

# COMSOL® Application Builder

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

J. Speyrer<sup>1</sup>, A. Maurer<sup>1</sup>, D. Enfrun<sup>1</sup>, R. Rozsnyo<sup>1</sup>

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

**Contact:**

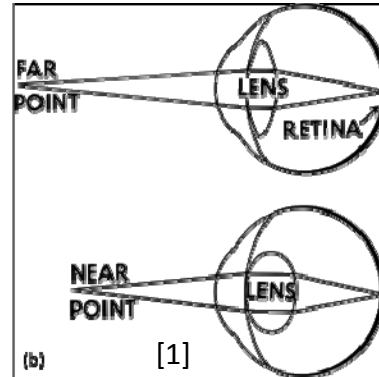
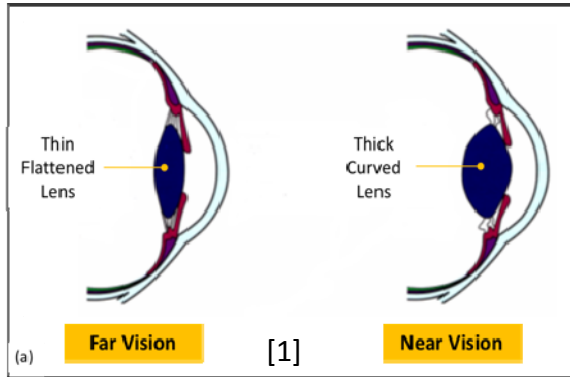
David Enfrun, CEO Kejako

[d.enfrun@kejako.com](mailto:d.enfrun@kejako.com)

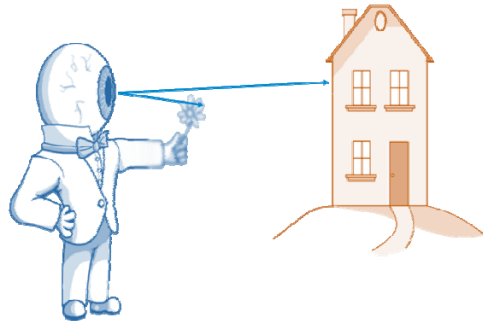
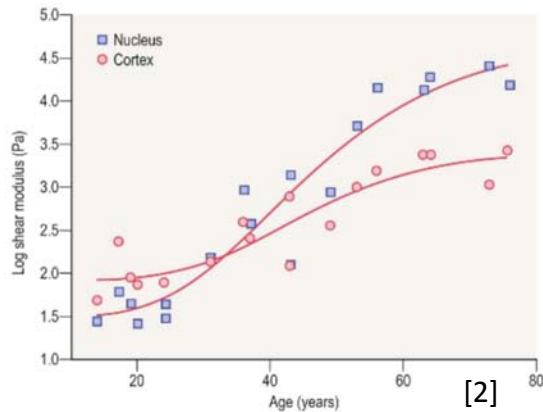
+41 (0)79 946 27 51



# 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 stiffening of the lens with age
- ▶ Presbyopia- eyes lose ability to see things up close clearly

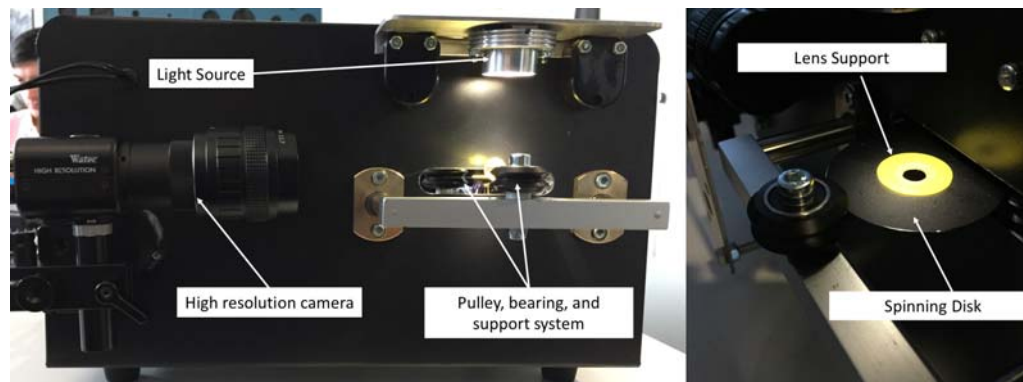


**Presbyopia affects nearly 1.7 billion people worldwide today, and that number is expected to soar to 2.1 billion by 2020**

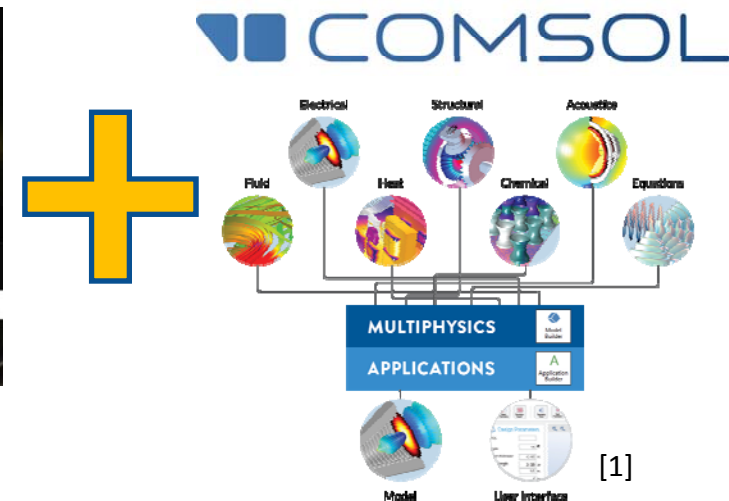
1. « Accommodation (eye) » Wikipedia, the Free Encyclopedia, Wikimedia Foundation, Inc, 17 June 2017, en.wikipedia.org/wiki/Accommodation\_(eye). Accessed 2 Jan. 2018.  
 2. Kaufman, Paul L., et al. Adler's Physiology of the Eye. Elsevier Health Sciences, 2011

# Problem to Solve

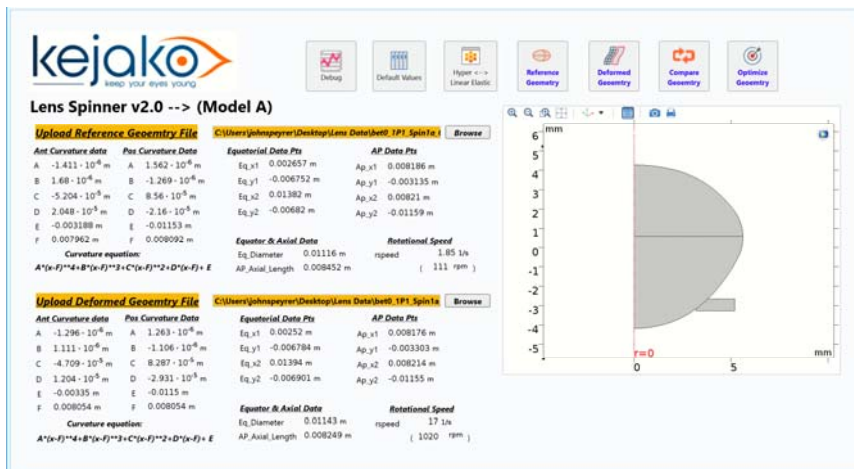
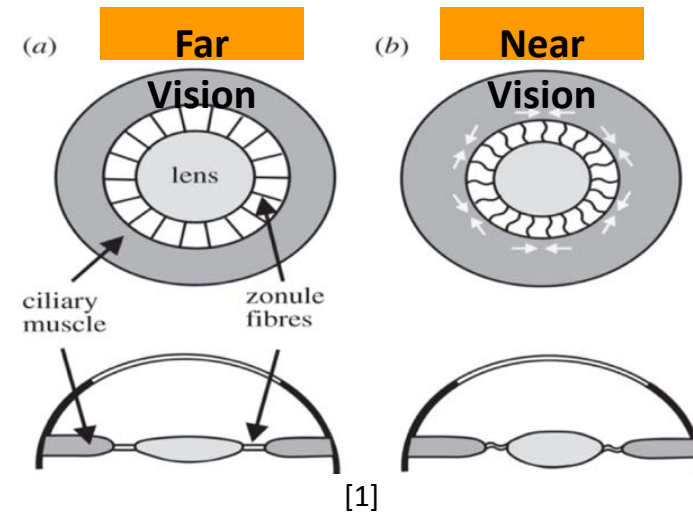
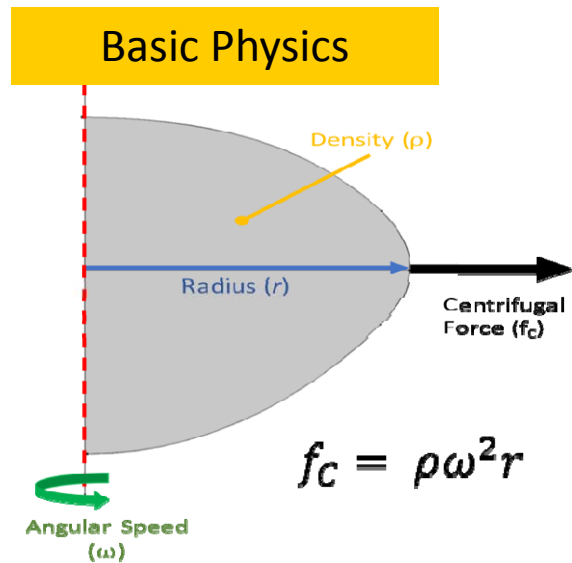
- ▶ Derive the Crystalline lens' shear modulus value
  - ▶ Using a Lens Spinning Fixture to simulate in-vivo forces on the lens, which induces deformation of the lens thereby changing the lens' shape
  - ▶ Using FEA modelling to reverse engineer the shear modulus value of the lens based on lens spinning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



LENS SPINNING FIXTURE



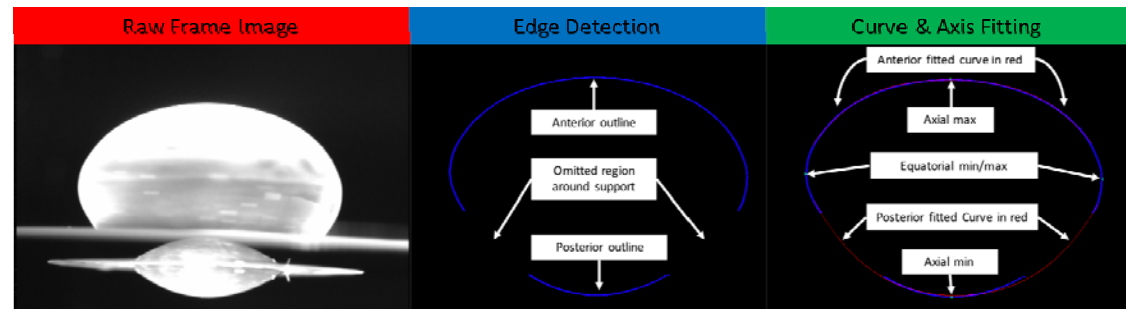
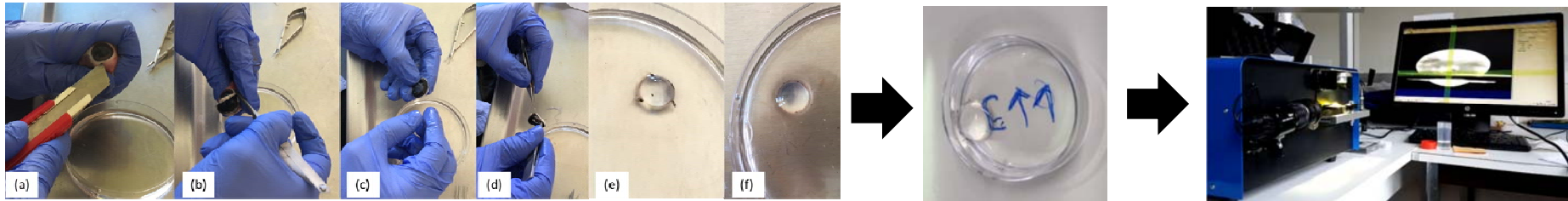
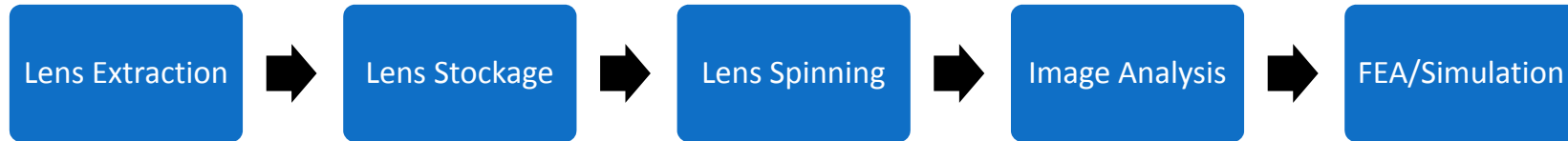
# Working Principle of Operation



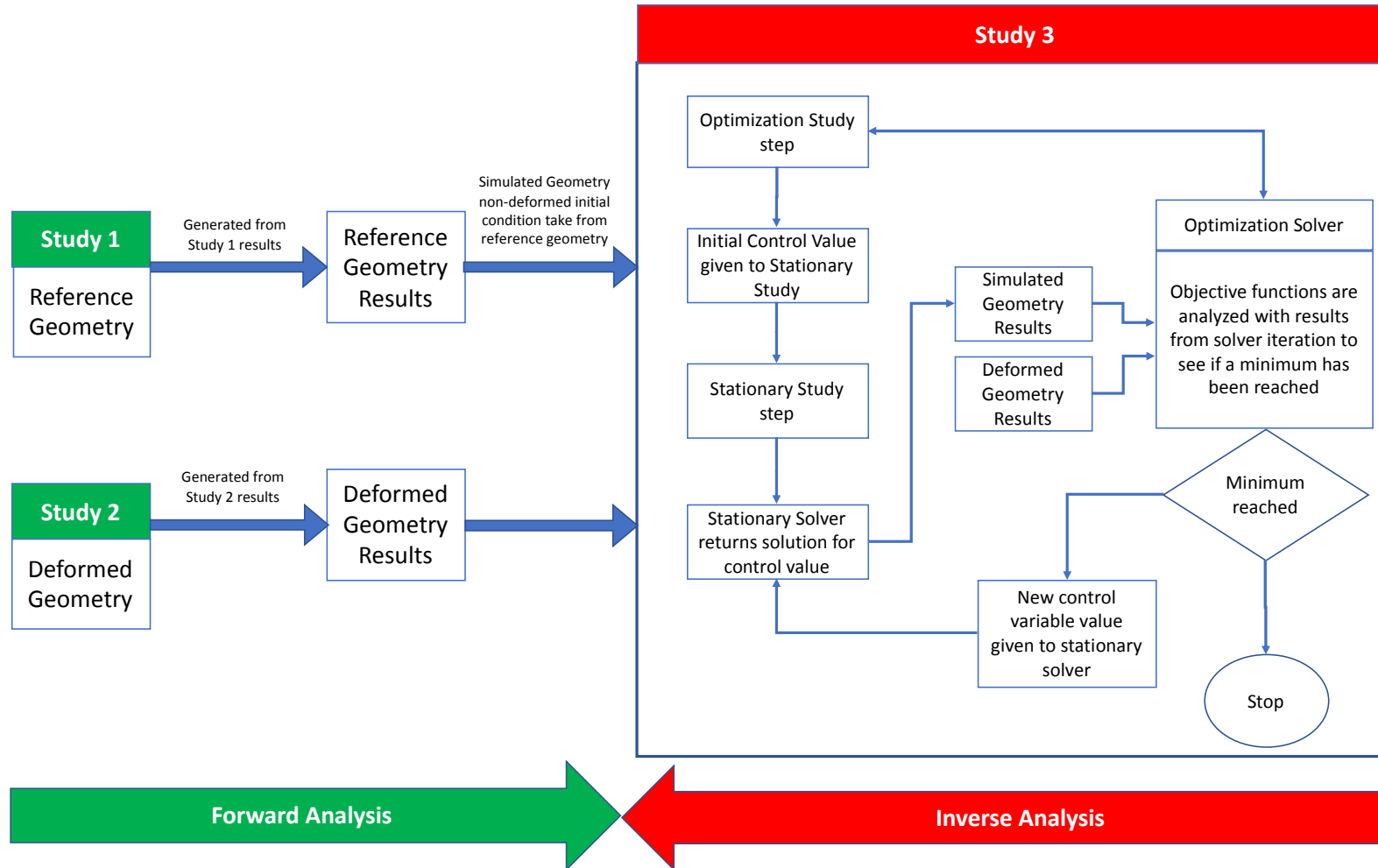
- ▶ Use of centrifugal force to induced radial and axial deformation
- ▶ Mimics in-vivo behavior
- ▶ Non-destructive, however indirect measurement of lens stiffness
- ▶ FEA needed to reverse engineering shear modulus values from geometry deformation values

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, [rspb.royalsocietypublishing.org/content/370/1666/20140308](http://rspb.royalsocietypublishing.org/content/370/1666/20140308).

# Lens Spinning Testing Process



# Simulation Process Methodology



# Geometry Construction



Un-defomed Reference Geometry		
Parameter	Value	Description
ref1_aa	-0.00160095 [mm]	anterior curve polynomial coefficient A
ref1_ab	0.00403389 [mm]	anterior curve polynomial coefficient B
ref1_ac	-0.05298955 [mm]	anterior curve polynomial coefficient C
ref1_ad	0.043721257 [mm]	anterior curve polynomial coefficient D
ref1_ae	-3.59858151 [mm]	anterior curve polynomial coefficient E
ref1_af	7.37903077 [mm]	anterior curve polynomial coefficient F
ref1_apx1	7.86106925 [mm]	r-coordinate -max axial axis point
ref1_apx2_offset	-0.04105678 [mm]	z-position correction of x-coordinate -max/min axial axis point
ref1_apx2	7.943183081 [mm]	r-coordinate -min axial axis point
ref1_apx1_offset	-3.560077519 [mm]	z-coordinate -max axial axis point
ref1_apx1_offset	0.029375895 [mm]	z-position correction of z-coordinate -max axial axis point
ref1_apx2	-11.78824806 [mm]	z-coordinate -min axial axis point
ref1_apx2_offset	0.048786271 [mm]	z-position 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 equatorial axis point
ref1_eqx2	13.47576744 [mm]	r-coordinate -max equatorial axis point
ref1_eqx1	-7.114250577 [mm]	z-coordinate -min equatorial axis point
ref1_eqx2	-7.327908978 [mm]	z-coordinate -max equatorial axis point
ref1_pa	0.000543134 [mm]	posterior curve polynomial coefficient A
ref1_pb	-0.001168287 [mm]	posterior curve polynomial coefficient B
ref1_pc	0.116322623 [mm]	posterior curve polynomial coefficient C
ref1_pd	-0.043918009 [mm]	posterior curve polynomial coefficient D
ref1_pe	-11.73554749 [mm]	posterior curve polynomial coefficient E
ref1_pf	7.799269652 [mm]	posterior curve polynomial coefficient F
ref1_rspeed	0 [rpm]	rotational speed setpoint of deformed geometry

26 variables

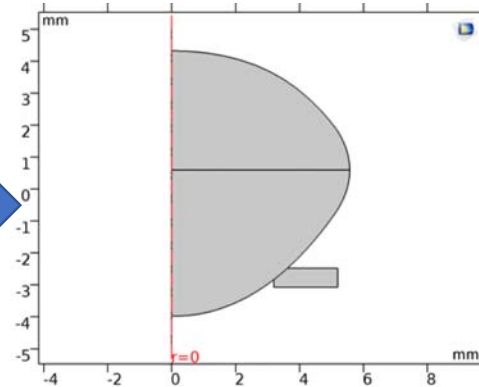


Deformed Geometry		
Parameter	Value	Description
G1_aa	-0.00160095 [mm]	anterior curve polynomial coefficient A
G1_ab	0.00403389 [mm]	anterior curve polynomial coefficient B
G1_ac	-0.05298955 [mm]	anterior curve polynomial coefficient C
G1_ad	0.043721257 [mm]	anterior curve polynomial coefficient D
G1_ae	-3.59858151 [mm]	anterior curve polynomial coefficient E
G1_af	7.37903077 [mm]	anterior curve polynomial coefficient F
G1_apx1	7.86106925 [mm]	r-coordinate -max axial axis point
G1_apx2_offset	-0.0410567779967659 [mm]	z-position correction of x-coordinate -max axial axis point
G1_apx2	7.943183081 [mm]	r-coordinate -min axial axis point
G1_apx1_offset	-3.560077519 [mm]	z-coordinate -max axial axis point
G1_apx1_offset	0.029375895 [mm]	z-position correction of z-coordinate -max axial axis point
G1_apx2	-11.78824806 [mm]	z-coordinate -min axial axis point
G1_apx2_offset	0.048786271 [mm]	z-position 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 equatorial axis point
G1_eqx2	13.47576744 [mm]	r-coordinate -max equatorial axis point
G1_eqx1	-7.114250577 [mm]	z-coordinate -min equatorial axis point
G1_eqx2	-7.327908978 [mm]	z-coordinate -max equatorial axis point
G1_pa	0.000543134 [mm]	posterior curve polynomial coefficient A
G1_pb	-0.001168287 [mm]	posterior curve polynomial coefficient B
G1_pc	0.116322623 [mm]	posterior curve polynomial coefficient C
G1_pd	-0.043918009 [mm]	posterior curve polynomial coefficient D
G1_pe	-11.73554749 [mm]	posterior curve polynomial coefficient E
G1_pf	7.799269652 [mm]	posterior curve polynomial coefficient F
G1_rspeed	1000 [rpm]	rotational speed setpoint of deformed geometry

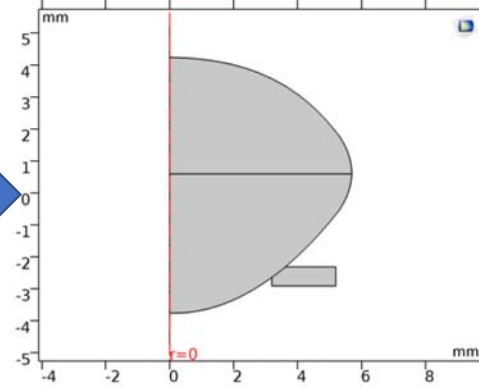
26 variables



- Reference Geometry (geom2)
  - eq2 (pt1)
  - ap\_ant (pt2)
  - ap\_pos (pt3)
  - Parametric Curve 1 (pc1)
  - Parametric Curve 2 (pc2)
  - Interpolation Curve 1 (ic1)
  - Bézier Polygon 3 (b3)
  - Move 1 (mov1)
  - Bézier Polygon 1 (b1)
  - Convert to Solid 1 (csol1)
  - Rectangle 1 (r1)
  - Partition Domains 1 (pard1)
  - Delete Entities 1 (del1)
  - Move 2 (mov2)
  - Form Union (fin)



- Deformed Geometry (geom3)
  - eq2 (pt1)
  - af\_ant (pt2)
  - af\_pos (pt3)
  - Parametric Curve 1 (pc1)
  - Parametric Curve 2 (pc2)
  - Interpolation Curve 1 (ic1)
  - Bézier Polygon 4 (b4)
  - Move 1 (mov1)
  - Bézier Polygon 1 (b1)
  - Rectangle 1 (r1)
  - Convert to Solid 1 (csol1)
  - Partition Domains 2 (pard2)
  - Delete Entities 2 (del2)
  - Move 2 (mov2)
  - Form Union (fin)





# Application Builder

The screenshot displays the Application Builder interface. On the left, there are two code editors. The top editor, titled 'form1: button1: onClick', contains the following code:

```
1
2
3 useGraphics(model.component("comp2").geom("geom2"), "graphics2");
4 zoomExtents("graphics2");
5
```

The bottom editor, titled 'form1: fileimport1: onDataChange', contains the following code:

```
1 // Load CSV file containg reference geometry parameters
2 String[][] readCSVFile = readCSVFile("upload:///file");
3
4 // Set reference geometry global paramters values
5 int N = readCSVFile.length;
6
7 // Iterate i from 0 to N minus 1
8 for (int i = 0; i < N; ++i) {
9     model.param().set(readCSVFile[i][0], readCSVFile[i][1]);
10 }
```

The main interface features a central data table and a 2D plot. The table is titled 'Upload Reference Geoemtry File' and contains the following data:

Ant Curvature data		Pos Curvature Data		Equatorial Data Pts		AP Data Pts	
A	-1.411 · 10 <sup>-6</sup> m	A	1.562 · 10 <sup>-6</sup> m	Eq_x1	0.002657 m	Ap_x1	0.008186 m
B	1.68 · 10 <sup>-6</sup> m	B	-1.269 · 10 <sup>-6</sup> m	Eq_y1	-0.006752 m	Ap_y1	-0.003135 m
C	-5.204 · 10 <sup>-5</sup> m	C	8.56 · 10 <sup>-5</sup> m	Eq_x2	0.01382 m	Ap_x2	0.00821 m
D	2.048 · 10 <sup>-5</sup> m	D	-2.16 · 10 <sup>-5</sup> m	Eq_y2	-0.00682 m	Ap_y2	-0.01159 m
E	-0.003188 m	E	-0.01153 m				
F	0.007962 m	F	0.008092 m				

Below the table, there are sections for 'Curvature equation' and 'Equator & Axial Data'.

The 2D plot on the right shows a lens profile with a vertical axis labeled 'mm' ranging from -5 to 6 and a horizontal axis labeled 'mm' ranging from 0 to 5. The plot shows a curved surface on the right side, with a vertical line at x=0 labeled 'r=0'. The plot is titled 'Upload Deformed Geoemtry File'.

Numbered callouts '1' and '2' are present. Callout '1' points to the 'Upload Reference Geoemtry File' section. Callout '2' points to the 'form1: button1: onClick' code editor.



# Application Builder

**kejako**  
keep your eyes young

Debug Default Values Hyper <--> Linear Elastic Reference Geometry Deformed Geometry Compare Geometry Optimize Geometry

### Lens Spinner v2.0 --> (Model A)

**Upload Reference Geoemtry File** C:\Users\johnspeyrer\Desktop\Lens Data\bet0\_1P1\_Spin1a.t Browse

Ant Curvature data	Pos Curvature Data	Equatorial Data Pts	AP Data Pts
A -1.411 · 10 <sup>-6</sup> m	A 1.562 · 10 <sup>-6</sup> m	Eq_x1 0.002657 m	Ap_x1 0.008186 m
B 1.68 · 10 <sup>-6</sup> m	B -1.269 · 10 <sup>-6</sup> m	Eq_y1 -0.006752 m	Ap_y1 -0.003135 m
C -5.204 · 10 <sup>-5</sup> m	C 8.56 · 10 <sup>-5</sup> m	Eq_x2 0.01382 m	Ap_x2 0.00821 m
D 2.048 · 10 <sup>-5</sup> m	D -2.16 · 10 <sup>-5</sup> m	Eq_y2 -0.00682 m	Ap_y2 -0.01159 m
E -0.003188 m	E -0.01153 m		
F 0.007962 m	F 0.008092 m		

**Curvature equation:**  
 $A*(x-F)**4+B*(x-F)**3+C*(x-F)**2+D*(x-F)+E$

Equator & Axial Data	Rotational Speed
Eq_Diameter 0.01116 m	rspeed 1.85 1/s
AP_Axial_Length 0.008452 m	( 111 rpm )

**Upload Deformed Geoemtry File** C:\Users\johnspeyrer\Desktop\Lens Data\bet0\_1P1\_Spin1a.t Browse

Ant Curvature data	Pos Curvature Data	Equatorial Data Pts	AP Data Pts
A -1.296 · 10 <sup>-6</sup> m	A 1.263 · 10 <sup>-6</sup> m	Eq_x1 0.00252 m	Ap_x1 0.008176 m
B 1.111 · 10 <sup>-6</sup> m	B -1.106 · 10 <sup>-6</sup> m	Eq_y1 -0.006784 m	Ap_y1 -0.003303 m
C -4.709 · 10 <sup>-5</sup> m	C 8.287 · 10 <sup>-5</sup> m	Eq_x2 0.01394 m	Ap_x2 0.008214 m
D 1.204 · 10 <sup>-5</sup> m	D -2.931 · 10 <sup>-5</sup> m	Eq_y2 -0.006901 m	Ap_y2 -0.01155 m
E -0.00335 m	E -0.0115 m		
F 0.008054 m	F 0.008054 m		

**Curvature equation:**  
 $A*(x-F)**4+B*(x-F)**3+C*(x-F)**2+D*(x-F)+E$

Equator & Axial Data	Rotational Speed
Eq_Diameter 0.01143 m	rspeed 17 1/s
AP_Axial_Length 0.008249 m	( 1020 rpm )

2D Plot (mm):

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

**Model Builder**

Property	Name	Value	Unit	Property group
<input checked="" type="checkbox"/> Density	rho	rho_lens	kg/m <sup>3</sup>	Basic
<input checked="" type="checkbox"/> Lamé parameter $\mu$	muLame	(comp2.mat15.def.E)/(2*(1+nu_lens))	N/m <sup>2</sup>	Lamé parameters
Poisson's ratio	nu	nu_lens	1	Basic
Young's modulus	E	an6(E_const1.k1.delta_d1)	Pa	Basic
Lamé parameter $\lambda$	lambLame	((2*comp2.mat15.Lame.muLame)*(nu_lens))/(1-(2*nu_lens))	N/m <sup>2</sup>	Lamé parameters

Material model selection options:

- Hyperelastic Material
  - Material model: Neo-Hookean
  - Nearly incompressible material
  - Lamé parameter  $\mu$ : From material
  - Initial bulk modulus:  $K = (2*comp2.mat15.Lame.muLame)/(1+nu_lens) / (3*(1-2*nu_lens))$
  - Density: From material
- Linear Elastic Material
  - Nearly incompressible material
  - Solid model: Isotropic
  - Specify: Young's modulus and Poisson's ratio
  - Young's modulus: From material
  - Poisson's ratio: From material
  - Density: From material

## Application Builder

**1**

**Upload Reference Geomtry File** C:\Users\johnspyrer\Desktop\Lens Data\bet0\_1P1\_Spin1a

Ant Curvature data	Pos Curvature Data	Equatorial Data Pts	AP Data Pts
A -1.411 · 10 <sup>-6</sup> m	A 1.562 · 10 <sup>-6</sup> m	Eq_x1 0.002657 m	Ap_x1 0.008186 m
B 1.68 · 10 <sup>-6</sup> m	B -1.269 · 10 <sup>-6</sup> m	Eq_y1 -0.006752 m	Ap_y1 -0.003135 m
C -5.204 · 10 <sup>-5</sup> m	C 8.56 · 10 <sup>-5</sup> m	Eq_x2 0.01382 m	Ap_x2 0.00821 m
D 2.048 · 10 <sup>-5</sup> m	D -2.16 · 10 <sup>-5</sup> m	Eq_y2 -0.00682 m	Ap_y2 -0.01159 m
E -0.003188 m	E -0.01153 m		
F 0.007962 m	F 0.008092 m		

Curvature equation:  $A*(x-f)^4 + B*(x-f)^3 + C*(x-f)^2 + D*(x-f) + E$

Equator & Axial Data: Eq Diameter 0.01116 m, AP\_Axial\_Length 0.008452 m

Rotational Speed: rspeed 1.85 1/n ( 111 rpm )

**Upload Deformed Geomtry File** C:\Users\johnspyrer\Desktop\Lens Data\bet0\_1P1\_Spin1a

Ant Curvature data	Pos Curvature Data	Equatorial Data Pts	AP Data Pts
A -1.296 · 10 <sup>-6</sup> m	A 1.263 · 10 <sup>-6</sup> m	Eq_x1 0.00252 m	Ap_x1 0.008176 m
B 1.111 · 10 <sup>-6</sup> m	B -1.106 · 10 <sup>-6</sup> m	Eq_y1 -0.006784 m	Ap_y1 -0.003303 m
C -4.709 · 10 <sup>-5</sup> m	C 8.287 · 10 <sup>-5</sup> m	Eq_x2 0.01394 m	Ap_x2 0.008214 m
D 1.204 · 10 <sup>-5</sup> m	D -2.931 · 10 <sup>-5</sup> m	Eq_y2 -0.006901 m	Ap_y2 -0.01155 m
E -0.00335 m	E -0.0115 m		
F 0.008054 m	F 0.008054 m		

Curvature equation:  $A*(x-f)^4 + B*(x-f)^3 + C*(x-f)^2 + D*(x-f) + E$

Equator & Axial Data: Eq Diameter 0.01143 m, AP\_Axial\_Length 0.008249 m

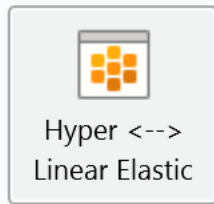
Rotational Speed: rspeed 17 1/n ( 1020 rpm )

1. Switch between Hyper Elastic and Linear Elastic material models

# Application Builder

## Model Builder

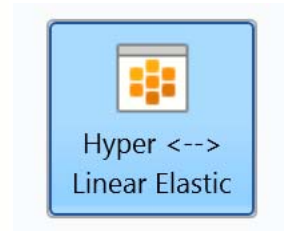
- Solid Mechanics 2 {solid2}
  - Linear Elastic Material 1 {lemm1}
  - Axial Symmetry 1 {axi1}
  - Free 1 {free1}
  - Initial Values 1 {init1}
  - Hyperelastic Material 1 {hmm1}**
  - Linear Elastic Material 2 {lemm2}
  - Fixed Constraint 1 {fix1}
  - Gravity 1 {gr1}
  - Rotating Frame 1 {rotf1}
  - Contact 1 {cnt1}
  - Equation View {info}



1

## Model Builder

- Solid Mechanics 2 {solid2}
  - Linear Elastic Material 1 {lemm1}
  - Axial Symmetry 1 {axi1}
  - Free 1 {free1}
  - Initial Values 1 {init1}
  - Hyperelastic Material 1 {hmm1}
  - Linear Elastic Material 2 {lemm2}**
  - Fixed Constraint 1 {fix1}
  - Gravity 1 {gr1}
  - Rotating Frame 1 {rotf1}
  - Contact 1 {cnt1}
  - Equation View {info}



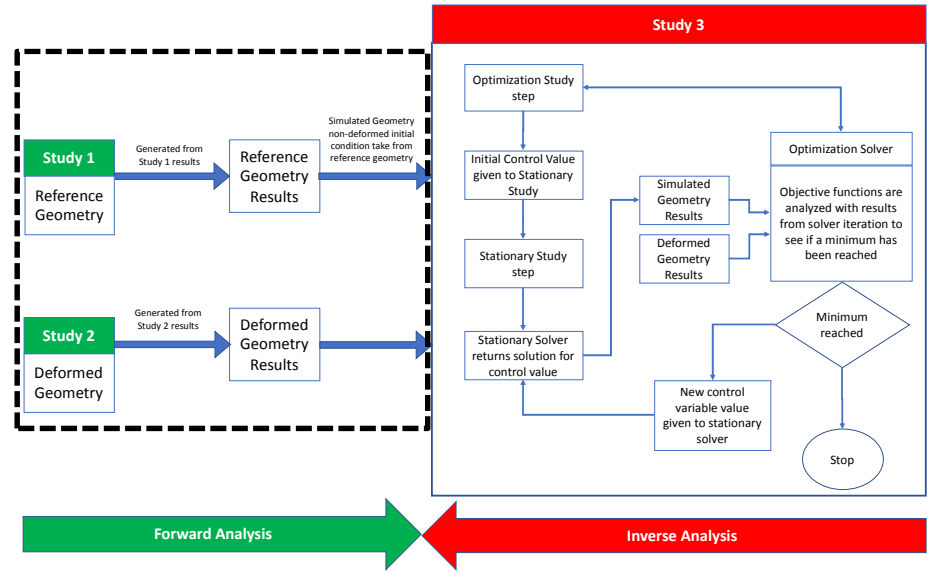
### Application Builder

```
1
2 if (bvar3 == true) {
3   // condition was true
4   model.component("comp2").physics("solid2").feature("hmm1").active(true);
5   model.component("comp2").physics("solid2").feature("lemm2").active(false);
6   model.component("comp3").physics("solid3").feature("hmm1").active(true);
7   model.component("comp3").physics("solid3").feature("lemm2").active(false);
8 }
9 else {
10  // condition was false
11  model.component("comp2").physics("solid2").feature("hmm1").active(true);
12  model.component("comp2").physics("solid2").feature("lemm2").active(false);
13  model.component("comp3").physics("solid3").feature("hmm1").active(true);
14  model.component("comp3").physics("solid3").feature("lemm2").active(false);
15 }
16
17
18
```

1. Switch between Hyper Elastic and Linear Elastic material models

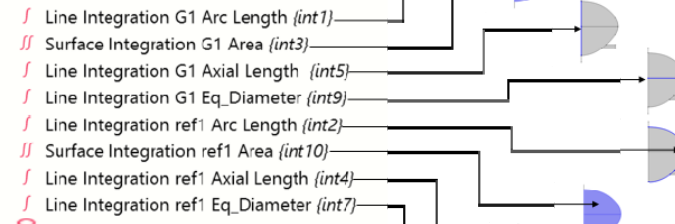
# Simulation Studies 1 & 2

- Study 1 {std1}
  - Step 1: Stationary {stat}
  - Solver Configurations
  - Job Configurations
- Study 2 {std2}
  - Step 1: Stationary {stat}
  - Solver Configurations
  - Job Configurations



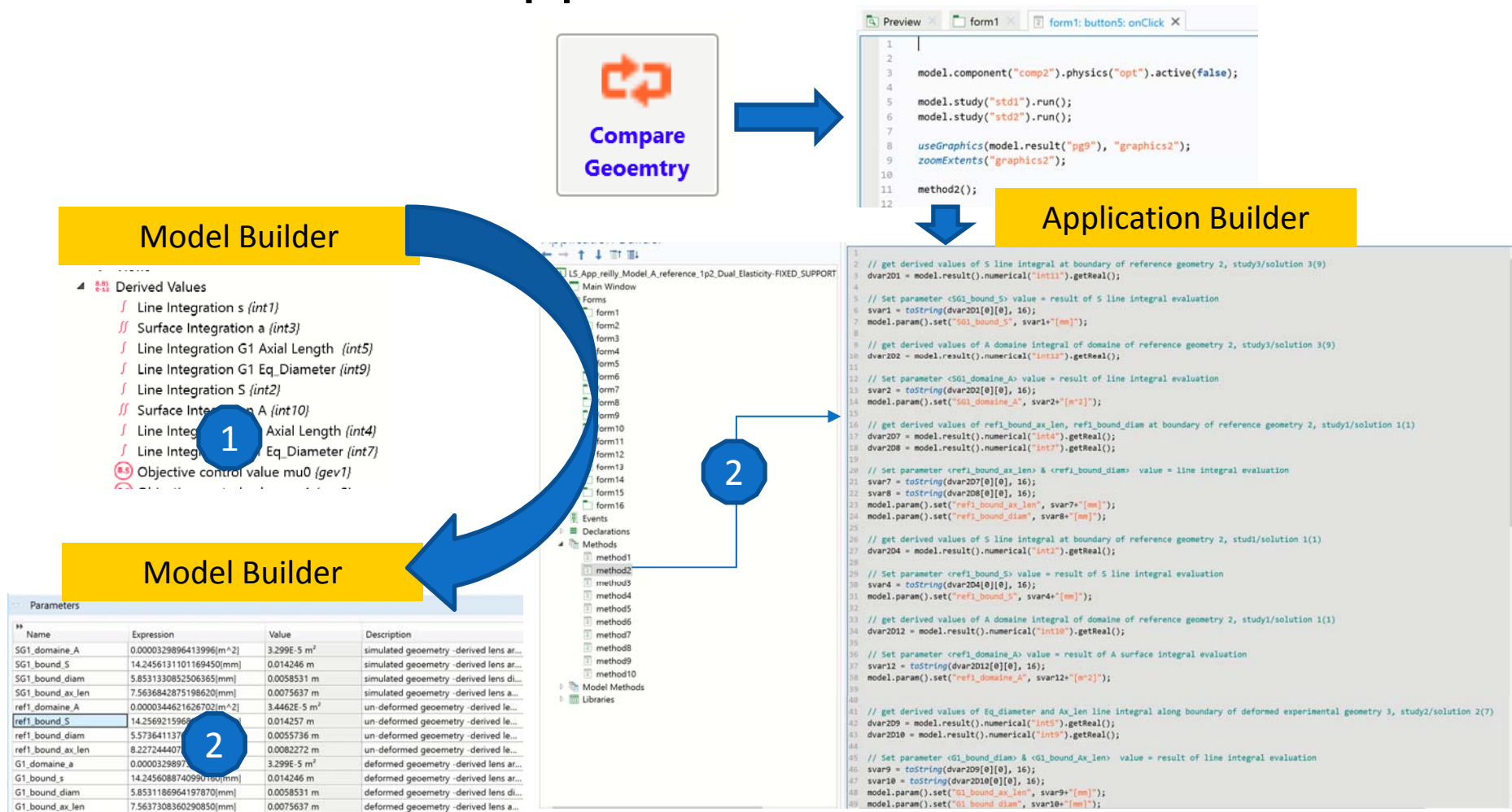
- Forward analysis stationary study solutions for reference and deformed geometries
- Defined Physics, Constraints, and material models are applied to the geometries
- Key dimensions extracted using derived values, which are needed as inputs to reverse analysis optimization study

## Derived Values



Name	Expression	Value	Description
G1_bound_s	14.1724228391034100(mm)	0.014172 m	deformed geometry - derived lens arc length
G1_domaine_a	0.000330674109894(m^2)	3.30678 5 m <sup>2</sup>	deformed geometry - derived lens area
G1_bound_ax_len	7.5975522145883390(mm)	0.0075976 m	deformed geometry - derived lens axial length
G1_bound_diam	5.8381155240263300(mm)	0.0058381 m	deformed geometry - derived lens diameter
ref1_domaine_A	0.000344621627339(m^2)	3.44628 5 m <sup>2</sup>	un-deformed geometry - derived lens area
ref1_bound_S	14.1846093226014870(mm)	0.014185 m	un-deformed geometry - derived lens arc length
ref1_bound_ax_len	8.227244407271570(mm)	0.0082272 m	un-deformed geometry - derived lens axial length
ref1_bound_diam	5.3736411370000000(mm)	0.0053736 m	un-deformed geometry - derived lens diameter

# 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

**kejako** keep your eyes young

Debug Default Values Hyper <--> Linear Elastic Reference Geometry Deformed Geometry Compare Geometry Optimize Geometry

### Lens Spinner v2.0 --> (Model A)

**Upload Reference Geomtry File** C:\Users\johnspeyrer\Desktop\Lens Data\bet0\_1P1\_Spin1a ( Browse

Ant Curvature data	Pos Curvature Data	Equatorial Data Pts	AP Data Pts
A -1.411 · 10 <sup>-6</sup> m	A 1.562 · 10 <sup>-6</sup> m	Eq_x1 0.002657 m	Ap_x1 0.008186 m
B 1.68 · 10 <sup>-6</sup> m	B -1.269 · 10 <sup>-6</sup> m	Eq_y1 -0.006752 m	Ap_y1 -0.003135 m
C -5.204 · 10 <sup>-5</sup> m	C 8.56 · 10 <sup>-5</sup> m	Eq_x2 0.01382 m	Ap_x2 0.00821 m
D 2.048 · 10 <sup>-5</sup> m	D -2.16 · 10 <sup>-5</sup> m	Eq_y2 -0.00682 m	Ap_y2 -0.01159 m
E -0.003188 m	E -0.01153 m		
F 0.007962 m	F 0.008092 m		

**Curvature equation:**  
 $A*(x-F)**4+B*(x-F)**3+C*(x-F)**2+D*(x-F)+E$

**Equator & Axial Data**      **Rotational Speed**  
 Eq\_Diameter 0.01116 m      rspeed 1.85 1/s  
 AP\_Axial\_Length 0.008452 m      ( 111 rpm )

**Upload Deformed Geomtry File** C:\Users\johnspeyrer\Desktop\Lens Data\bet0\_1P1\_Spin1a ( Browse

Ant Curvature data	Pos Curvature Data	Equatorial Data Pts	AP Data Pts
A -1.296 · 10 <sup>-6</sup> m	A 1.263 · 10 <sup>-6</sup> m	Eq_x1 0.00252 m	Ap_x1 0.008176 m
B 1.111 · 10 <sup>-6</sup> m	B -1.106 · 10 <sup>-6</sup> m	Eq_y1 -0.006784 m	Ap_y1 -0.003303 m
C -4.709 · 10 <sup>-5</sup> m	C 8.287 · 10 <sup>-5</sup> m	Eq_x2 0.01394 m	Ap_x2 0.008214 m
D 1.204 · 10 <sup>-5</sup> m	D -2.931 · 10 <sup>-5</sup> m	Eq_y2 -0.006901 m	Ap_y2 -0.01155 m
E -0.00335 m	E -0.0115 m		
F 0.008054 m	F 0.008054 m		

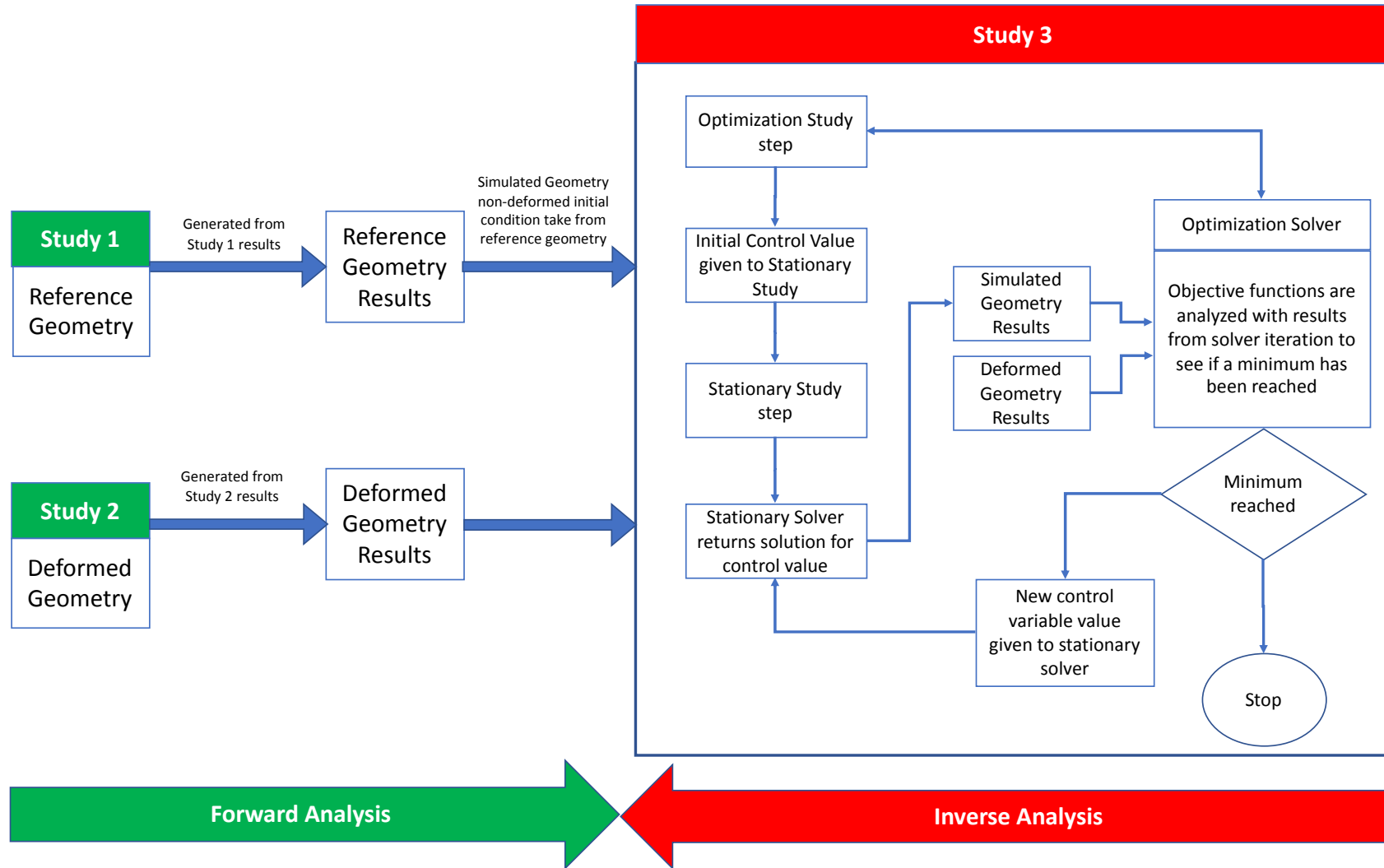
**Curvature equation:**  
 $A*(x-F)**4+B*(x-F)**3+C*(x-F)**2+D*(x-F)+E$

**Equator & Axial Data**      **Rotational Speed**  
 Eq\_Diameter 0.01143 m      rspeed 17 1/s  
 AP\_Axial\_Length 0.008249 m      ( 1020 rpm )

Line Graph: R,Z-coordinate (mm)

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







# Application Builder

The screenshot displays the 'Run Optimization Study' window. On the left, a sidebar shows the 'keja' logo and 'Lens Spinner v' with options to 'Upload Reference Ge' and 'Upload Deformed G'. The main window has a top toolbar with icons for 'Hyper <--> Linear Elastic', 'Reference Geometry', 'Deformed Geometry', 'Compare Geometry', and 'Optimize Geometry'. A 'Compute' button is highlighted with a blue circle '2'. Below the toolbar is an 'Optimization Results Table' with columns for 'comp2.E\_const1' and 'Objective'. The table contains 20 rows of numerical data. To the right of the table is a 'Browse' button and a 'speed' parameter set to '1.85 1/s' and '11 rpm'. A 'Browse' button is also present below the speed parameters. On the far right, a plot shows 'z-coordinate (mm)' vs 'r-coordinate (mm)'. The plot title is 'Optimization --> mu0= 1323.63 mu1= 276.674'. The plot compares 'Sim' (Simulation, solid blue line) and 'Exp' (Experimental, dashed grey line). A blue circle '1' is positioned above the plot area.

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



# Thank you for your attention



[www.kejako.com](http://www.kejako.com)