The loop vector equations are:
\[ (\dot{\mathbf{l}}_{\text{G}} + \dot{\mathbf{l}}_{\text{G/G}}) - (\dot{\mathbf{l}}_{\text{G}} + \dot{\mathbf{l}}_{\text{G/G}}) = \mathbf{i}_k \hat{\mathbf{s}}_k \]

EXPERIMENTAL MODEL
- Torso is based on the i-Suit, a prototype planetary spacesuit
- i-Suit Dimensions expanded to make very large torso, which is easy to ingress/egress
- Manually adjustable linkages
- Used in conjunction with analytical models to demonstrate feasibility and advantages of morphing concept

RESULTS
- The Inverse Kinematics (IK) of the system (calculating the link lengths given the pose of the rings), have been modeled and solved analytically
- The Forward Kinematics, opposite to the IK, have been solved numerically (model shown on right)
- The experimental model has demonstrated that the Morphing Upper Torso can be reconfigured, prior to pressurization, to any required suit dimensions, as shown below

CONCLUSIONS
- The Morphing Upper Torso is a feasible suit architecture which may solve many of the challenges facing spacesuit engineers
- Given incremental evolution of technology, this human-robotic symbiosis can be implemented in four progressive modes, each mode providing enhanced capabilities:
  - Passive Static: Links are lengthened during donning and doffing, thus greatly increasing don/doff ease and efficiency, and then manually reset to individual dimensions prior to pressurization. This enables one suit to fit perfectly to multiple users.
  - Active Pressurized: Links can be adjusted after pressurization, providing adjustment for body shape changes.
  - Active Reconfigurable: The suit can be set to specific configurations for each task such as walking, hammering, or sitting.
  - Active Adaptive: The suit continually adjusts to wearer’s body kinematics in real time.
- Many challenges still remain: better actuator technology is required, mass and power must be minimized, much more experimental testing is needed
- This work leads towards a fully augmented pressure suit, which will significantly increase the astronaut's capabilities and the efficiency of future planetary EVA

FUTURE WORK
- Integration into MX-2, including suit-mounted robotic arm for enhanced human-robotic symbiosis
- Motion capture study is underway to obtain ring trajectories
- Controller design is underway to track these trajectories