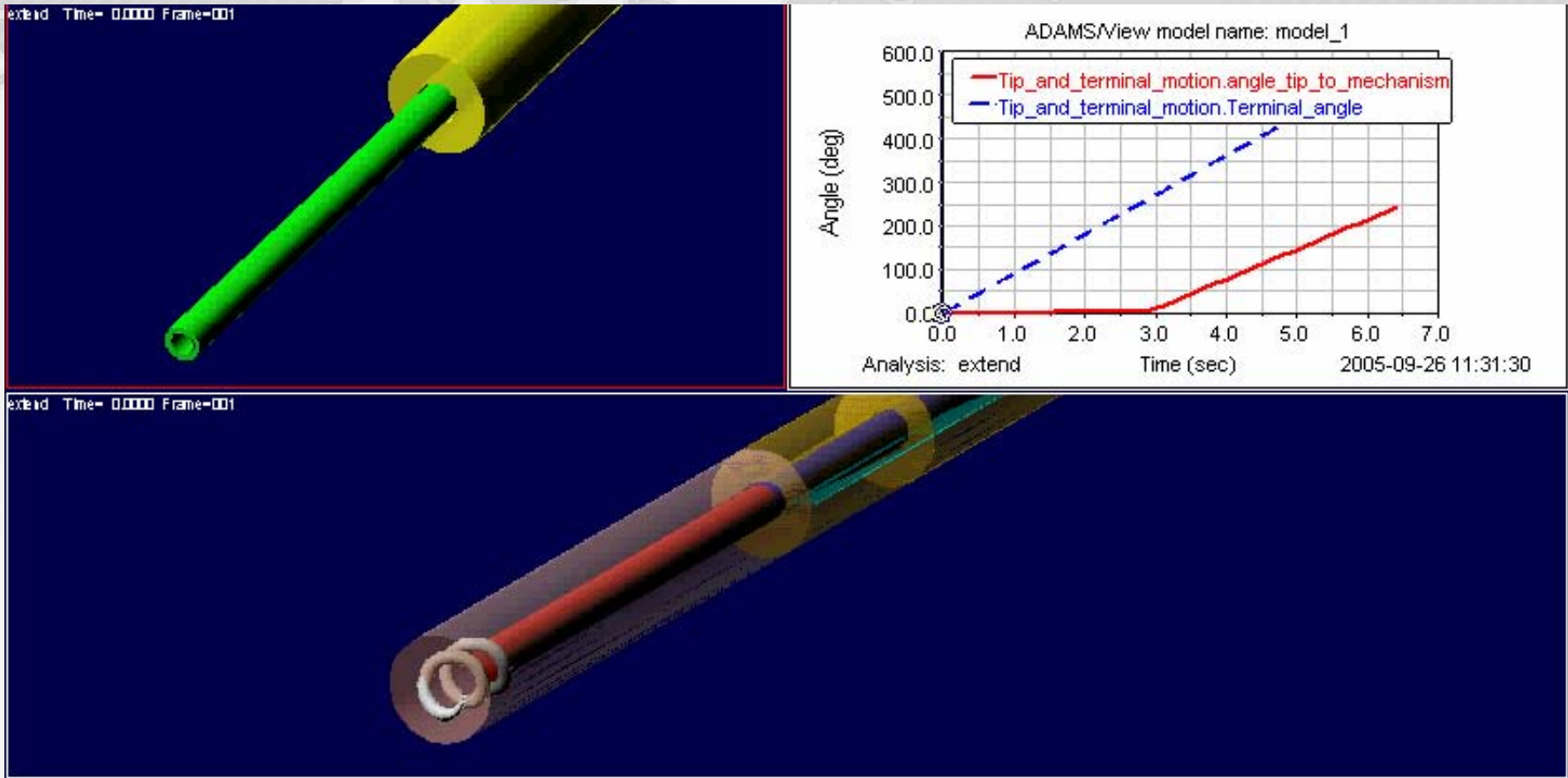
Analysis: Other Features

- The “environment” for the lead is a rigid geometry of the anatomy that can be created or based on a real patient.
- Advances in MRI and CT scan technology promises to make this process easier.





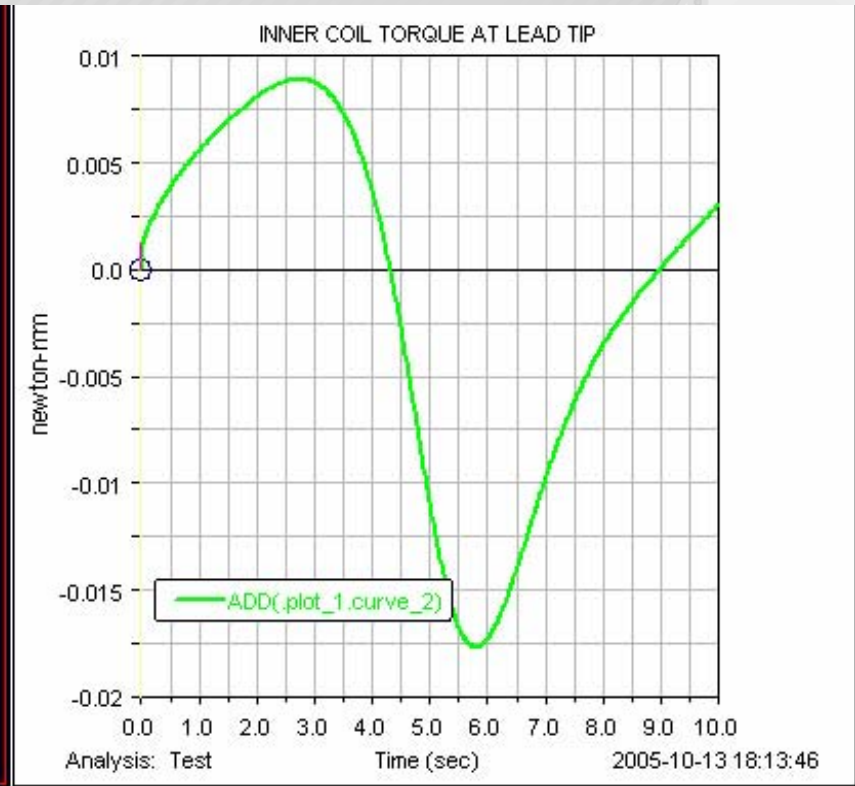
Results: Extending the Helix





Results: Comparison to Experiment

- What is the peak torque created in the inner coil during the (idealized) motion that lead sees in the right atrium of the heart?
- Results agree with experiment well (<10% error).



Conclusions

- **We were successful in building an initial version of a pacemaker lead dynamic model.**
- **Significance:**
 - Use of a rigid-body dynamics code to model a dynamic flexible object.
 - Alternative to FEA models, which generally do not include working tip mechanisms.
- **Return on Investment:**
 - Promises to provide a system-level model of the device behavior.
 - Allows the study of parameters that are almost impossible to measure experimentally.
 - Reduces the need for animal testing.

Acknowledgements

The authors would like to acknowledge Jesper Slattengren for his significant contribution to the success of this project.

References

- (1)** Chipperfield, K, and Vance, J, “Modeling of Hydraulic Hose Paths”, Proceedings of 2002 ASME Design Engineering Technical Conferences and Computer and Information in Engineering Conference, ASME DAC-34152, 2002.
- (2)** Keil, M, et al, “Modeling and Validation of Large Hydraulic Hose Deflections”, Proceedings of the 20th Annual Brake Colloquium and Exhibition, SAE 2002-01-2589, 2002.

Thank you!



Questions?

