COMSOL® Application Builder

Lets end-users harness the power of numerical modeling and simulation (Poster: 112)

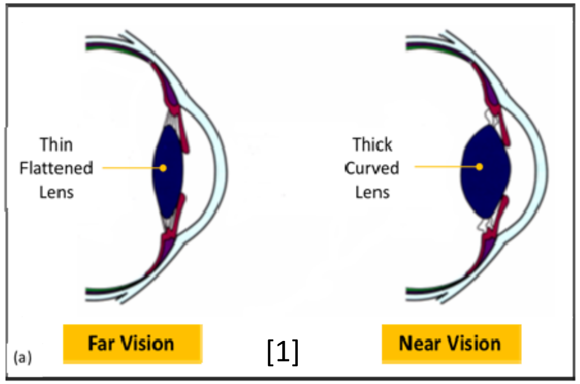
J. Speyrer[1], A. Maurer[1], D. Enfrun[1], R. Rozsnyo[1]

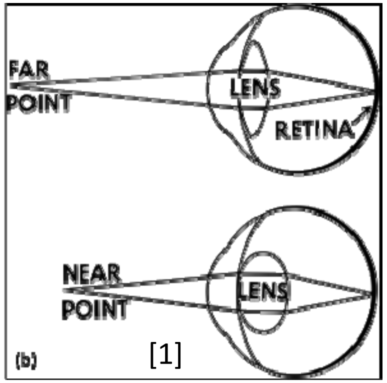
1. R&D, Kejako, Plan-les-Ouates, GE, Switzerland
2. MNCM, HES-SO-University of Applied Sciences and Arts, Geneva, GE, Switzerland

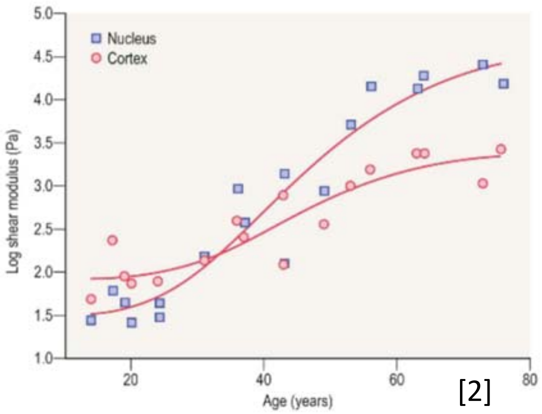
Contact:
David Enfrun, CEO Kejako
d.enfrun@kejako.com
+41 (0)79 946 27 51

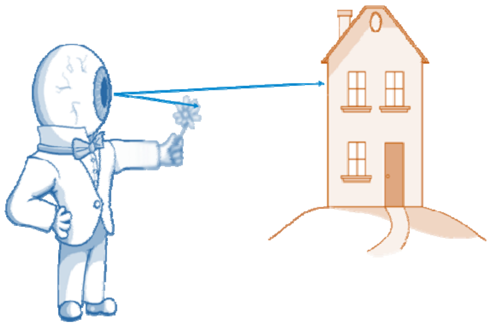
COMSOL CONFERENCE 2018 LAUSANNE

Introduction









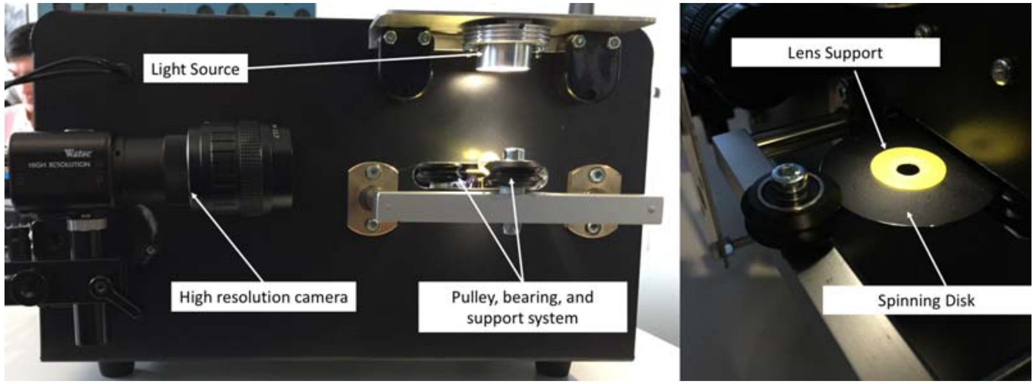
- Kejako is focused on developing innovative treatment solutions to combat and reverse the effects of presbyopia
- Presbyopia is a naturally occurring age-related disease affecting the crystalline lens
- Presbyopia" means "old eye" in Greek
- Presbyopia – results from stiffing of the lens with age
- Presbyopia- eyes lose ability to see things up close clearly

Presbyopia affects nearly 1.7 billion people worldwide today, and that number is expected to soar to 2.1 billion by 2020

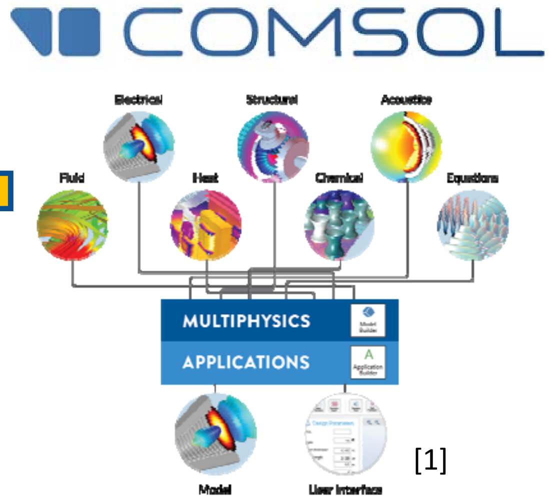
1. « Accommodation (eye) » Wikipedia, the Free Encyclopedia, Wikimedia Foundation, Inc, 17 June 2017, en.wikipedia.org/wiki/Accommodation_(eye). Accessed 2 Jan. 2018.
2. Kaufman, Paul L., et al. Adler's Physiology of the Eye. Elsevier Health Sciences, 2011

Problem to Solve

- Derive the Crystalline lens' shear modulus value
  - Using a Lens Spinning Fixture to simulate in-vivo forces on the lens, which induces deformation of the lens thereby changing the lens' shape
  - Using FEA modelling to reverse engineer the shear modulus value of the lens based on lens spinning extracted geometrical data



LENS SPINNING FIXTURE

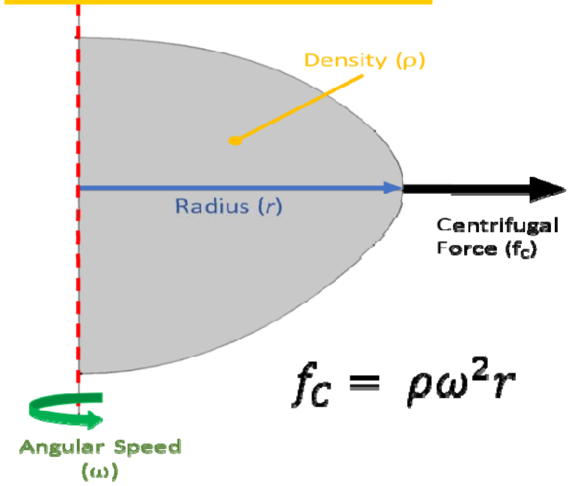


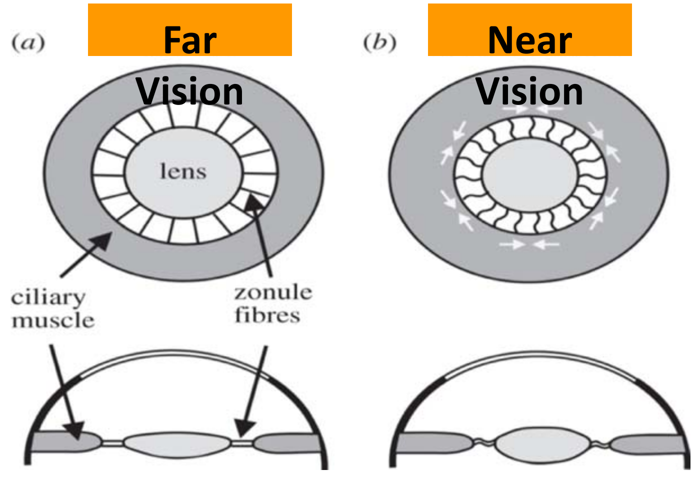
[1]

1. « COMSOL Multiphysics v 5.3 » COMSOL, 2017.

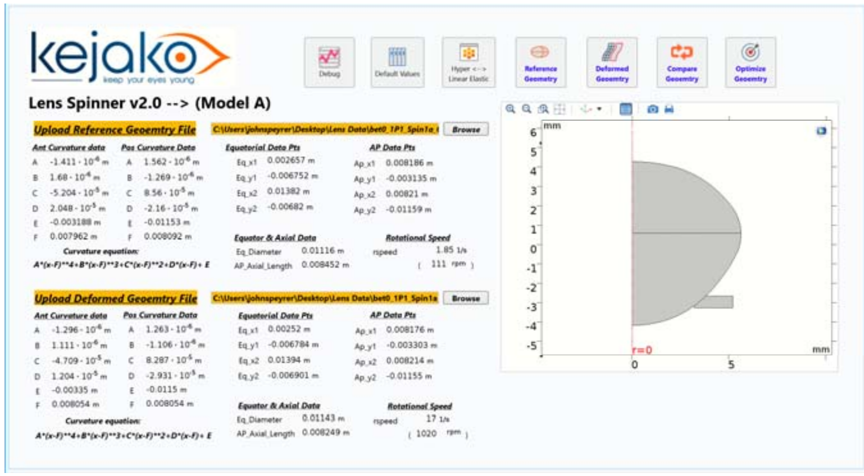
Working Principle of Operation

Basic Physics





[1]

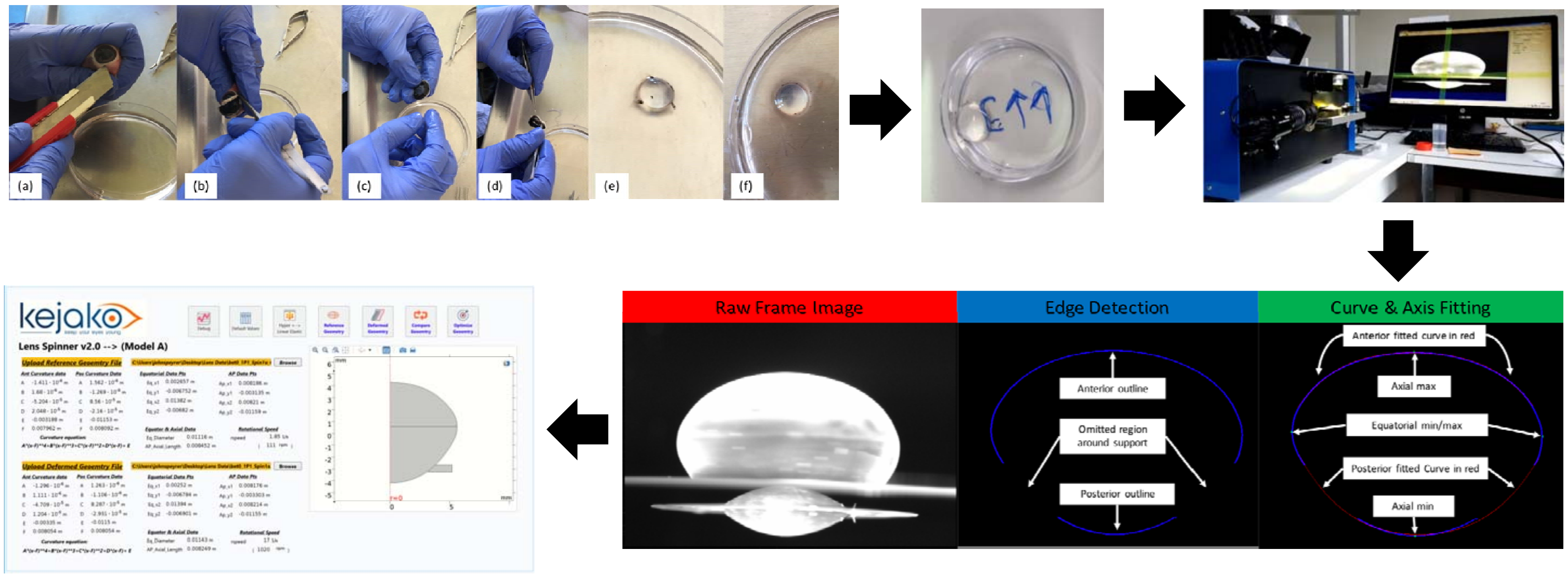


- Use of centrifugal force to induced radial and axial deformation
- Mimics in-vivo behavior
- Non-destrucutive, however indirect measurement of lens stiffness
- FEA needed to reverse engineering shear modulus values from geometry deformation values

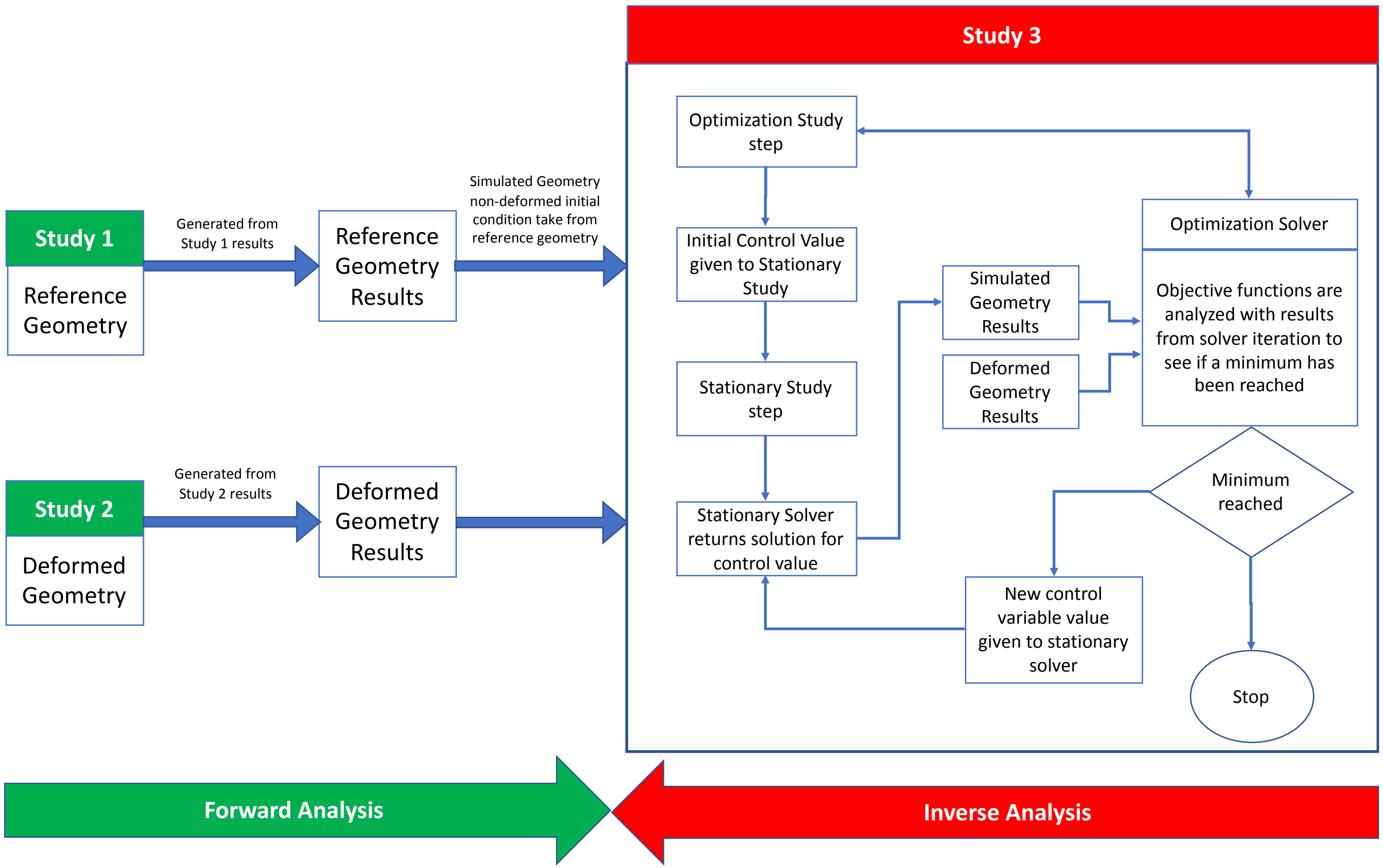
1. Land, Michael. « Focusing by Shape Change in the Lens of the Eye: A Commentary on Young (1801) 'On the Mechanism of the Eye? » Philosophical Transactions of the Royal Society B: Biological Sciences, 19 Apr. 2015, rstb.royalsocietypublishing.org/ content/370/1666/20140308.

Lens Spinning Testing Process

Lens Extraction → Lens Stockage → Lens Spinning → Image Analysis → FEA/Simulation



Simulation Process Methodology

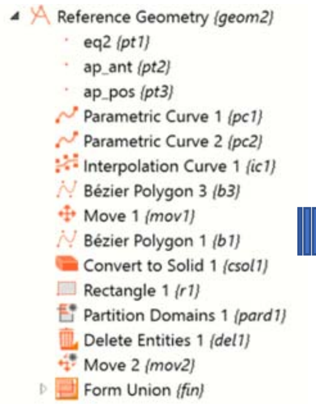


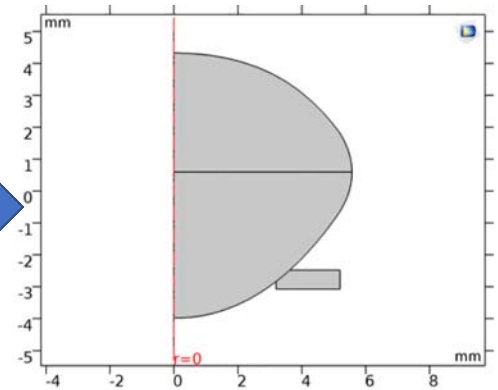
Geometry Construction

Parameters extracted from image analysis → Parameters imported into COMSOL → Parameterization of Geometries → Re-constructed Geometries

Un-defromed Reference Geometry		
Parameter	**Value**	**Description**
ref1_aA	-0.00160095 [mm]	anteroir curve polynominal coefficient A
ref1_aB	0.00403389 [mm]	anteroir curve polynominal coefficient B
ref1_aC	-0.05298915 [mm]	anteroir curve polynominal coefficient C
ref1_aD	0.043721257 [mm]	anteroir curve polynominal coefficient D
ref1_aE	-3.59858151 [mm]	anteroir curve polynominal coefficient E
ref1_aF	7.37903077 [mm]	anteroir curve polynominal coefficient F
ref1_apx1	7.861069525 [mm]	r-coordinate -max axial axis point
ref1_apx1x2_offset	-0.041056778 [mm]	z-position correction of x-coordinate -max/min axial axis point
ref1_apx2	7.943183081 [mm]	r-coordinate -min axial axis point
ref1_apy1	-3.560077519 [mm]	z-coordinate -max axial axis point
ref1_apy1_offset	0.029375895 [mm]	z-position correction of z-coordinate -max axial axis point
ref1_apy2	-11.78824806 [mm]	z-coordinate -min axial axis point
ref1_apy2_offset	-0.048786271 [mm]	z-postion correction of z-coordinate -min axial axis point
ref1_Axial_len	8.22872188 [mm]	axial length of lens
ref1_cutbk	0.4 [mm]	cut back distance from end of parameterized curve and start/end point of interpolation
ref1_Eq_diam	10.95914103 [mm]	diameter of lens
ref1_eqx1	2.520620155 [mm]	r-coordinate -min equatrorial axis point
ref1_eqx2	13.47576744 [mm]	r-coordinate -max equatrorial axis point
ref1_eqy1	-7.114250577 [mm]	z-coordinate -min equatrorial axis point
ref1_eqy2	-7.327959878 [mm]	z-coordinate -max equatrorial axis point
ref1_pA	0.000543114 [mm]	posterior curve polynominal coefficient A
ref1_pB	-0.001168287 [mm]	posterior curve polynominal coefficient B
ref1_pC	0.116322623 [mm]	posterior curve polynominal coefficient C
ref1_pD	-0.043916809 [mm]	posterior curve polynominal coefficient D
ref1_pE	-11.73554749 [mm]	posterior curve polynominal coefficient E
ref1_pF	7.799269652 [mm]	posterior curve polynominal coefficient F
ref1_rspeed	0 [rpm]	rotational speed setpoint of deformed geometry

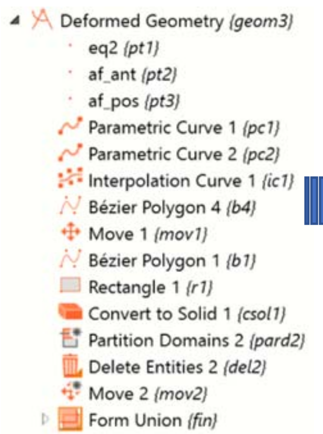
26 variables

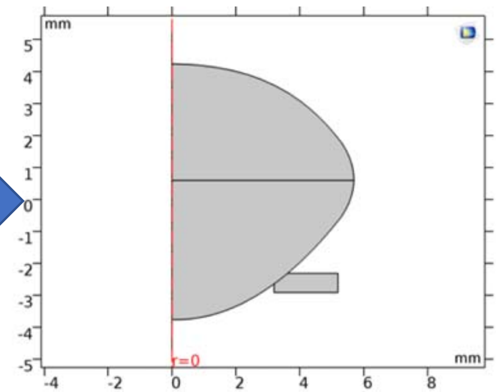




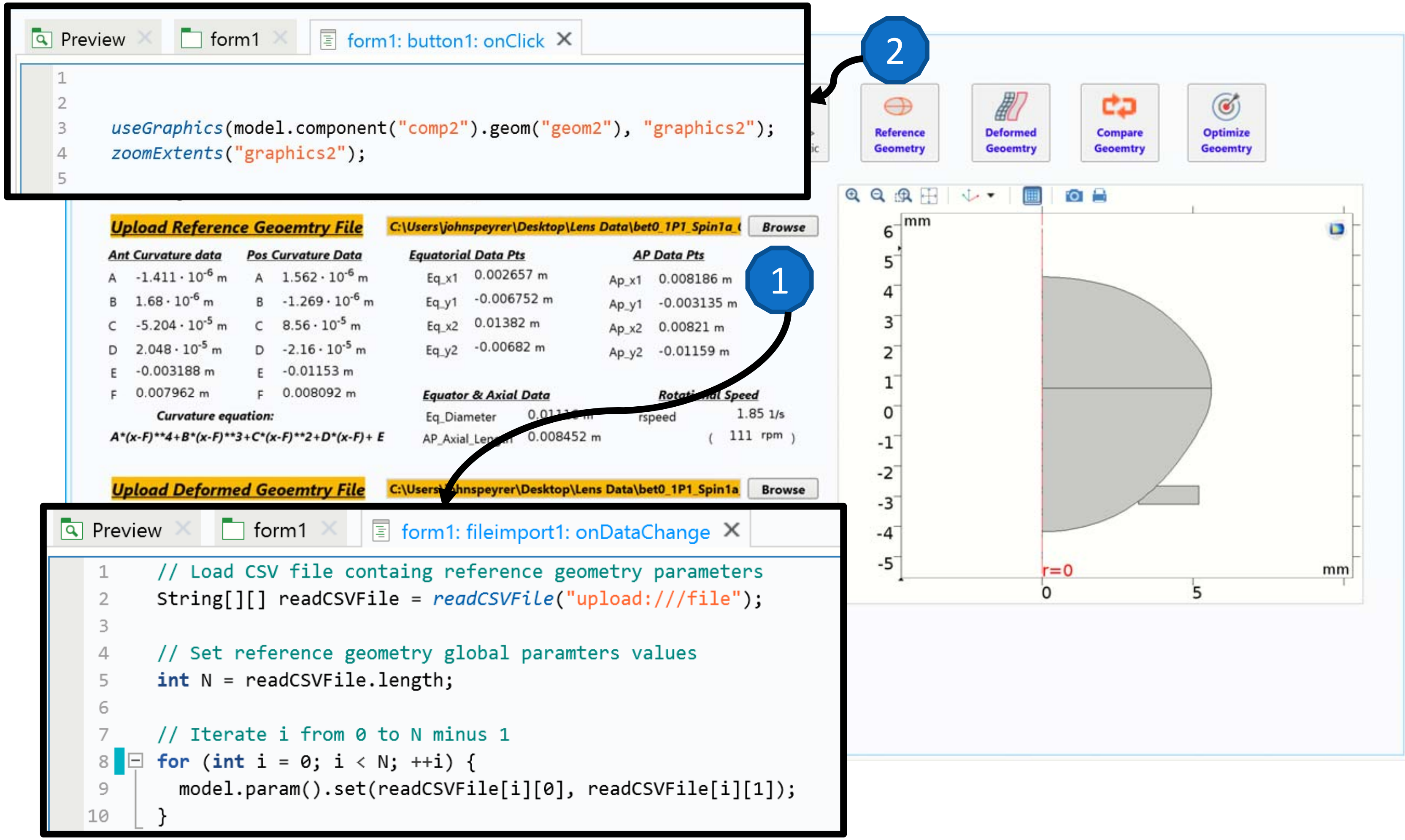
Defromed Geometry		
Parameter	**Value**	**Description**
G1_aA	-0.00160095 [mm]	anteroir curve polynominal coefficient A
G1_aB	0.00403389 [mm]	anteroir curve polynominal coefficient B
G1_aC	-0.05298915 [mm]	anteroir curve polynominal coefficient C
G1_aD	0.043721257 [mm]	anteroir curve polynominal coefficient D
G1_aE	-3.59858151 [mm]	anteroir curve polynominal coefficient E
G1_aF	7.37903077 [mm]	anteroir curve polynominal coefficient F
G1_apx1	7.861069525 [mm]	r-coordinate -max axial axis point
G1_apx1x2_offset	-0.0410567779967659 [mm]	z-postion correction of z-coordinate -max axial axis point
G1_apx2	7.943183081 [mm]	r-coordinate -min axial axis point
G1_apy1	-3.560077519 [mm]	z-coordinate -max axial axis point
G1_apy1_offset	0.029375895 [mm]	z-postion correction of z-coordinate -max axial axis point
G1_apy2	-11.78824806 [mm]	z-coordinate -min axial axis point
G1_apy2_offset	-0.048786271 [mm]	z-postion correction of z-coordinate -min axial axis point
G1_Axial_len	8.22872188 [mm]	axial length of lens
G1_cutbk	0.4 [mm]	cut back distance from end of parameterized curve and start/end point of interpolation
G1_Eq_diam	10.95914103 [mm]	diameter of lens
G1_eqx1	2.520620155 [mm]	r-coordinate -min equatrorial axis point
G1_eqx2	13.47576744 [mm]	r-coordinate -max equatrorial axis point
G1_eqy1	-7.114250577 [mm]	z-coordinate -min equatrorial axis point
G1_eqy2	-7.327959878 [mm]	z-coordinate -max equatrorial axis point
G1_pA	0.000543114 [mm]	posterior curve polynominal coefficient A
G1_pB	-0.001168287 [mm]	posterior curve polynominal coefficient B
G1_pC	0.116322623 [mm]	posterior curve polynominal coefficient C
G1_pD	-0.043916809 [mm]	posterior curve polynominal coefficient D
G1_pE	-11.73554749 [mm]	posterior curve polynominal coefficient E
G1_pF	7.799269652 [mm]	posterior curve polynominal coefficient F
G1_rspeed	1000 [rpm]	rotational speed setpoint of deformed geometry

26 variables

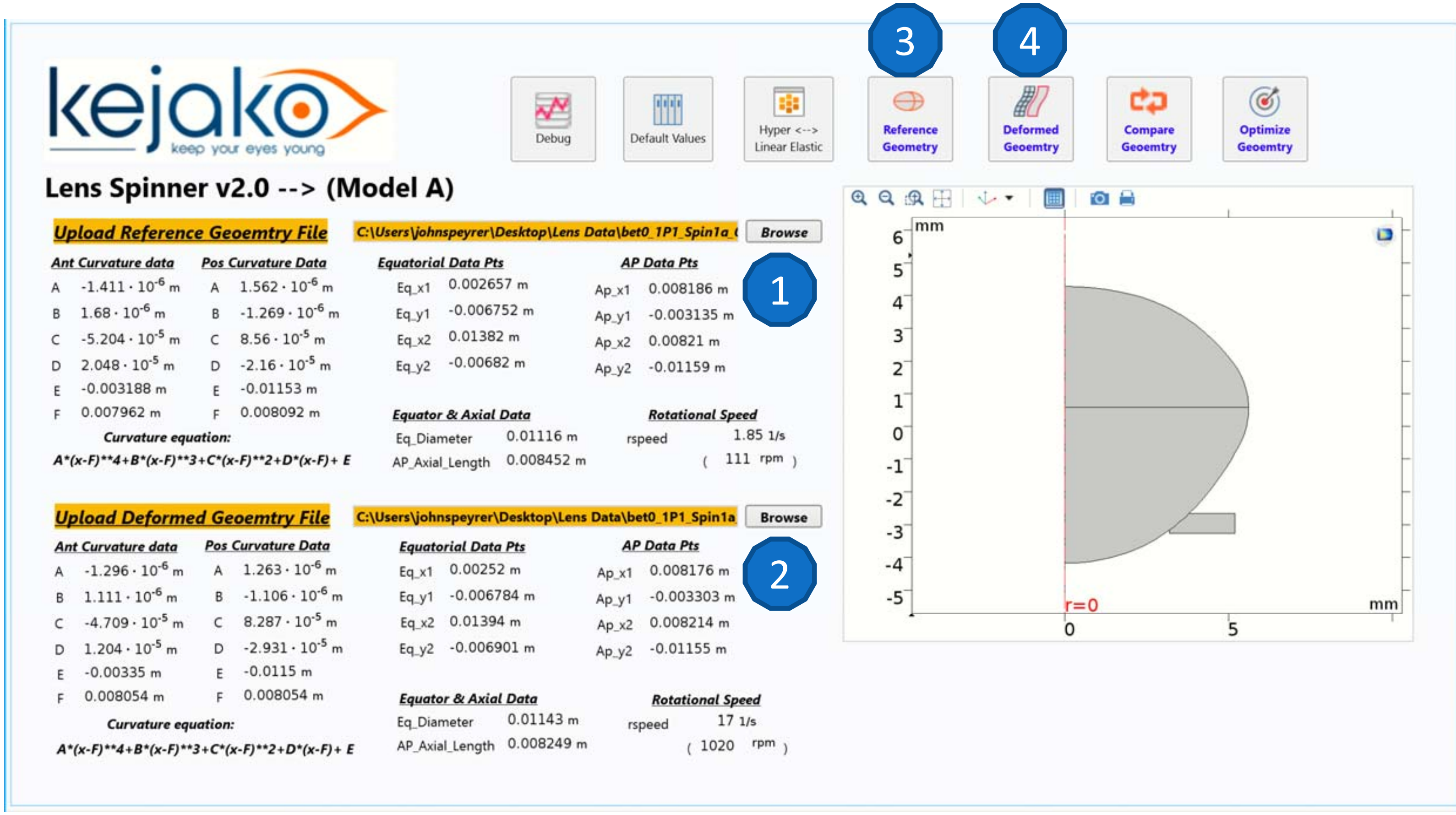




Application Builder

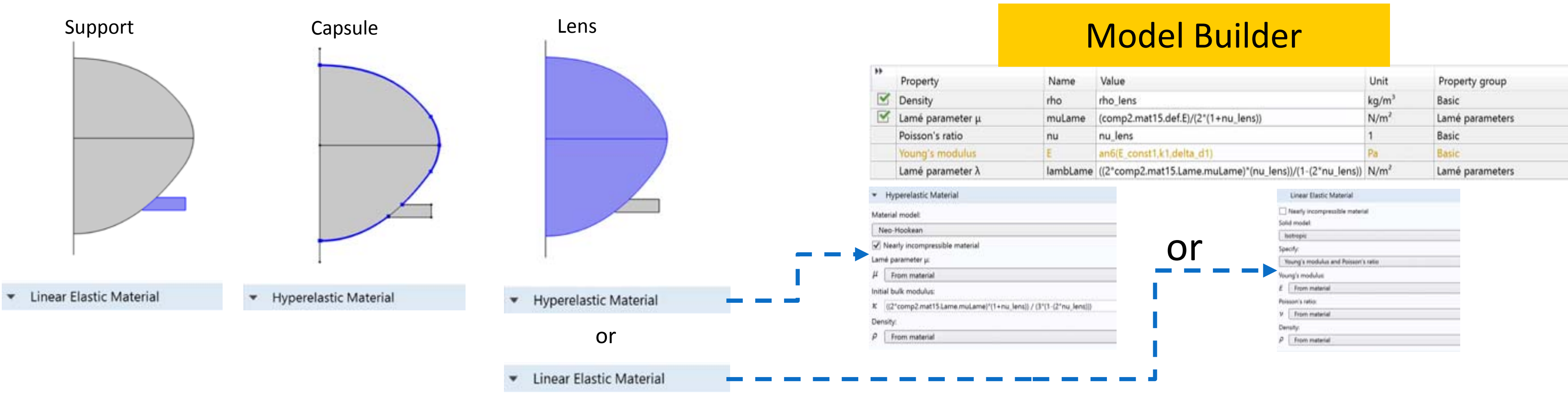


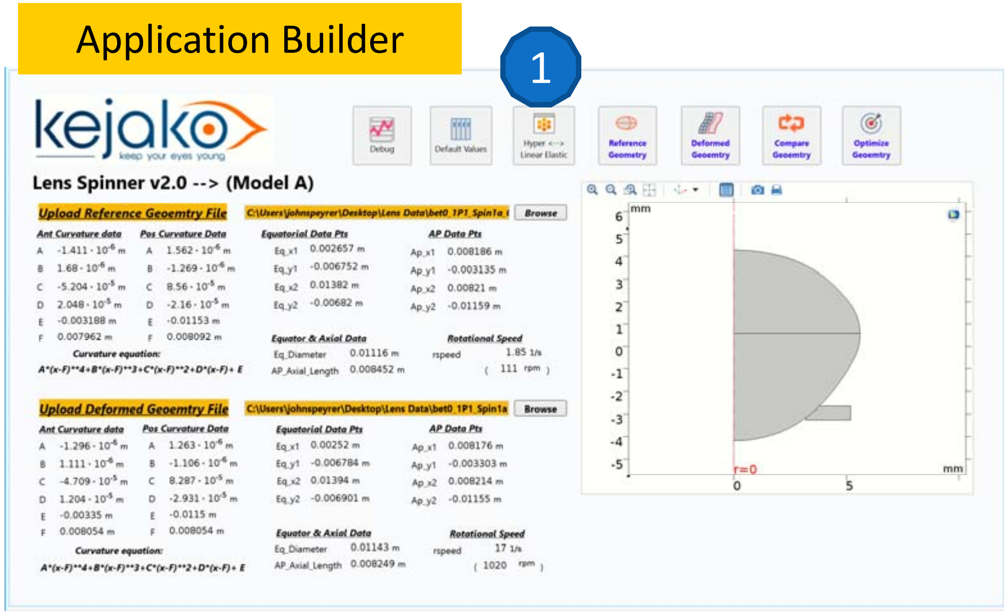
Application Builder



1. Browse and upload reference geometry parameters & Set Model Parameters
2. Browse and upload reference geometry parameters & Set Model Parameters
3. Reconstruct and display reference geometry
4. Reconstruct and display reference geometry

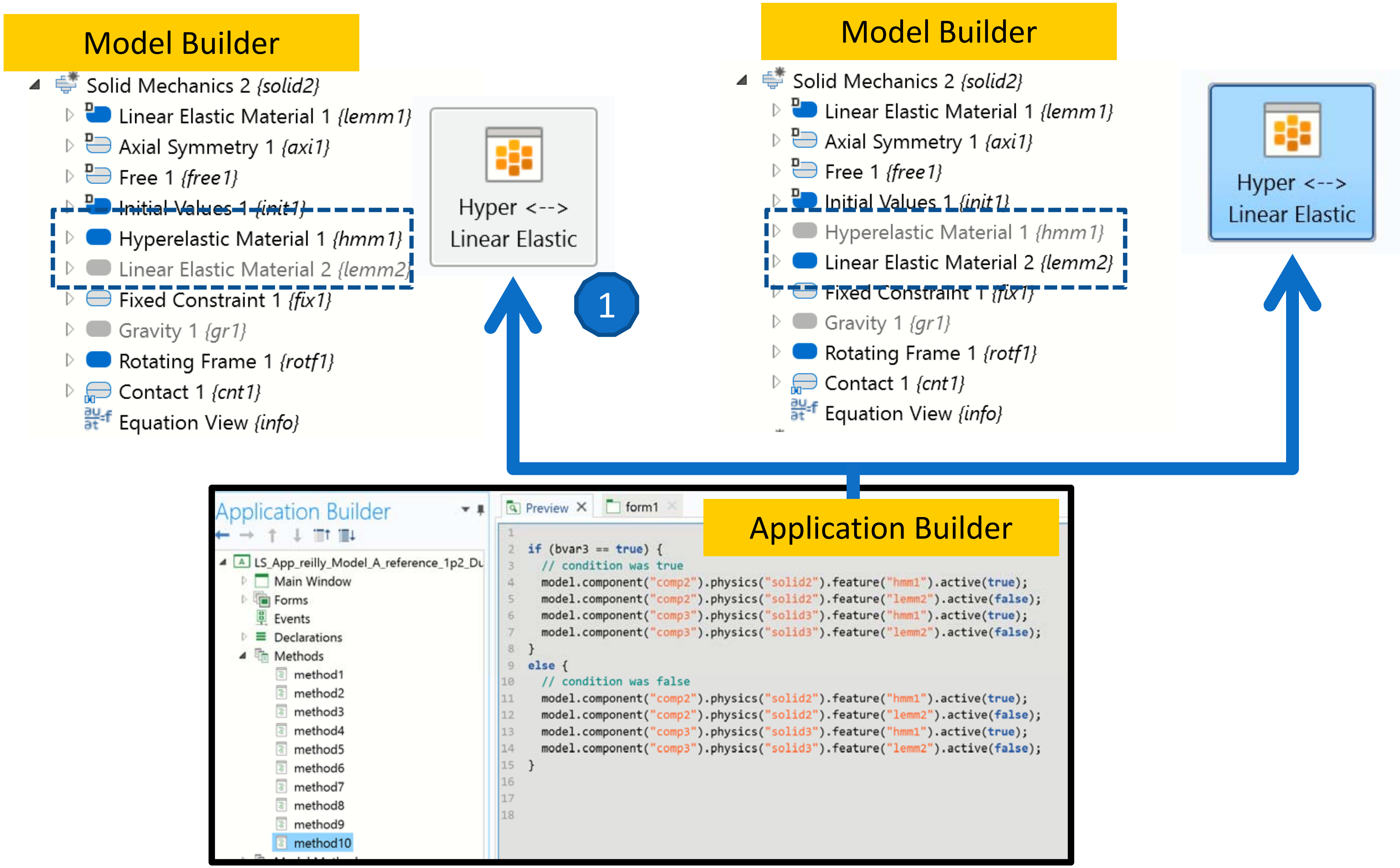
Material Properties





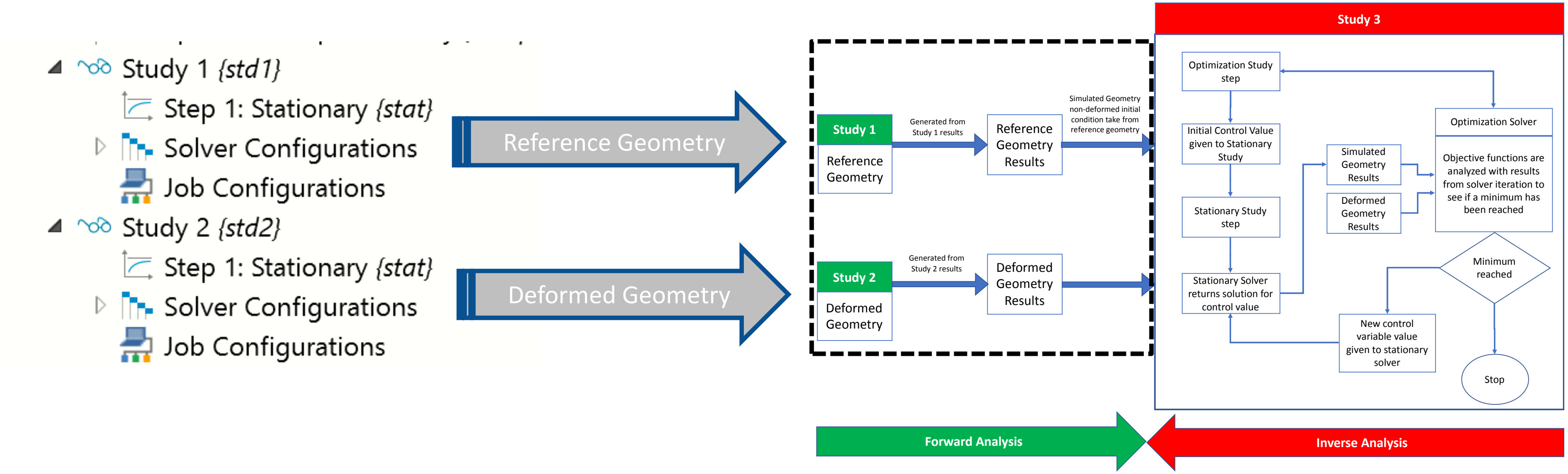
1. Switch between Hyper Elastic and Linear Elastic material models

Application Builder



1. Switch between Hyper Elastic and Linear Elastic material models

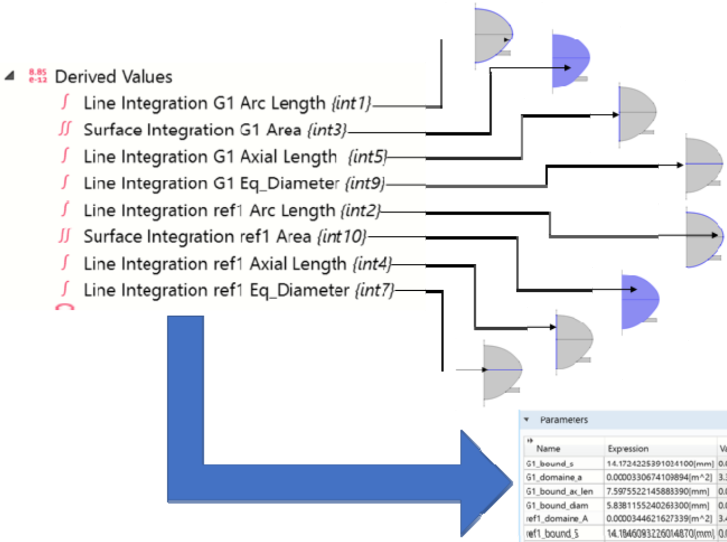
Simulation Studies 1 &2



- Forward analysis stationary study solutions for reference and deformed geometries

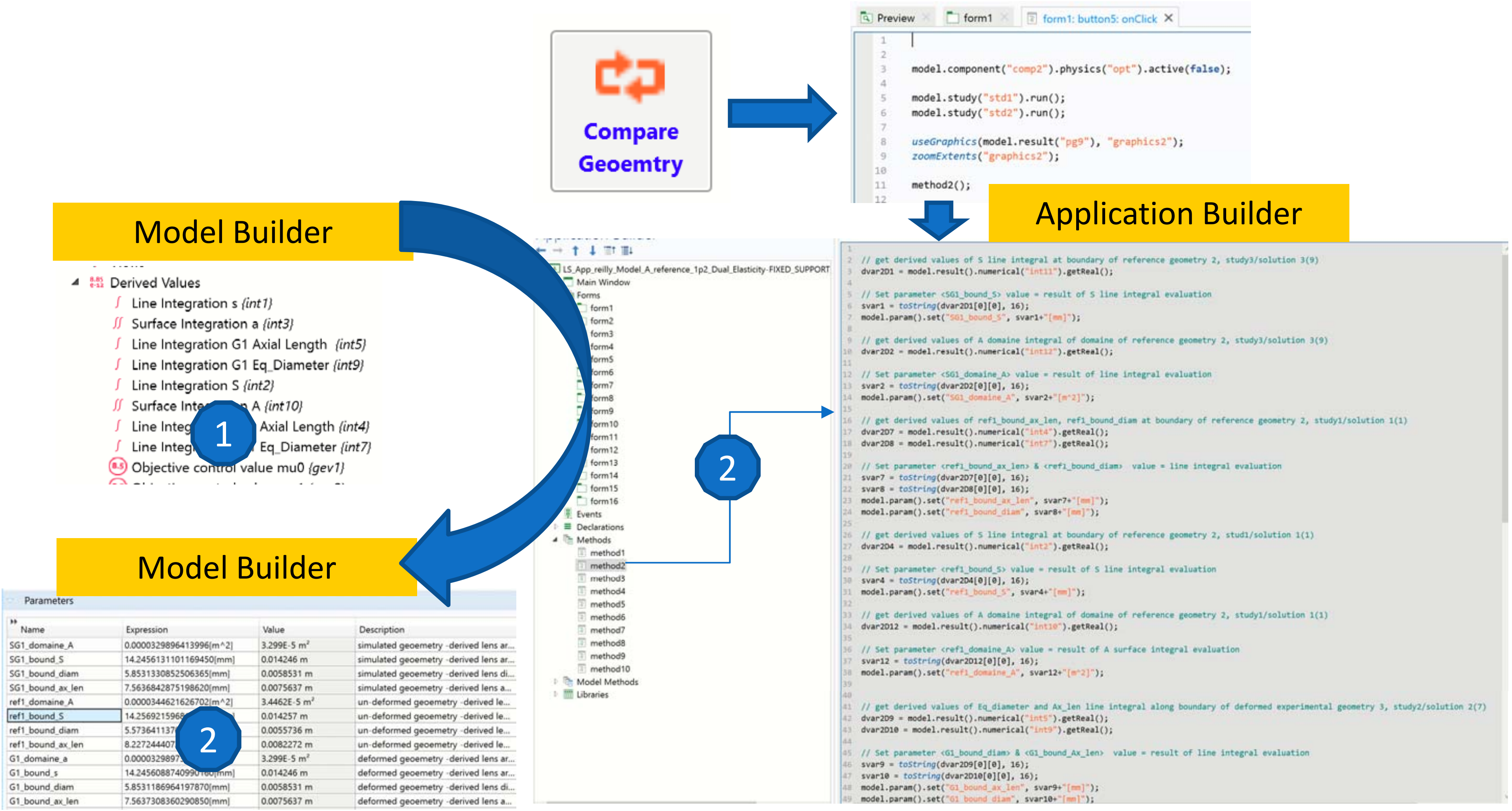
- Defined Physics, Constraints, and material models are applied to the geometries

- Key dimensions extracted using derived values, which are needed as inputs to reverse analysis optimization study



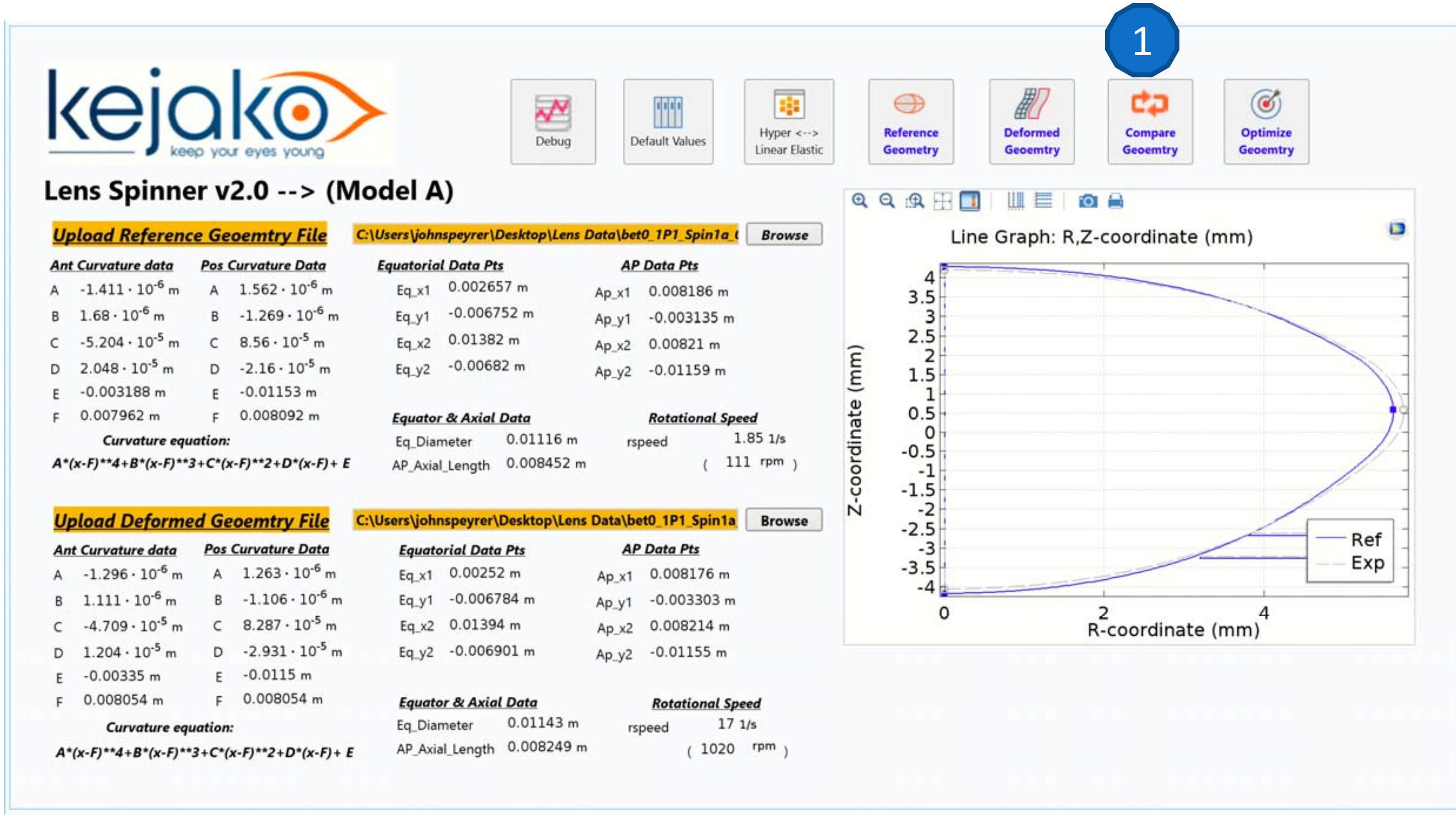
Name	Expression	Value	Description
G1_bound_s	14.1724225391024100[mm]	0.014172 m	deformed geoemetry -derived lens arc length
G1_domaine_a	0.0000330674109894[m^2]	3.3067E-5 m²	deformed geoemetry -derived lens area
G1_bound_ax_len	7.5975522145883390[mm]	0.0075976 m	deformed geoemetry -derived lens axial length
G1_bound_diam	5.8381155240263300[mm]	0.0058381 m	deformed geoemetry -derived lens diamter
ref1_domaine_A	0.0000344621627339[m^2]	3.4462E-5 m²	un-deformed geoemetry -derived lens area
ref1_bound_S	14.1846093226014870[mm]	0.014185 m	un-deformed geoemetry -derived lens arc length
ref1_bound_ax_len	8.2272444072771570[mm]	0.0082272 m	un-deformed geoemetry -derived lens axial length
ref1_bound_diam	5.5736411370000000[mm]	0.0055736 m	un-deformed geoemetry -derived lens diamter

Application Builder



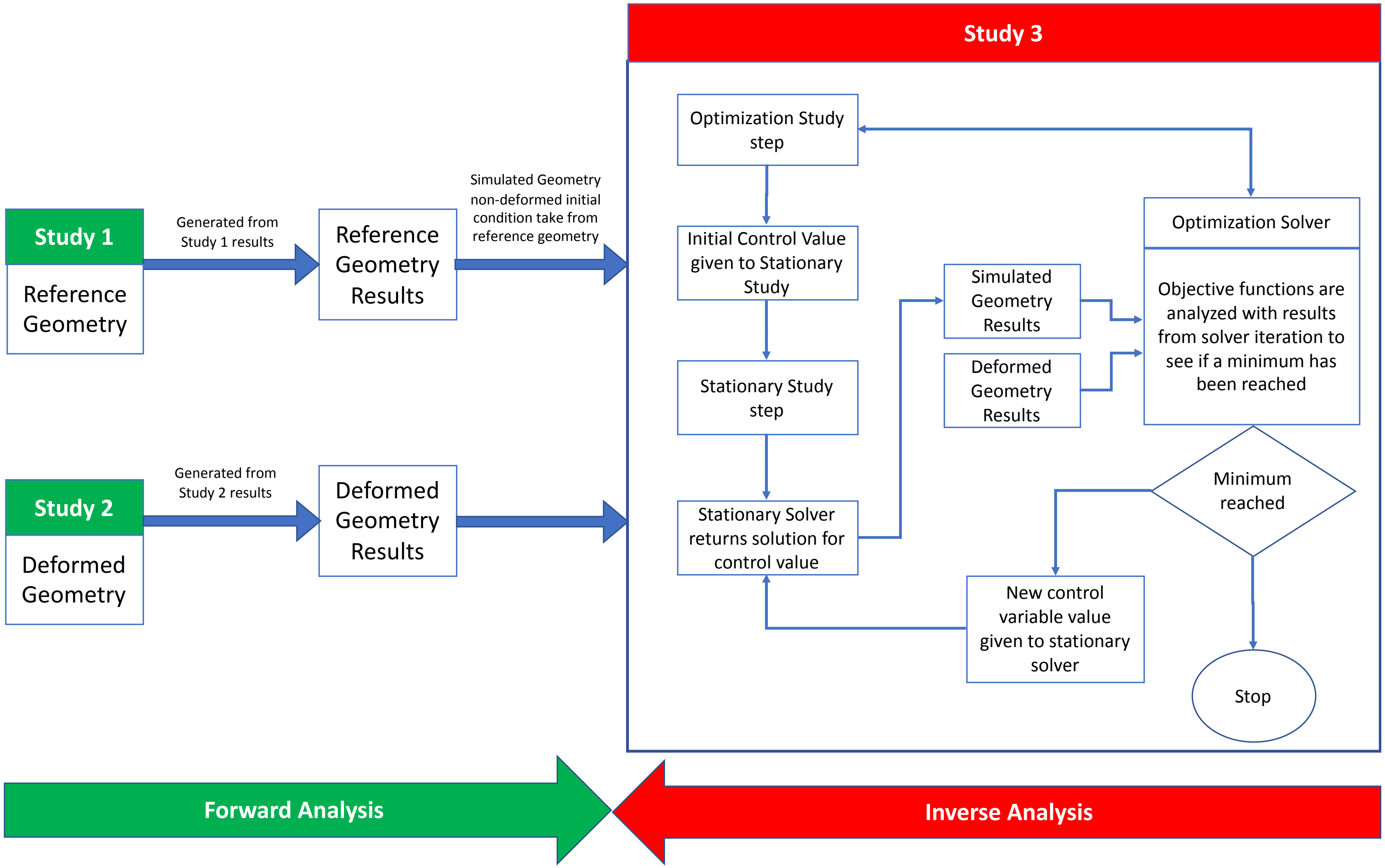
1. Derived Values defined in Simulation Model
2. Method created in Application builder executes derived value instances, then saves the results to global parameters in the model
3. Parameters updated with derived value results

Application Builder

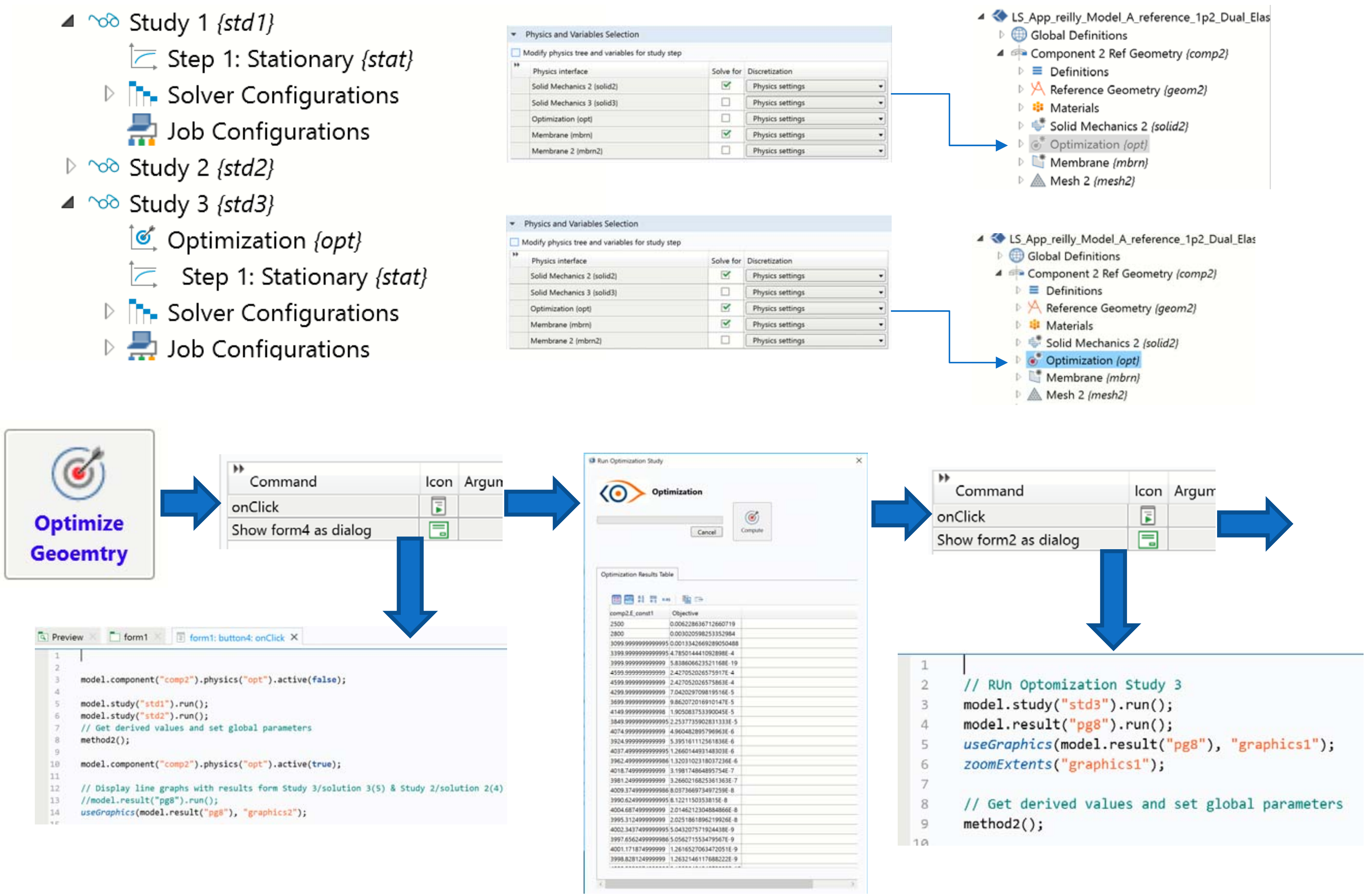


1. a) Launches Study 1 & Study 2
   b) Plots results to graphical window
   c) Get derived values with results from Study 1&2 and saves values to global parameters

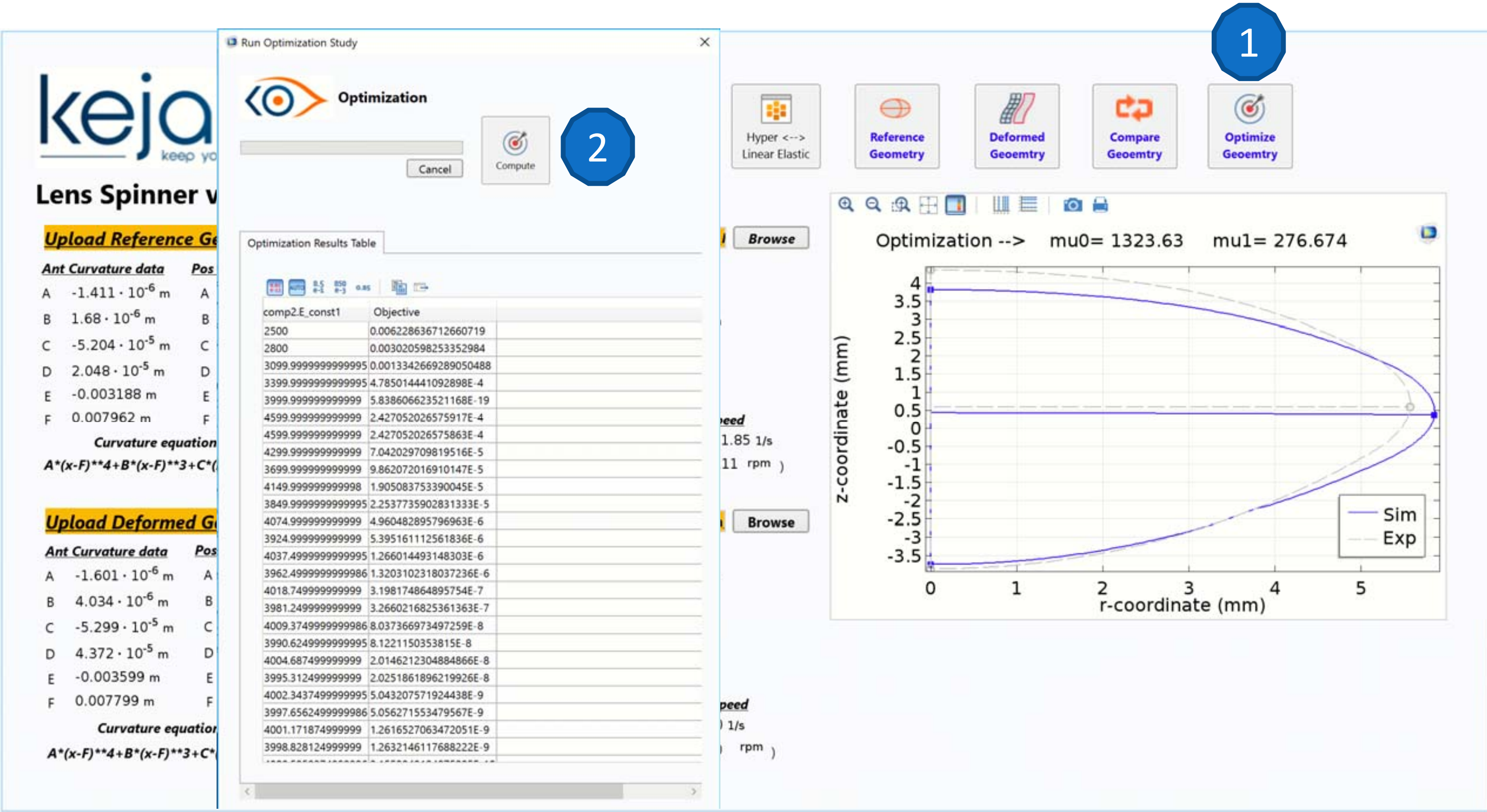
Simulation 3



Simulation 3

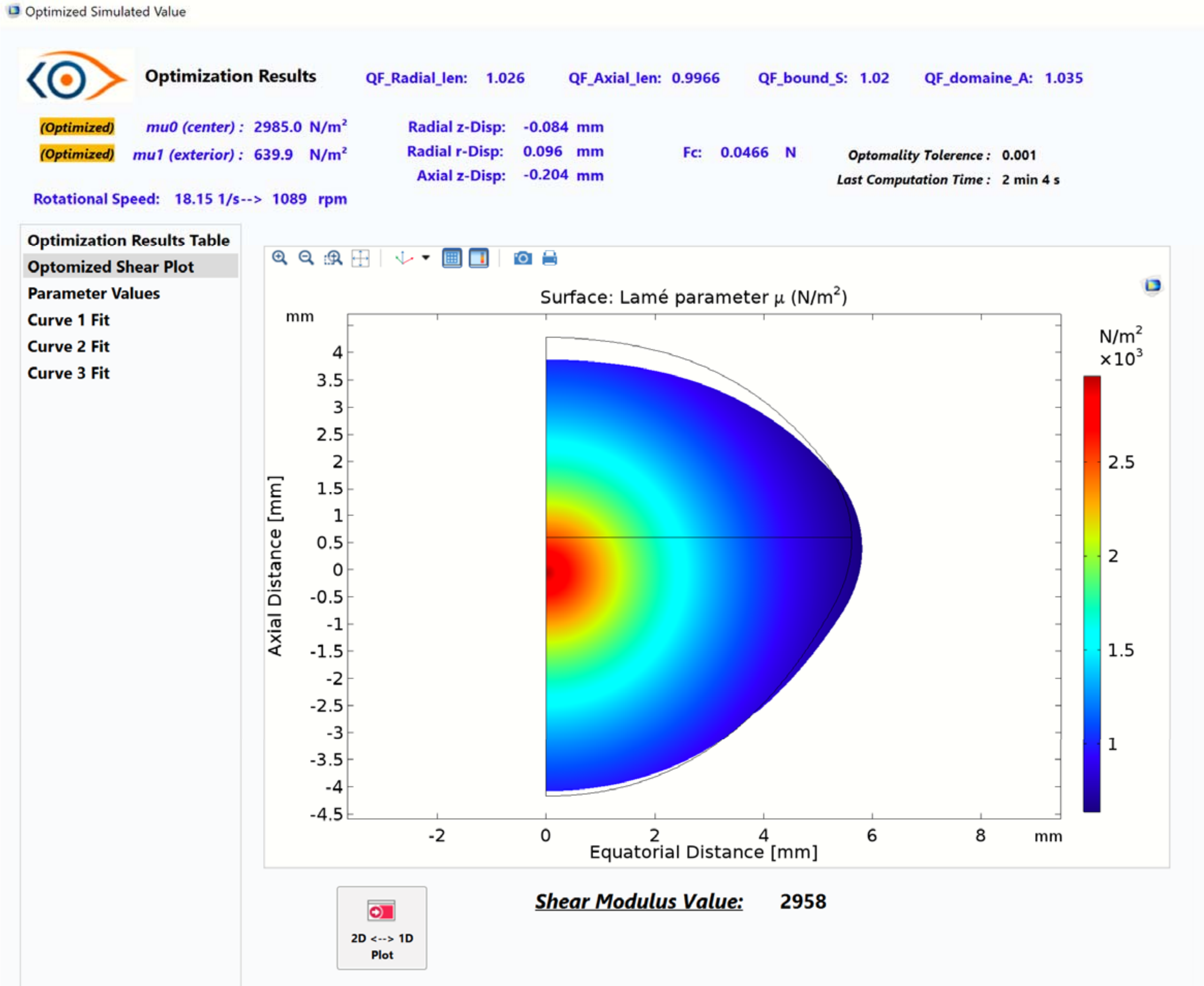


Application Builder



1. a) Activates Optimization in reference geometry physics tree
   b) Opens Optimization launch window
2. a) Launches Optimization Study 3
   b) Dynamically updates results table for each iteration
   c) Dynamically plot graphic results table for each iteration
   d) Closes Optimization window and Opens Results Summary Window

Application Builder



Thank you for your attention

www.kejako.com