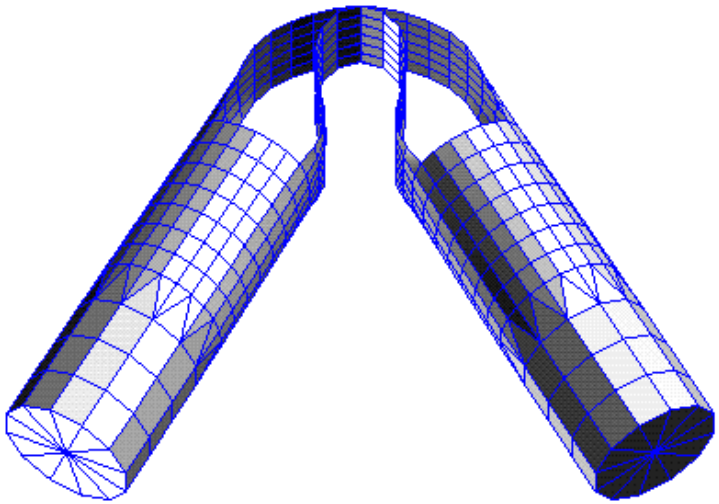
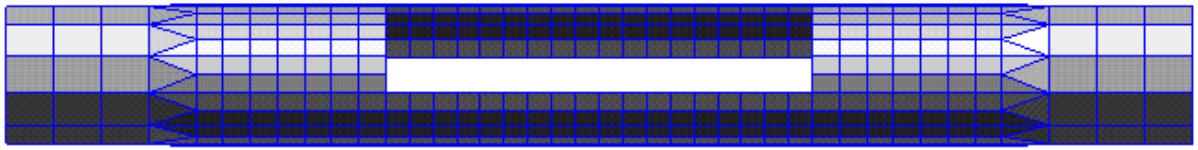
Nonlinear Analysis of the ST5 Magnetometer Boom





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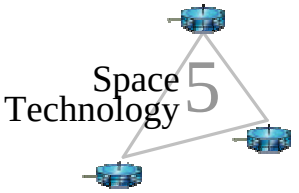
Agenda



- Problem Description
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- Typical Model
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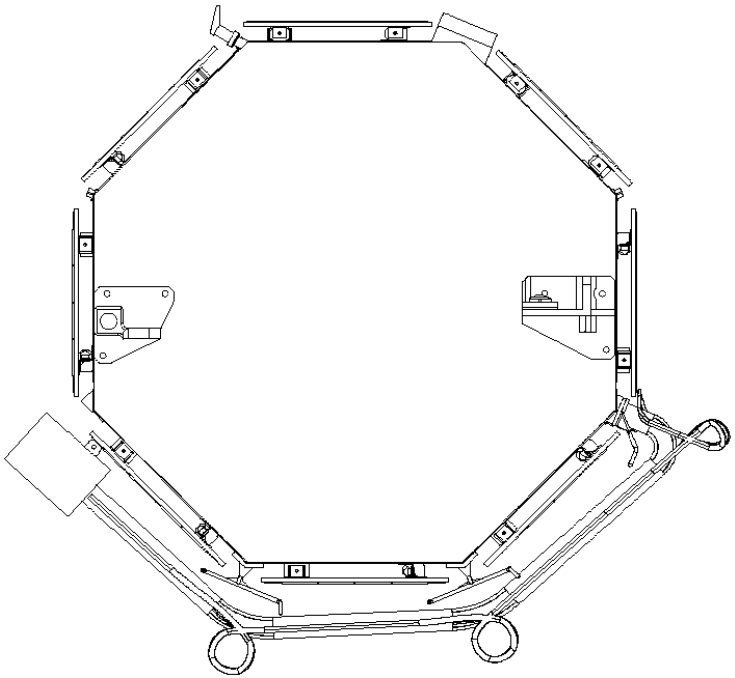
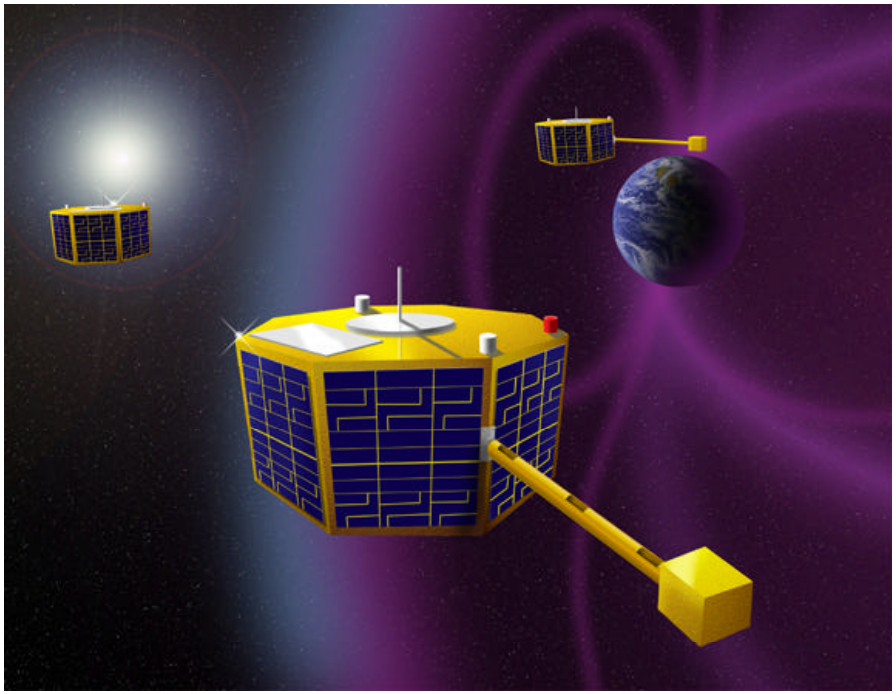
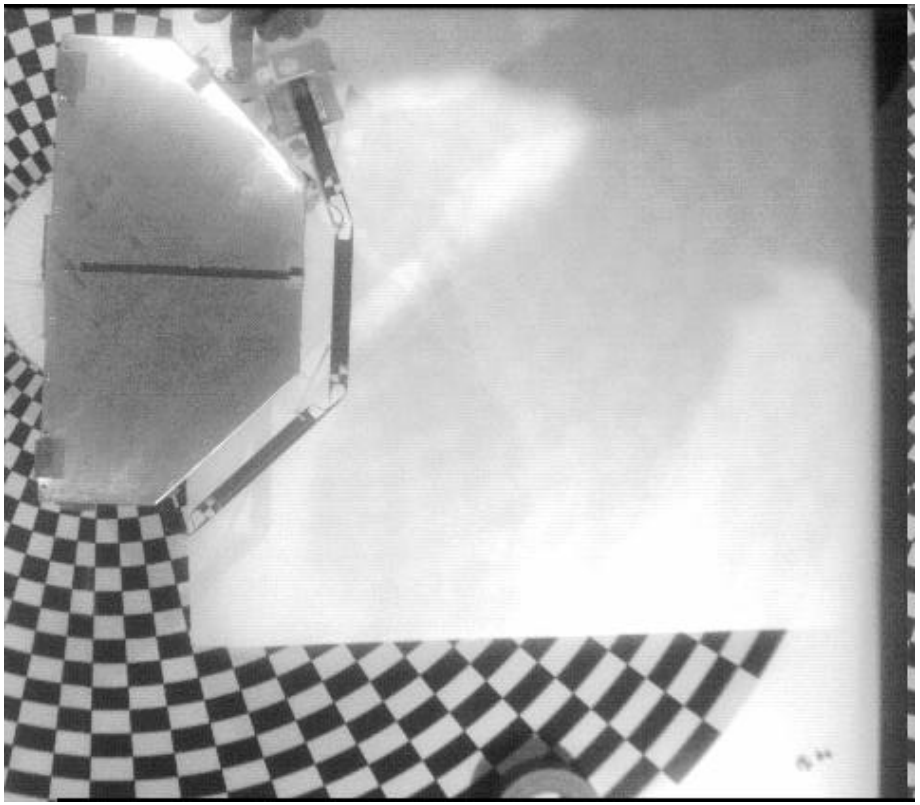
Problem Description





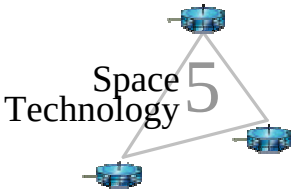
- Boom mounted magnetometer is one of the primary instruments on ST5
  - Mission consists of a three S/C constellation to test nanosatellite technologies
  - Overall S/C dimensions ~ 18 in wide and ~ 10 in high
  - Overall S/C weight ~ 50 lb

Problem Description (continued)



- Because of postbuckling behavior, regular linear statics solution sequences not adequate

Linear Versus Nonlinear Analysis

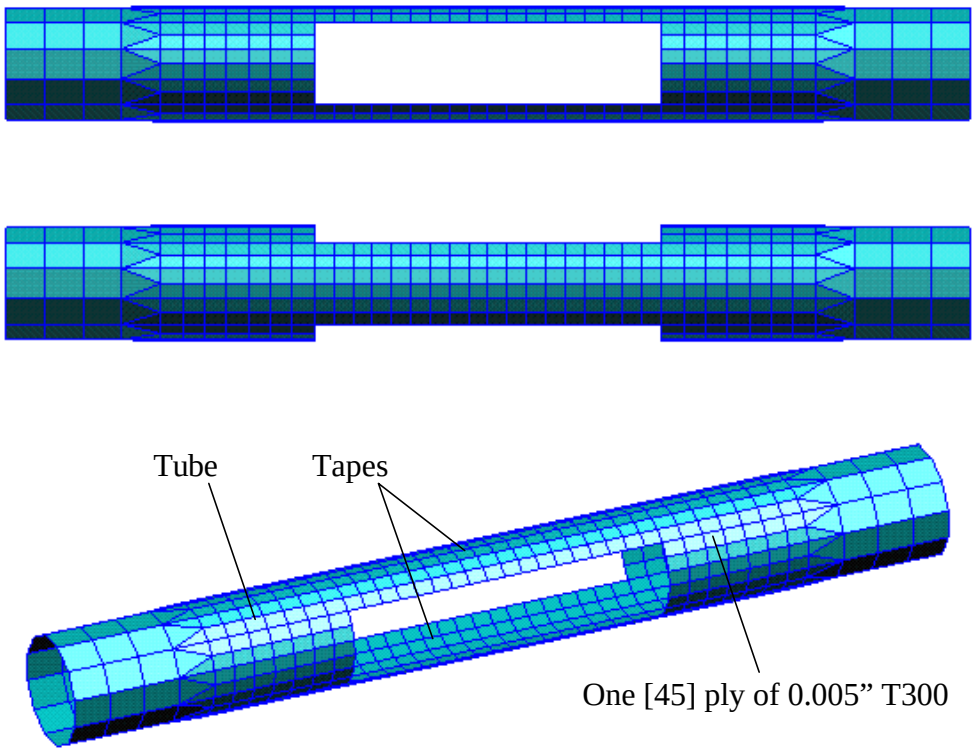


- Linear analysis
  - Comprises bulk of the work done at GSFC
  - Useful for analysis of deployed boom (normal modes, thermal distortion, etc)

- Nonlinear analysis
  - Minimal GSFC heritage, though capability has existed in various analysis codes
  - Only recently has nonlinear analysis been used for thin membranes, MEMS, and postbuckling

- Analysis of the boom has been marked by steady progress through a lot of trial and error

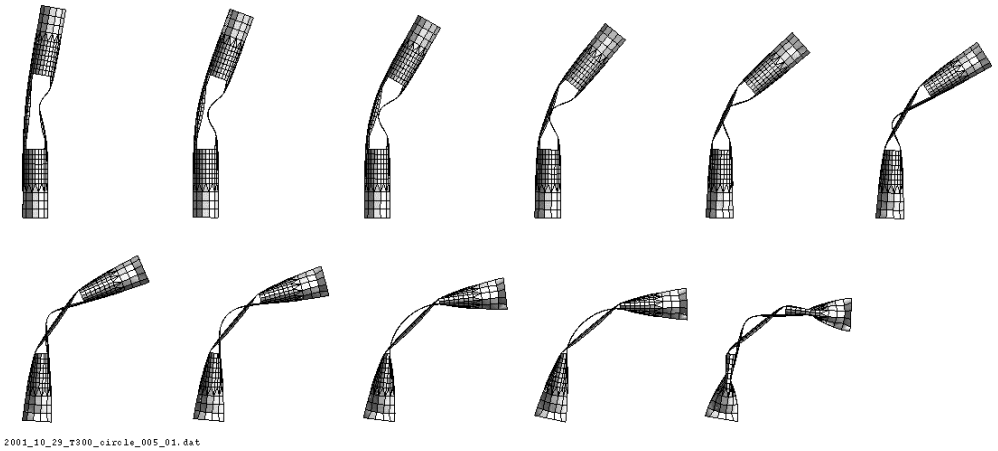
Typical Model

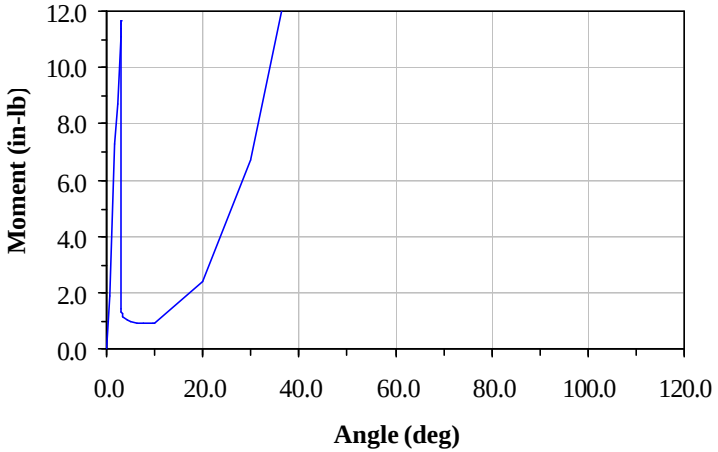


- Main items of interest are torque capability of joint and tape stresses
- Variables include material, radius of tapes, and size of windows

Trial and Error, Part 1

- Early runs did not take into account contact between the tapes and used rigid elements (RBE2) at each end to enforce a rotation

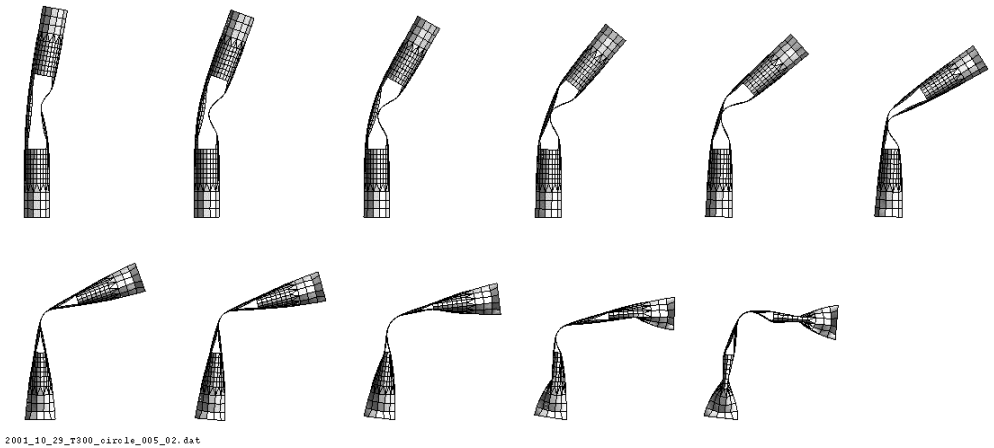


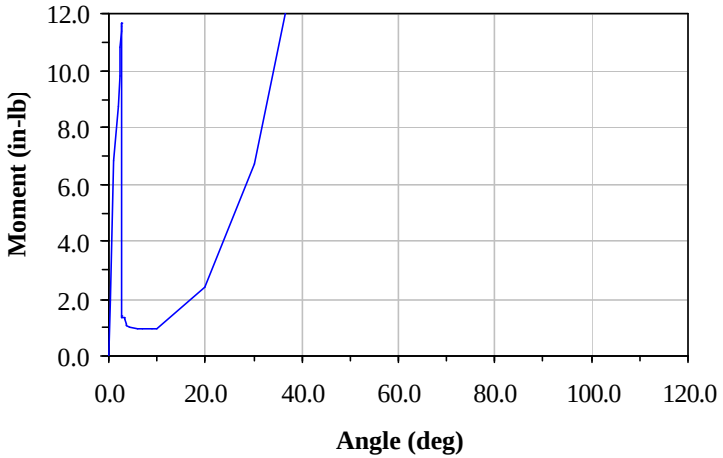


- Problem due to lack of contact between tapes is obvious
- Behavior of end moment after snap-thru does not seem correct
- Run time of 2.40 hrs

Trial and Error, Part 2

- Contact between the tapes added and used rigid elements (RBE2) at each end to enforce a rotation

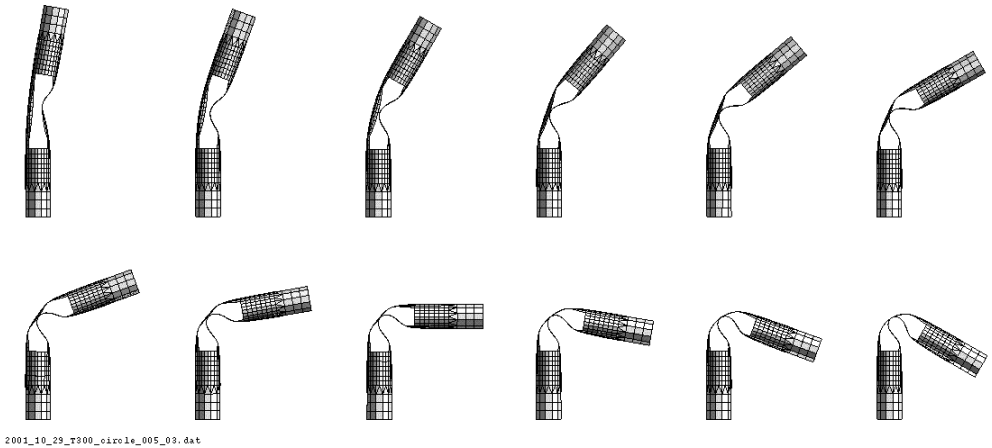


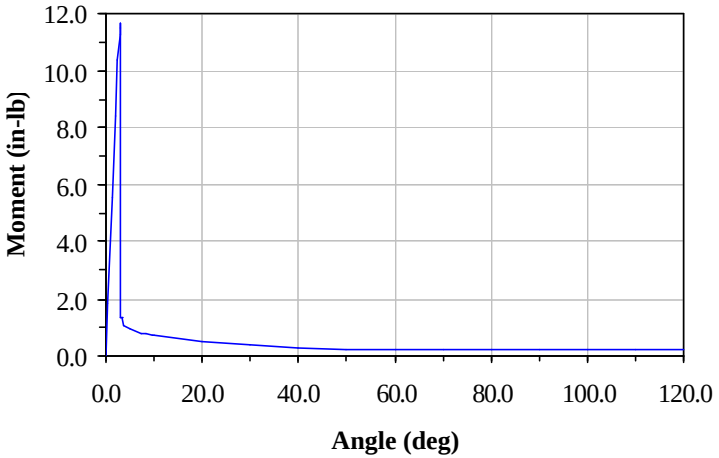


- Contact between tapes more correctly modeled
- Behavior of end moment after snap-thru still does not seem correct
- Run time of 9.50 hrs

Trial and Error, Part 3

- Contact between the tapes retained and rigid elements (RBE2) at each end replaced with massless aluminum plate elements to enforce a rotation



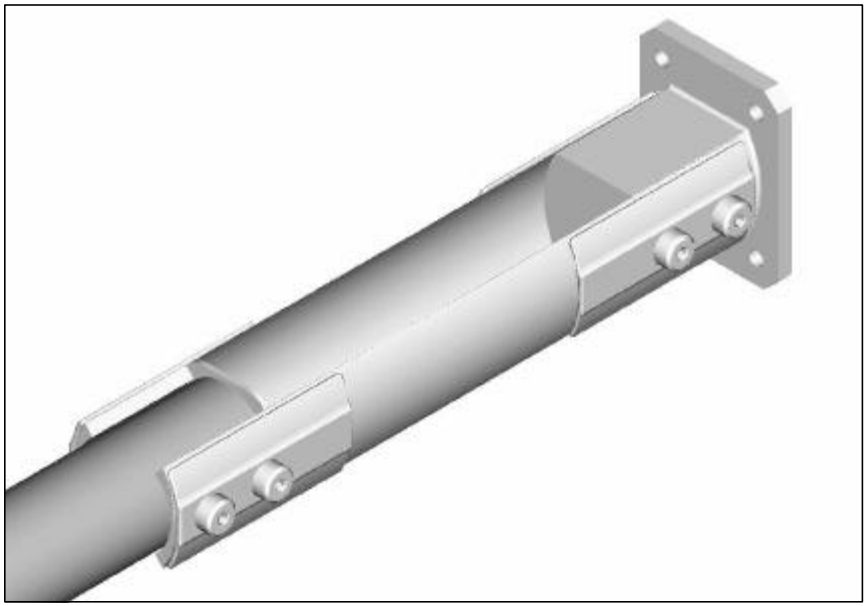


- Contact between tapes and behavior of end moment after snap-thru both seem correct and clean
- Run time of 3.35 hrs
- Important result was that the steady-state torque was too low

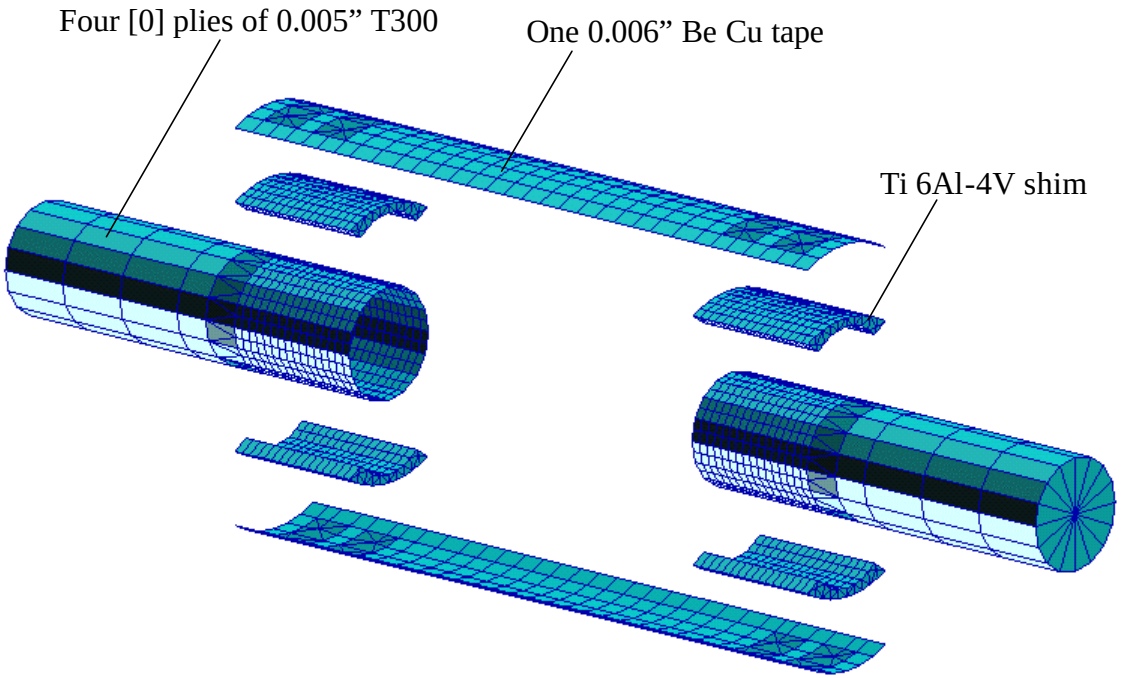
Refining the Design

- Because torques from integral boom designs using one to several plies of composite were not high enough, investigated other alternatives

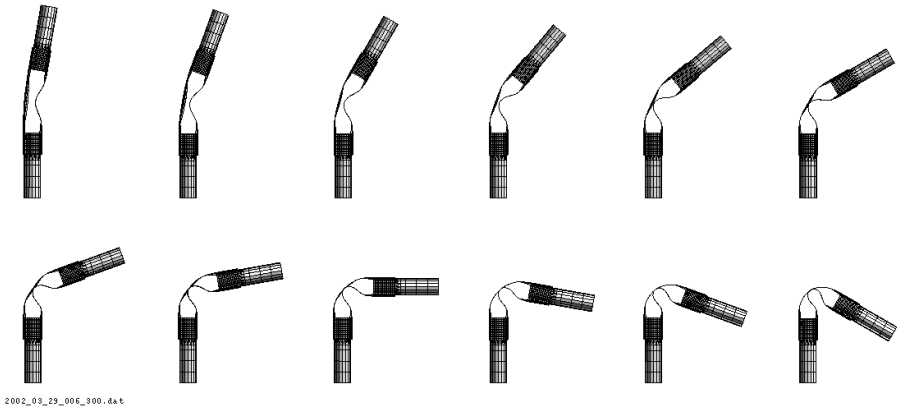
- Went from integral boom design to assembled boom design
  - Tube sections still made of composite
  - Tape sections made of Be Cu strips bolted to tube sections

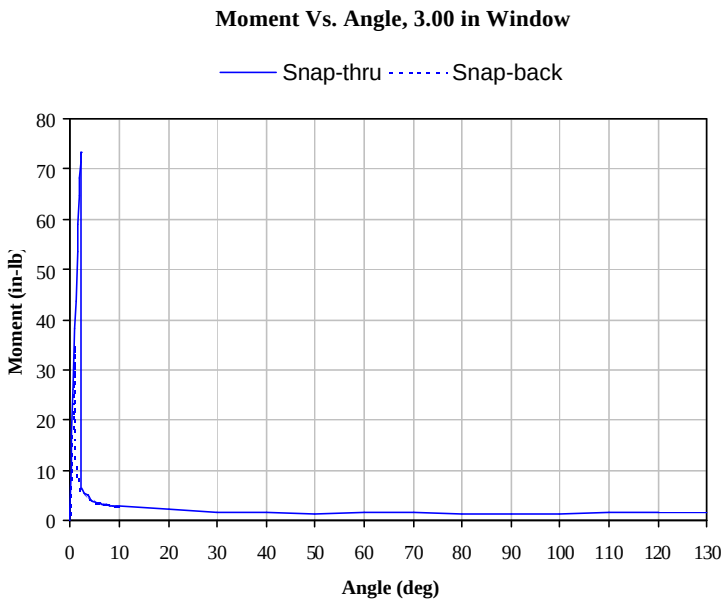


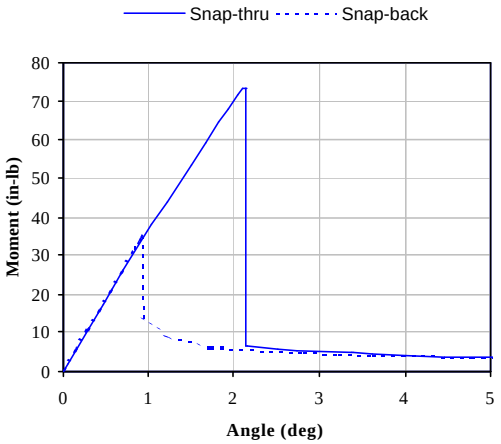
Latest Model



Latest Results

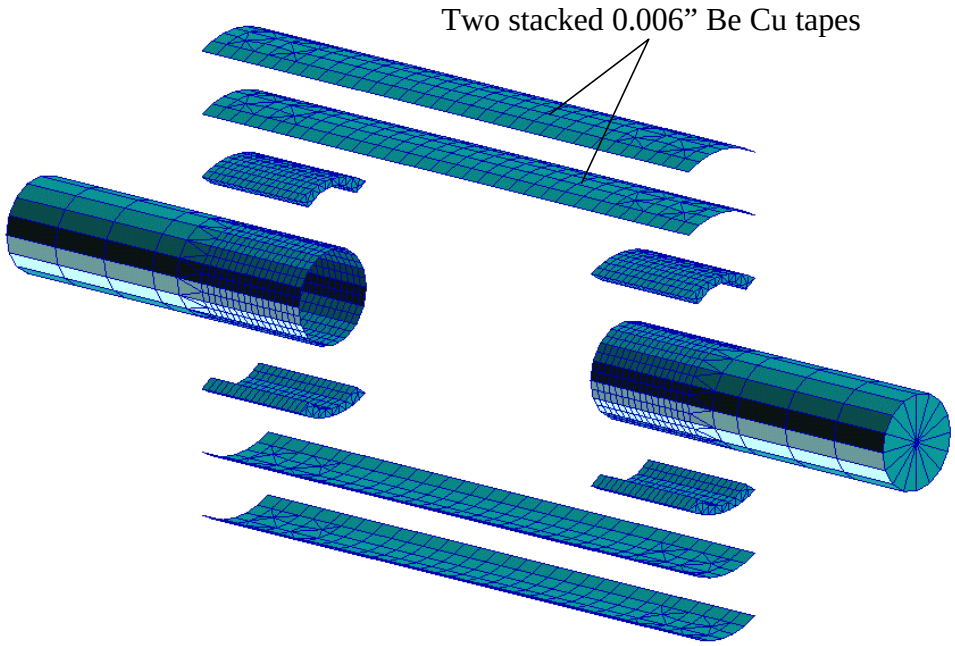






Latest Results (continued)

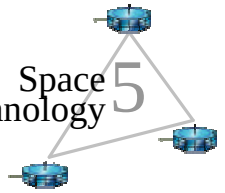
- Run time of 6.64 hrs
- Important result was that the steady-state torque was increased by quite a bit (up to ~ 1.4 in-lb)
- Be Cu tapes stacked to nominally double steady-state torque (because of additional complexity and excessive CPU time, did not attempt to run; verifying by testing)



Current Status

- Individual boom joints as well as full-length boom in fabrication
- Torque testing of individual joints to begin shortly followed by G-negated deployment tests of full-up boom mounted to a S/C mock-up

Conclusions / Lessons Learned



- Significant progress made in performing and understanding the nonlinear analyses of the boom since the last FEMCI workshop
- Doing trade studies of the different variables in the problem not very efficient because of large CPU times needed for each run
- Future analysis to support test program as needed