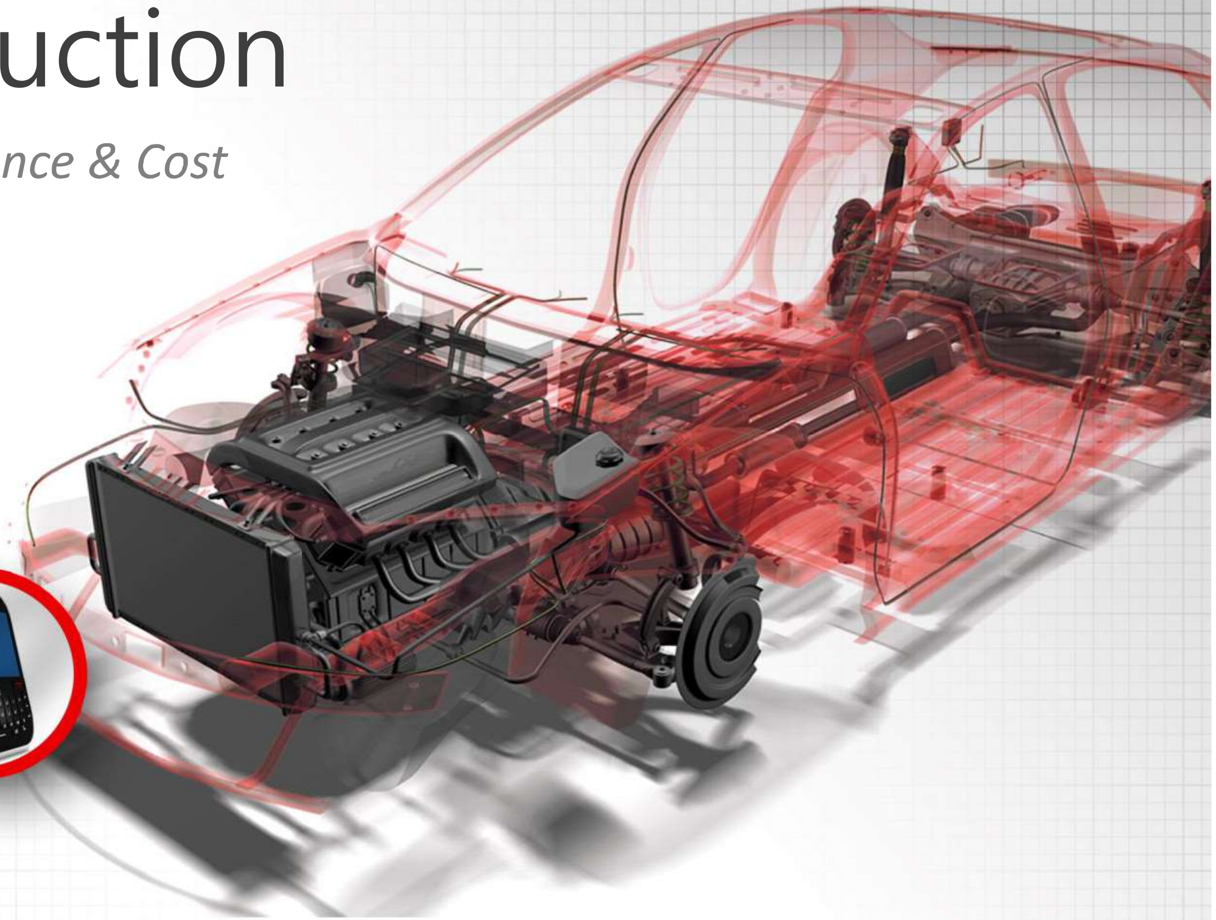
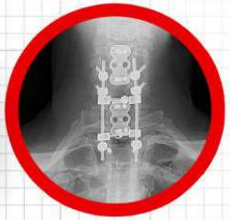
CETOL 6σ Introduction

Balance between Design Performance & Cost





Agenda

- About Sigmetrix
- CETOL 6σ Overview
- Customer Examples
- Q & A

About Sigmetrix

CETOL 6σ™

2000 ~

2002. CETOL v5.1 released. **Signed CAA V5 Gold Partner Agreement** with Dassault Systemes

2003-06. **CETOL v6.0 thru v7.2** released for ProE and CATIA R10 – 15

2005-07. CETOL v8.0 architecture, **SolidWorks Research Associate** CETOL SW 2006, ProE Wildfire, CATIA R15 – 16

2007. **CETOL v8.0 BETA** for ProE, CATIA and SolidWorks;TAX ProE WF 4.0 BETA

2008. **CETOL v8.0 Release for ProENGINEER, SolidWorks and CATIA V5**

2008. **ProENGINEER Tolerance Analysis Extension powered by CETOL Technology WF 4 Release**

2008. **ProENGINEER, CATIA & Solidworks CETOL v8.1 release (July 2008)**

2009. **Acquired** by Cybernet Systems Company, Ltd. the leading Mechanical CAE Solutions Company in Japan

2009. **CETOL v8.1 Release for ProENGINEER, SolidWorks and CATIA V5**

2010. **CETOL v8.2 Release for ProENGINEER, SolidWorks and CATIA V5**

2011. **TSNE, Certified Channel Partners in Korea**

2012. **GD&T Advisor v2.0 Release for ProENGINEER**

2013. **CETOL v8.3 Release for ProENGINEER, SolidWorks and CATIA V5**

2015**. CETOL v8.4 Release for CREO, SolidWorks and CATIA V5**

2016. **CETOL v9.0 Release for CREO and SolidWorks**

2017. CETOL v10.0 Release for UG Nx and CATIA V6

1990 ~

1990. **CEP established in Texas Instruments** (TI) to develop CAE applications for the global commercial market

1992. sign as **PTC's first Cooperative Software Development Partner**

1992-98. TITOL v1.0 thru v3.1 released (Integrated 1D, 2D and 3D Capability), expanded channel partners

1997. Texas Instruments Division acquired by Raytheon, **TITOL changed to CETOL**, Signed first Japan Distributor

1999. **Sigmetrix founded**, PTC global VAR of CETOL v4.0 for Pro/ENGINEER

산업군별 주요 고객사

CETOL 6σ™

Heavy Equipment & Transportation

HYUNDAI WIA, Cummins, John Deere, SKF, Caterpillar, Doosan, seco, Harley-Davidson Motor Cycles, Chrysler, Hyundai, SMR Automotive, Audi, Volvo, Volkswagen, Brooks Stevens

Medical

Synthes, Stryker, Mako Surgical Corp., Starkey, GSK GlaxoSmithKline, Medtronic, Zimmer, Intuity Medical, GE, Roche, Abbott, Varian medical systems, Boston Scientific, Covidien

High Tech Electronics

Tyco Electronics, Qualcomm, Nokia Connecting People, LG Display, Xerox, Ericsson, AMX

Power Systems

GE, Eaton, Emerson, Siemens, Energizer, Ballard, Mando Corporation

Security

Ingersoll Rand, Stanley Security Solutions, ASSA High Security Locks

HVAC

United Technologies, Carrier, Trane, Goodman Air Conditioning & Heating

Defense

Northrop Grumman, Honeywell, FN, Raytheon, Rafael

Consumer

Whirlpool, Tetra Pak, Rolex, Kodak, Western Digital, BIC

Automotive Suppliers

Fisher Dynamics, electricfil automotive, BorgWarner, Continental, AV, ArvinMeritor, forteq, BHTC Comfort in Motion, Gentex Corporation, Wahler, ZF, Cherry, Gill Industries, Inc., Kiekert, Harman

Oil, Gas, Energy

Schlumberger, Baker Hughes, Thomas Driven by magnetics

Consulting & CM

Phillips Plastics Corporation, Aircom, Tata, Flextronics, Foxconn

"SEE WHAT YOU'RE MISSING"

공차분석이 필요한 이유 (1)

CETOL 6σ

- R&D Engineer
  - prototype 모델의 조립이 올바르게 진행되어지는가?
- Product Design Engineer
  - Worst Case condition에 대해서도 하위 조립품까지 조립에 문제가 없는가?
- Manufacturing Engineer
  - 제품의 제작과 조립공정을 얼마나 더 낮은 비용으로까지 개선할 수 있는가?
- Quality Engineer
  - 생산된 1천개의 제품들 중, 안정적인 조립성과 성능에 대한 요구사항을 얼마나 충족시키는가?
- Reliability Engineer
  - 작동환경에서 제품의 성능과 요구사항을 얼마나 충족시키는가?

공차분석이 필요한 이유 (2)

CETOL 6σ

- 조립품질을 측정하고 그 결과를 바탕으로 공차를 조정하는 방법의 문제점은 다음과 같습니다.
  - 공차를 엄격하게 혹은 느슨하게 설정하는 이유는?
  - 설정한 공차 값의 근거는?
- 공차 계산은
  - 개인에 의존.
  - 전문적인 사내교육으로 가르치는 기업은 많지 않음.
  - 대부분 독학이나 업무를 통한 시행착오를 거쳐 습득.
- 누적공차 계산을 실시해도
  - 실제 양산에 옮기면 예상치 못한 문제가 발생하고
  - 결과적으로 실물을 통해 "문제발생 -> 설계에 피드백" 이라는 손실을 순환 반복
  - 시간과 비용이 증가하는 부담을 가집니다.

공차분석이 필요한 이유 (3)

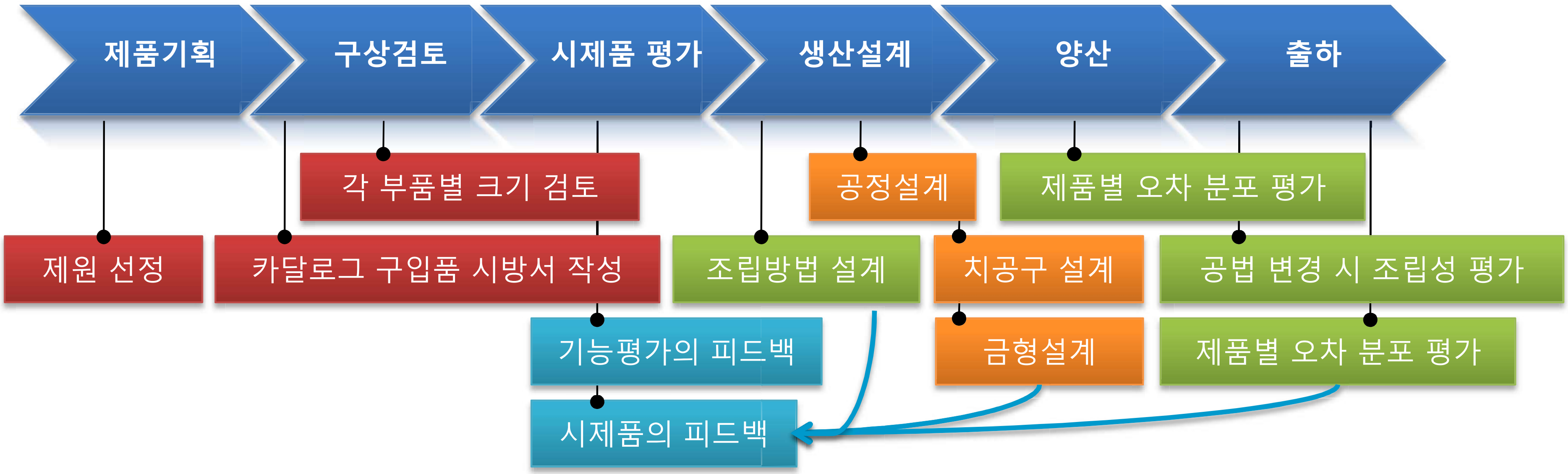
CETOL 6σ

- 부품이 정렬되지 않는 원인은 무엇인가요?
- 이 부품들을 직접 생산하나요?
  아니면 협력사로부터 구매하여 사용하나요?
- 제조과정에서 문제의 원인이 어떤 과정인가요?
- 문제를 해결하기 위해 무엇을 해야 하나요?
  - 좋은 공작기계에 더 많은 투자를 해야 할까요?
  - 생산된 부품을 검사하는데 더 많은 시간을 소비해야 할까요?
- 만약 공급자에게 문제가 있다면, 협력사를 만나서 문제 해결을 요구해야 할까요?
  아니면 다른 협력사를 찾아 보아야 할까요?
- 향후에도 이와 같은 문제를 방지하기를 원한다면, 설계변경을 어떻게 해야 할까요?

공차분석이 필요한 이유 (4)

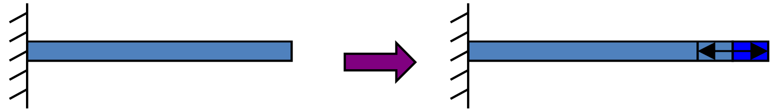
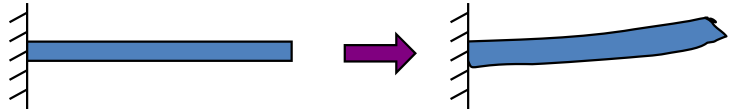
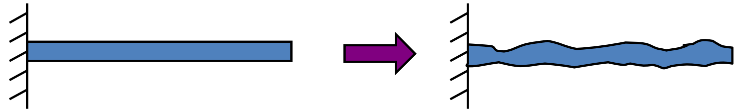
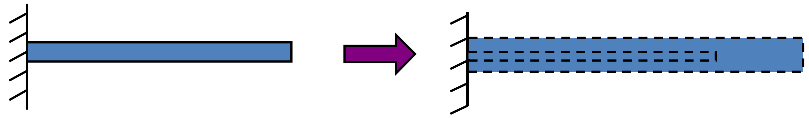
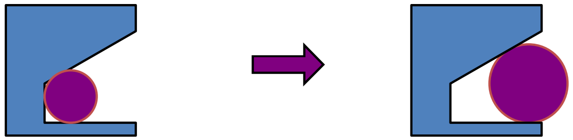
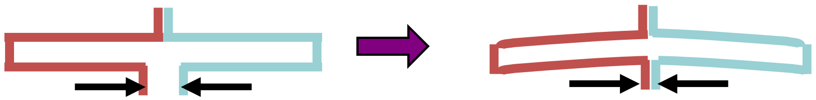
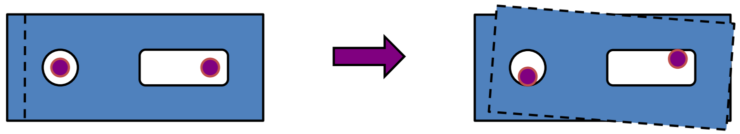
CETOL 6σ

- 제조의 모든 과정에서 “성능”, “조립성”, “비용”을 모두 고려해야 하며, 공차분석 데이터를 바탕으로 공차 수정에 대한 명확한 결정을 내릴 수 있어야 합니다.



The Problem is Pervasive…

CETOL 6σ™

Material Properties	Density, Stiffness, Hardness, Thermal Coefficient, Composite, etc.
Dimensional Variation	
Form Variation	
Surface Quality Variation	
Thermal Expansion	
Kinematic Adjustments	
Deformation Adjustments	
Assembly Process	

Variation Modeling Needs

CETOL 6σ

- Variation을 발생시키는 인자들

Parts

- Inconsistent datums
- Poor dimensioning
- Tool setup
- Draft angles
- Casting error
- Material shrinkage
- Gaging error
- Inspection processes
- Progressive die…

Assemblies

- Fastener shifts
- Joining methods
  - Gluing
  - Welding
  - Forming
- Assembly sequence
- Adjusting mechanisms
- Kinematic adjustments
- Fixtures…

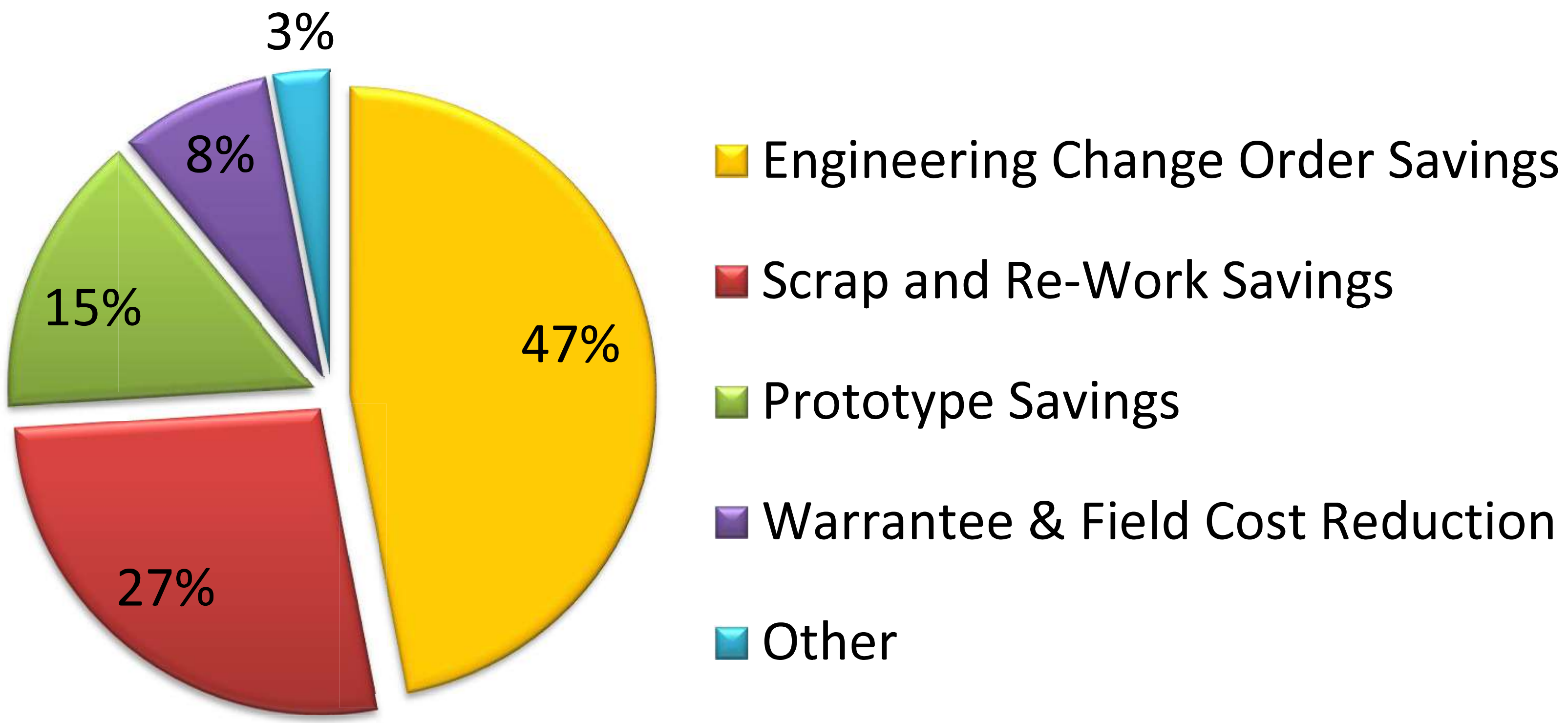
Environmental/Usage

- Gravity loading
- Dynamic loading
- Thermal effects
- Vibration
- Deformations

CETOL Customer Survey Results

CETOL 6σ

공차분석 s/w를 사용함으로써 얻는 좋은 점들은 무엇일까요?



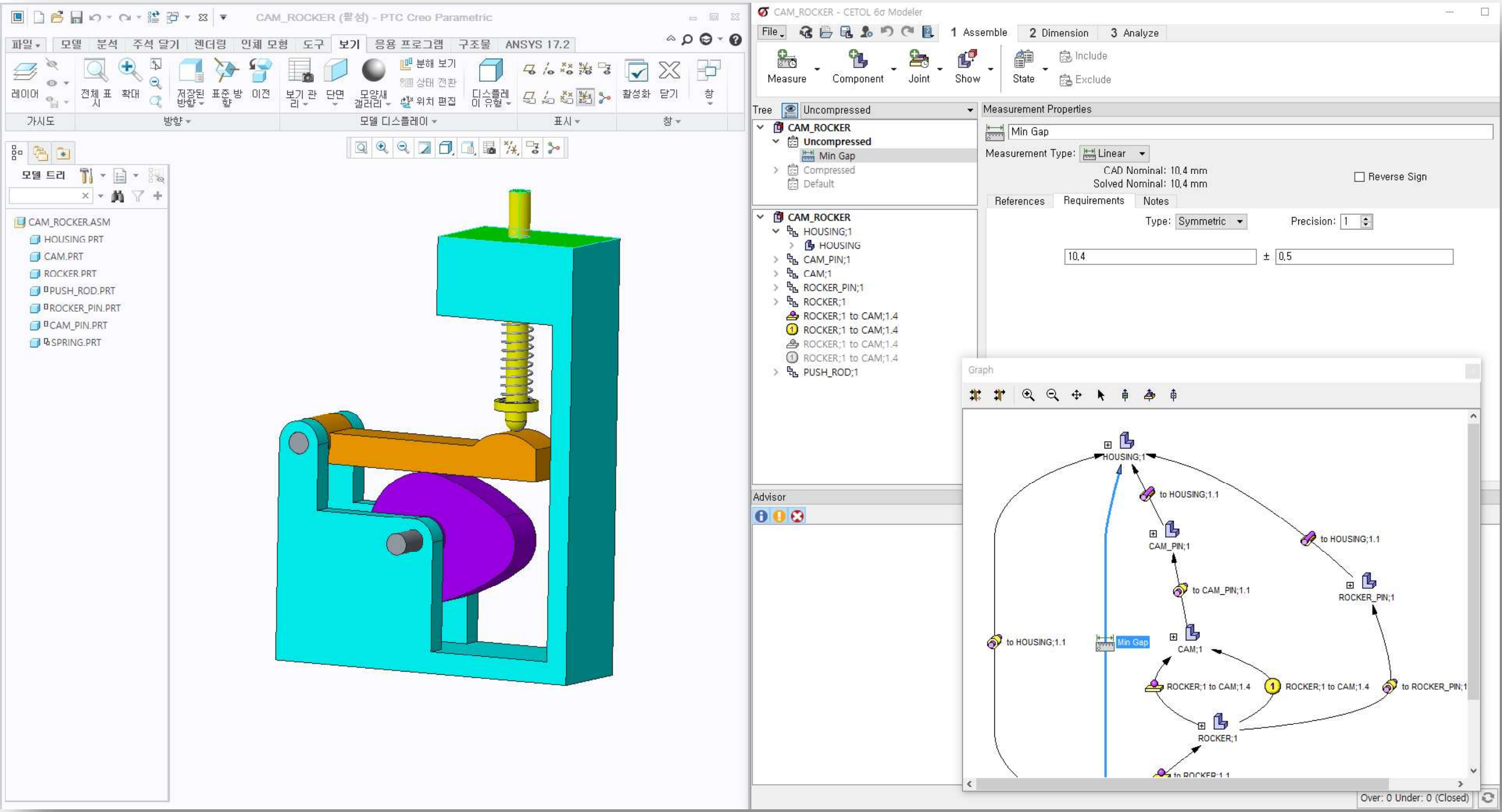
CETOL 6σ Overview

CETOL Pro/E & Creo Integration

CETOL 6σ

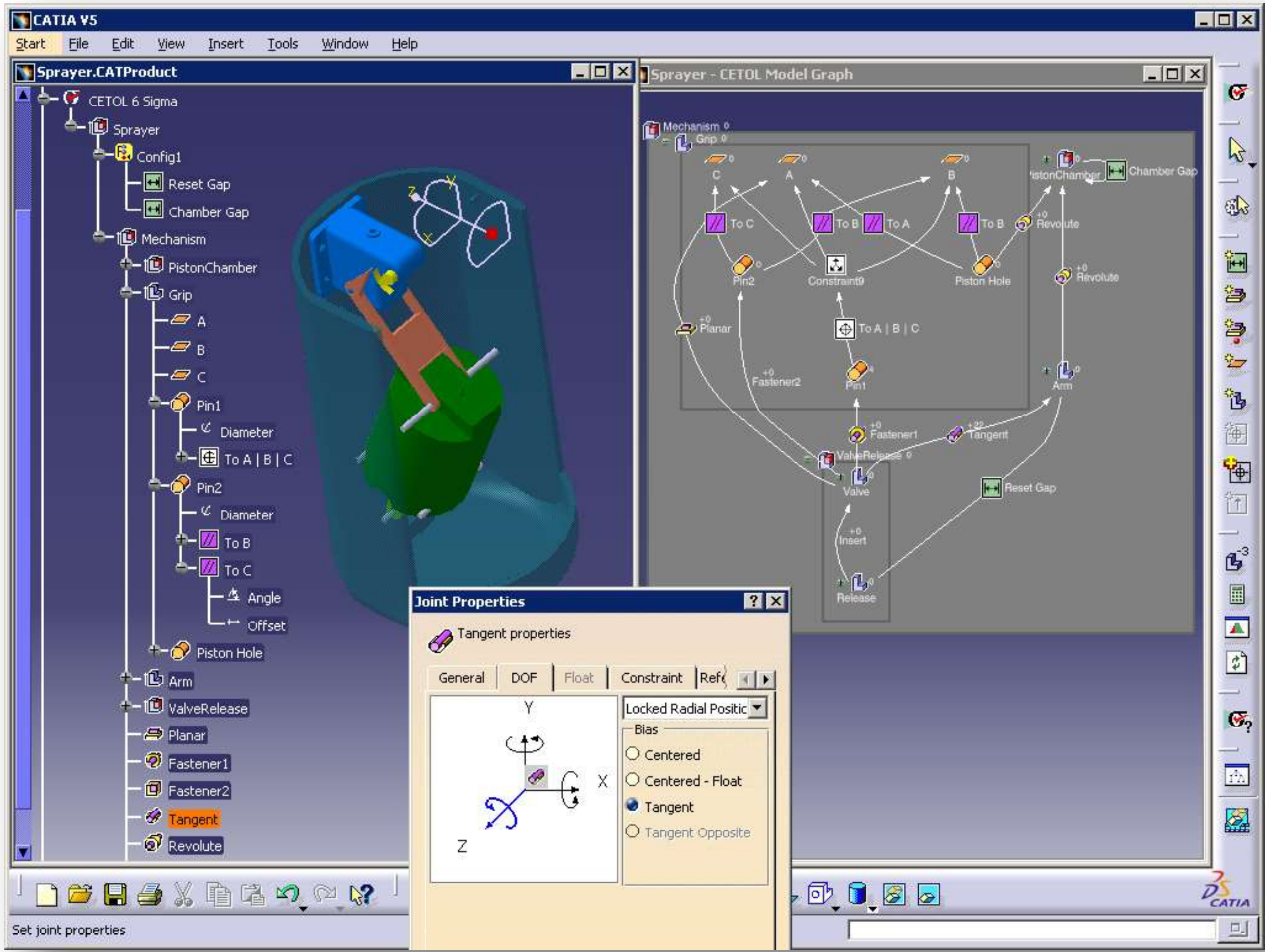
- 1992년부터 기술개발 제휴
- 1999년 Gold Partner 체결
- Pro/E & Creo 통합환경 개발 완료

PTC PartnerAdvantage GOLD



CETOL CATIA Integration

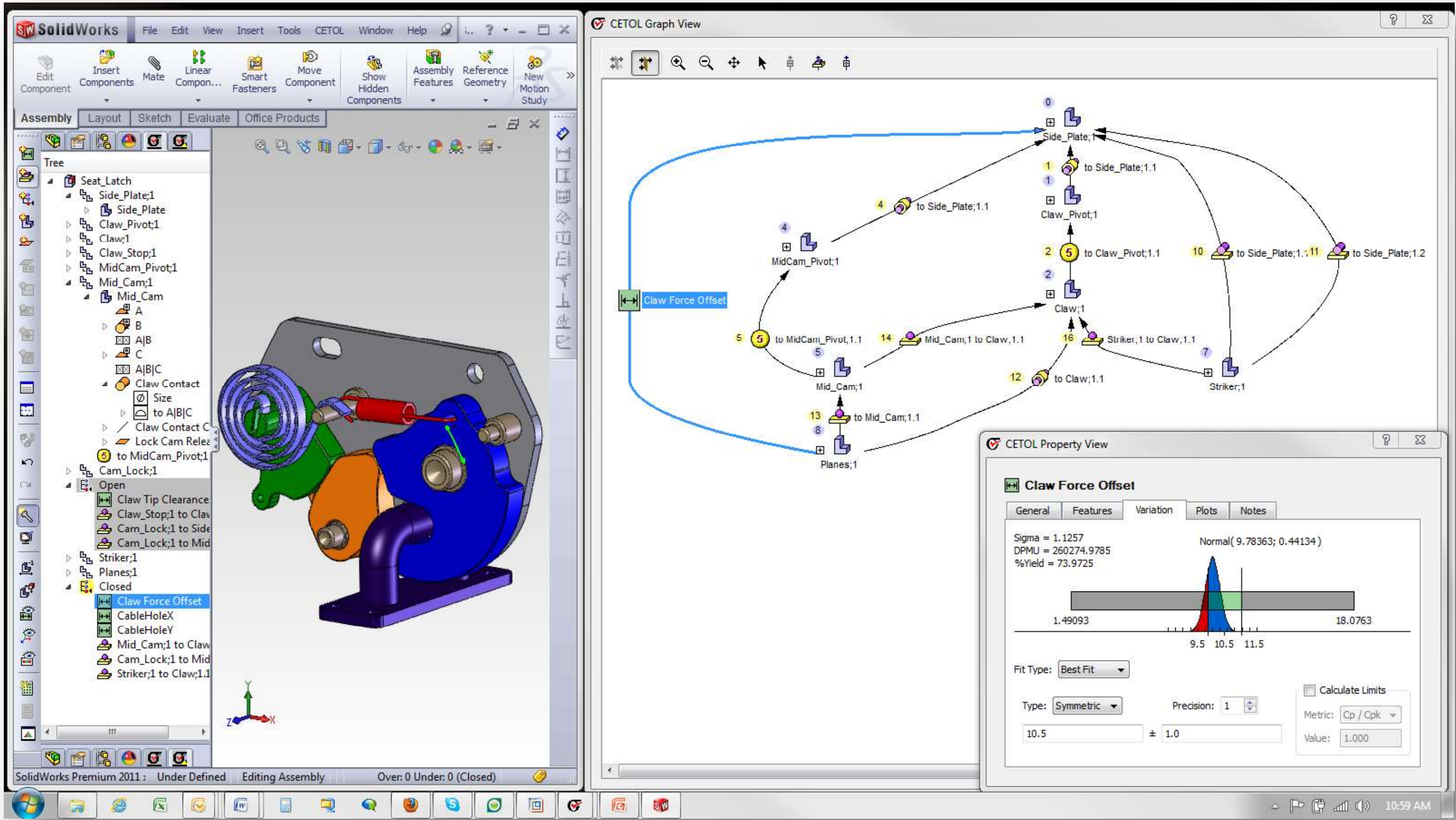
- 2002년 CATIA V5 통합환경 개발 완료
- 정밀한 곡면을 기반으로 공차분석 지원



"SEE WHAT YOU'RE MISSING"

CETOL Solidworks Integration

- Solidworks 통합환경 개발 완료
- 2008년 개발 제휴 – 모든 개발 API's 접근 가능

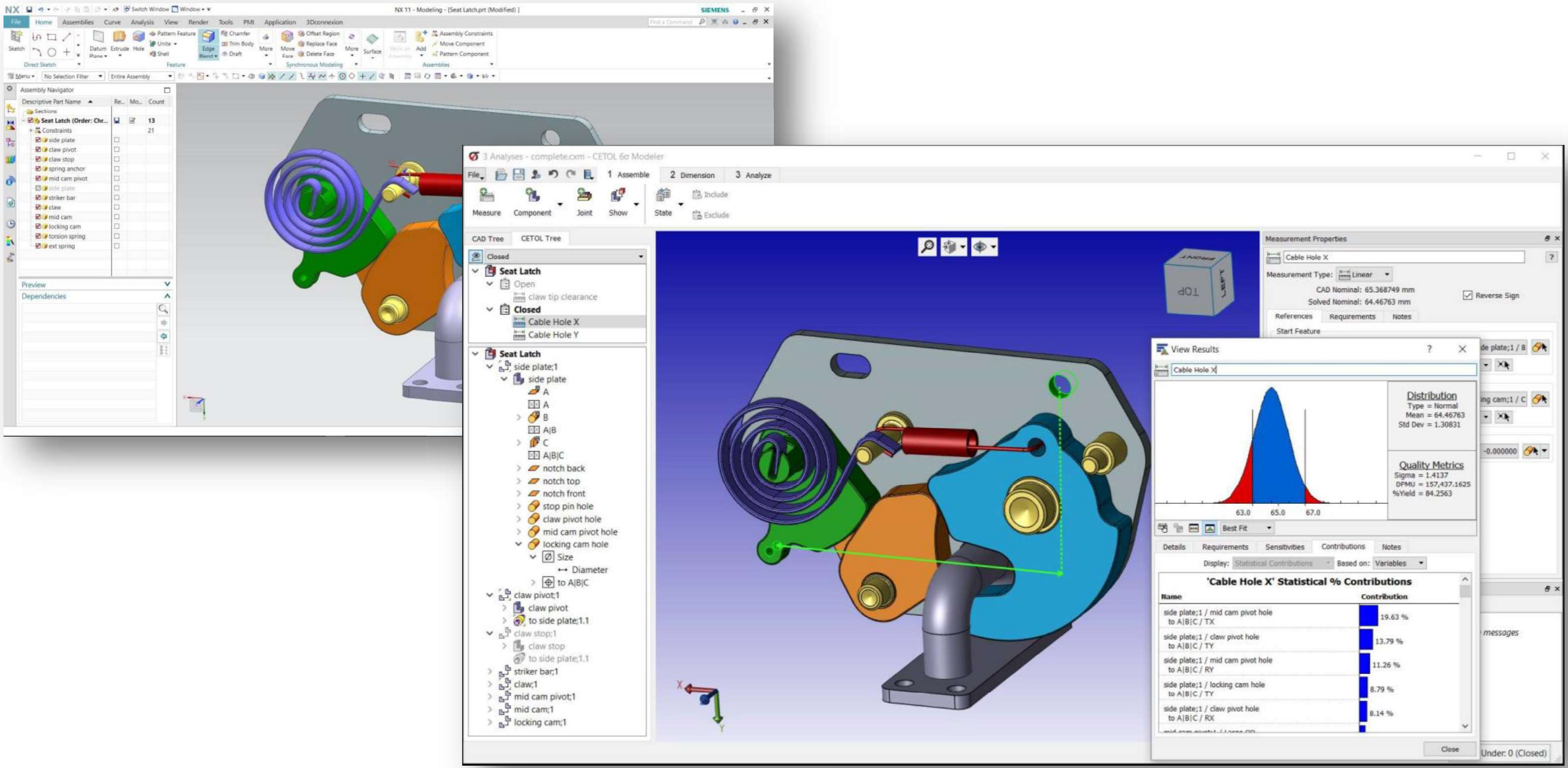


CETOL for SIEMENS NX

CETOL 6σ™

- 2016년부터 기술개발 제휴
- NX CAD 데이터 사용 환경 개발 완료

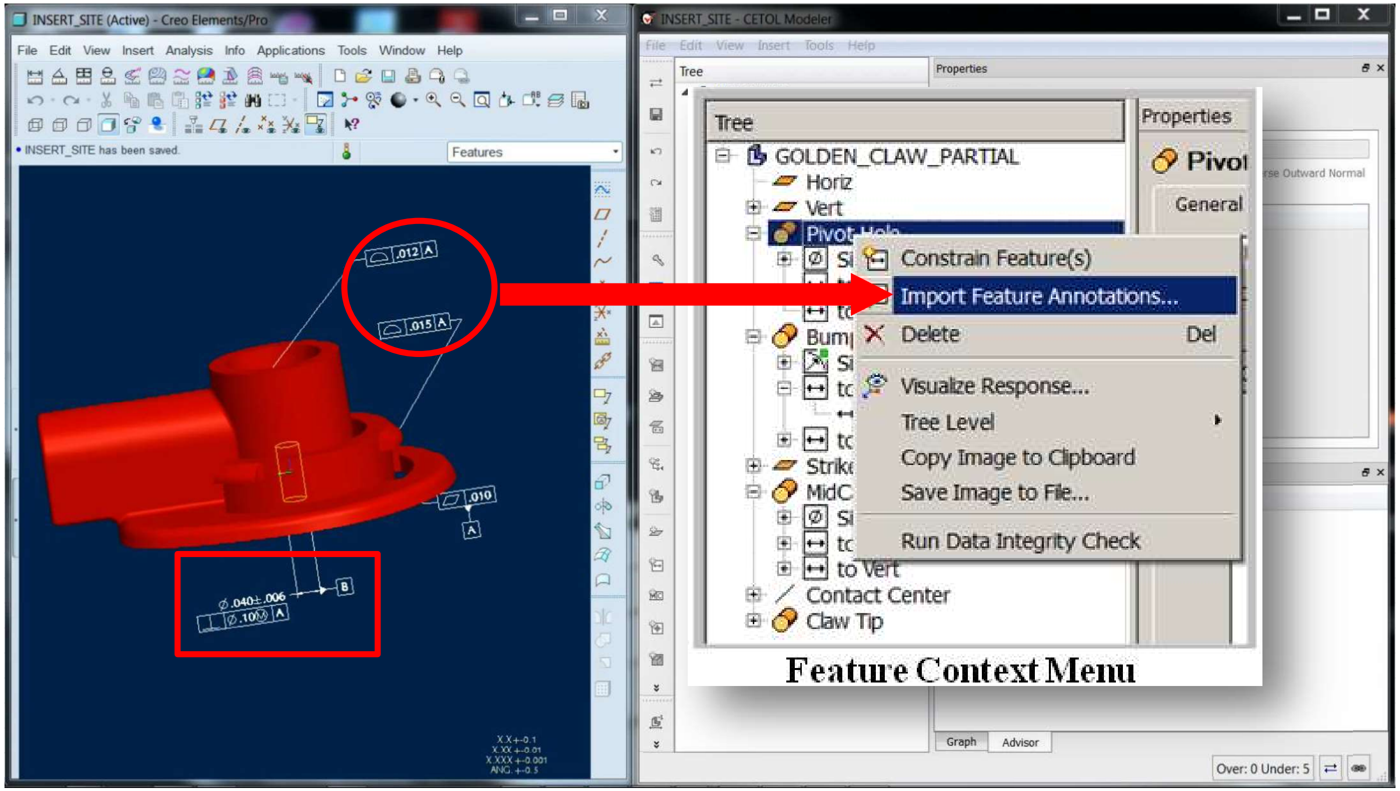
PLM Software SIEMENS NX



CAD Data Integration

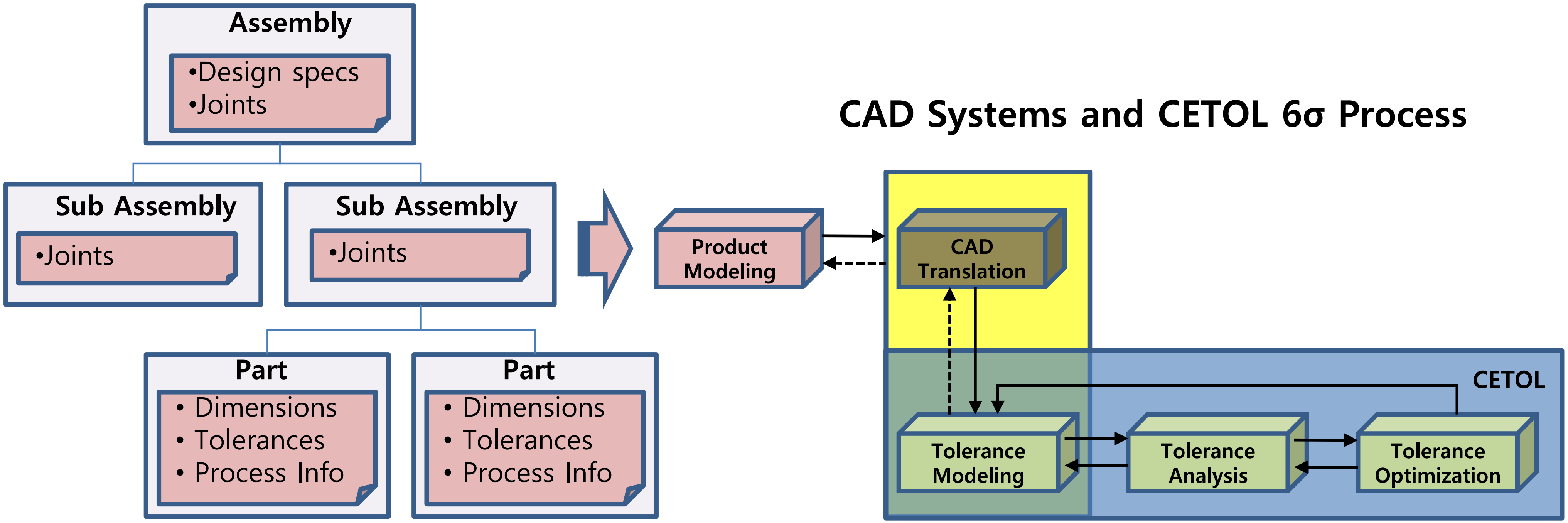
CETOL 6σ™

- 3D CAD와 완벽한 통합 환경
- Data 변환의 과정이 필요 없음
- CAD의 모든 Feature와 통합
  - **Sketches**
  - **Skeletons**
  - **Complex Surfaces**
  - **Full Solid Geometry**
  - **CAD Annotation**
    - **Dimension**
    - **GD&T**
    - **Auto update**

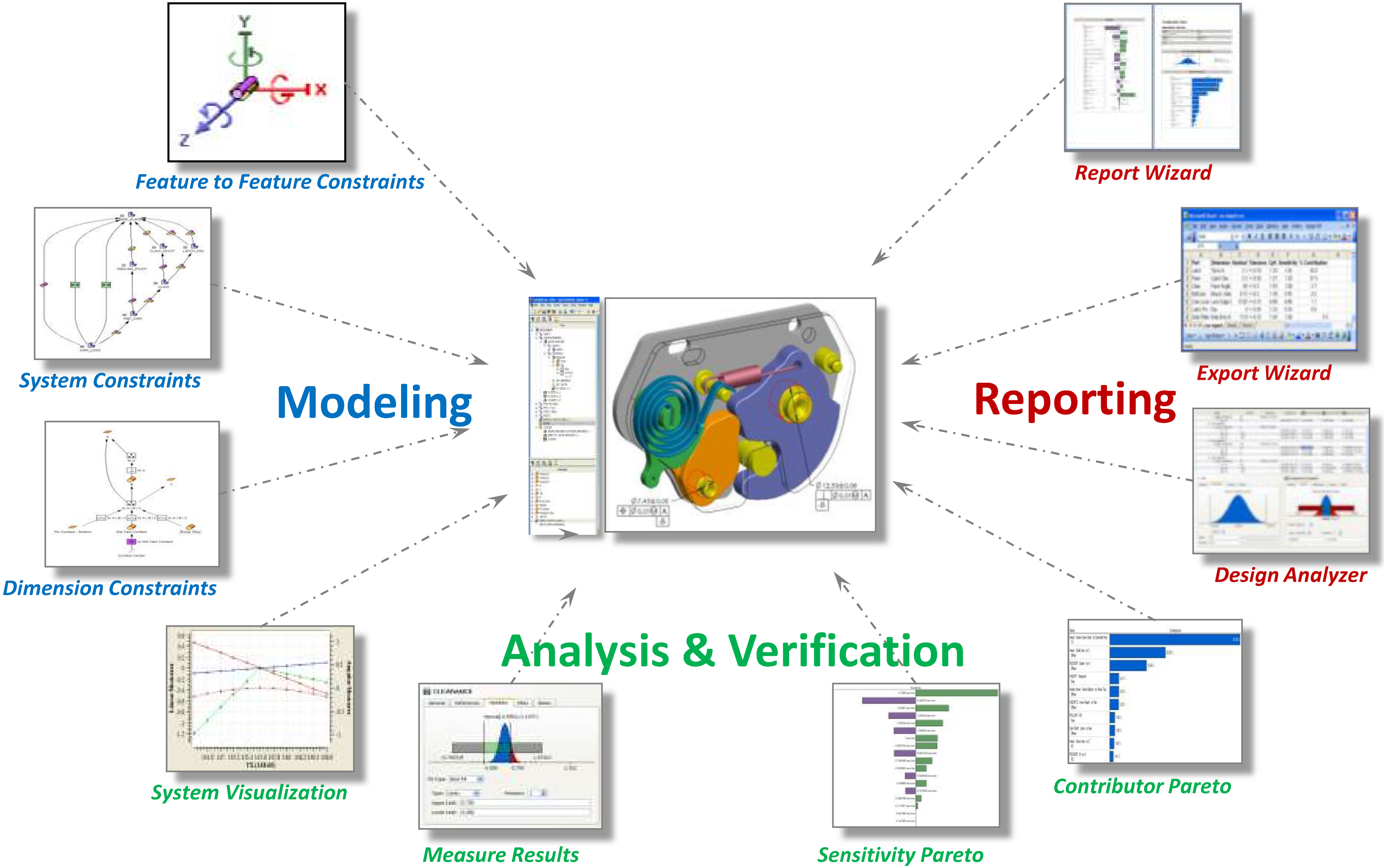


CAD Data Integration

- 3D CAD Assembly 계층구조 방식을 공차분석 모델로 사용
- 공차 모델링 정보는 CAD file에 저장
  분석 결과만 별도 파일(*.cxm)로 저장 가능 –> (결과 분석용)
- CAD file에 직접 저장되어 data 보관 용이 및 재사용 가능



Primary Components of CETOL



Tolerance Analysis Procedure

CETOL 6σ

CETOL 6σ Modeler

Assembly Modeling
- Joint 생성
- Joint 상세 설정

Define Objectives
- 측정지점 생성
- 측정지점 상세 설정

Part Modeling
- 형상 구속
  (dimensions, GD&T, etc.)
- 공차 정의

Validate Model
- Advisor message 확인
- 조립상태 검증
- 민감도 기반 검증

System Moment Method

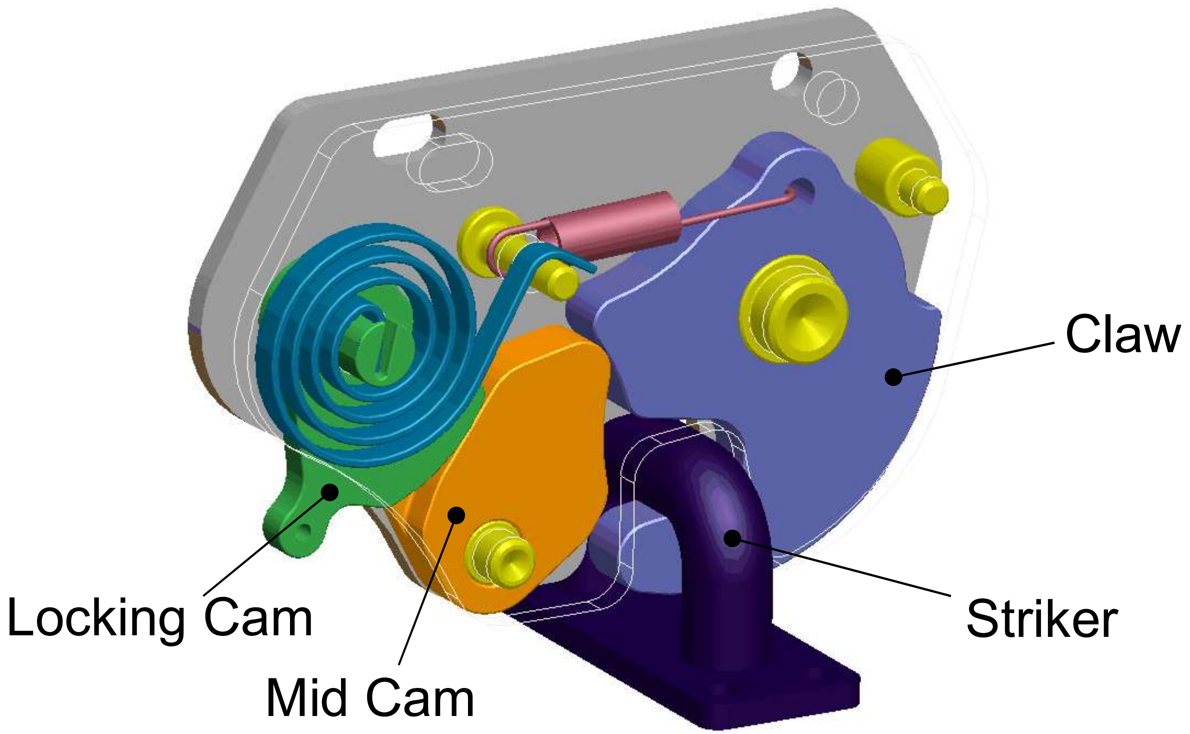
Run Analysis

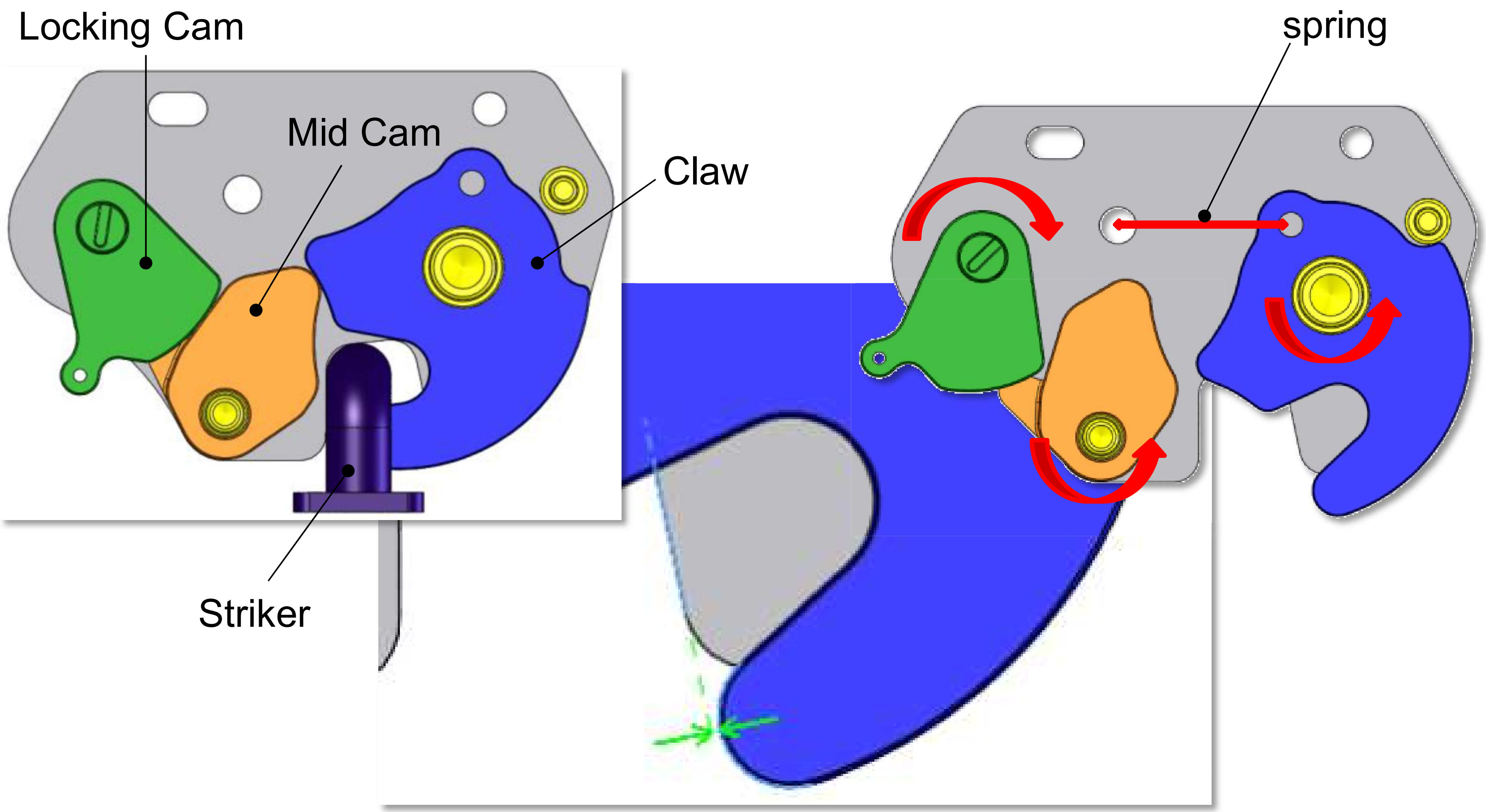
CETOL 6σ Analyzer

Review Results
- 측정지점의 공차 누적량 분석
- 민감도와 기여도 분석

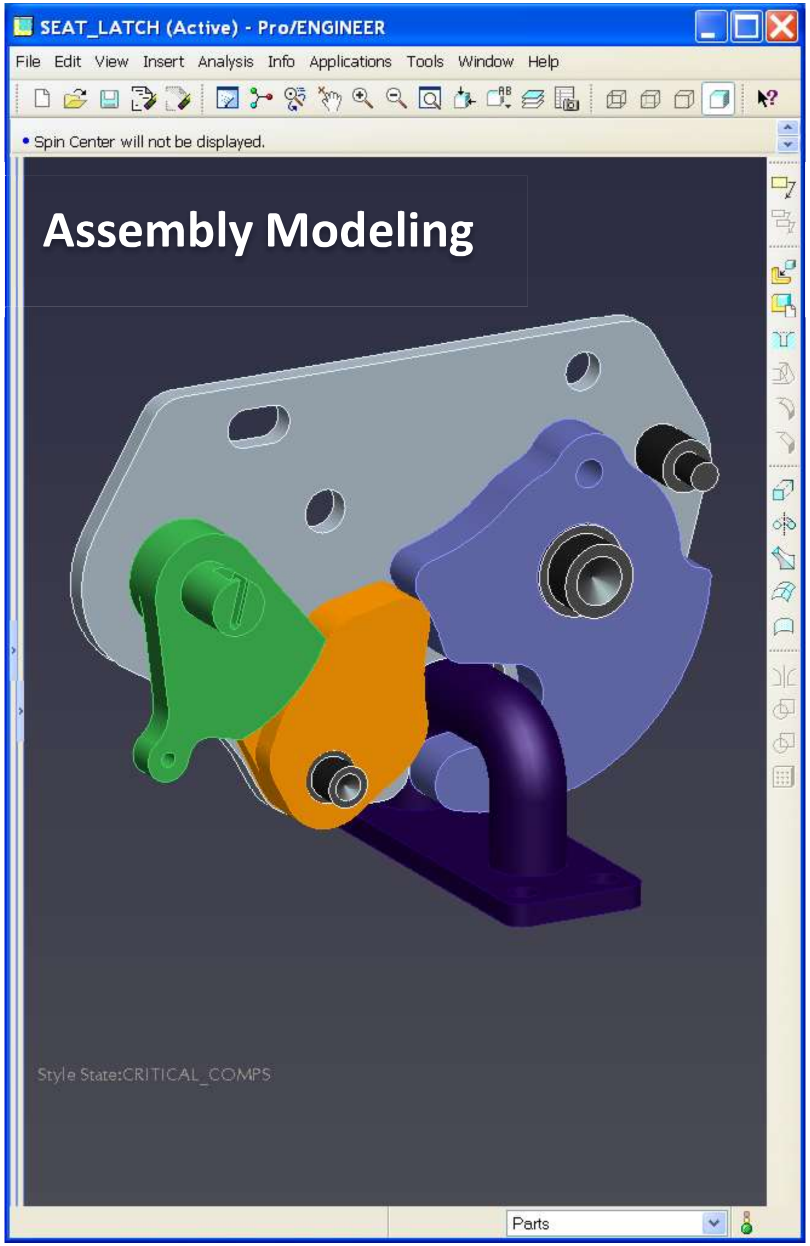
Improve Quality/Reduce Cost
- 공차 범위 조정
- 데이터 관리
- Etc.

Generate Report

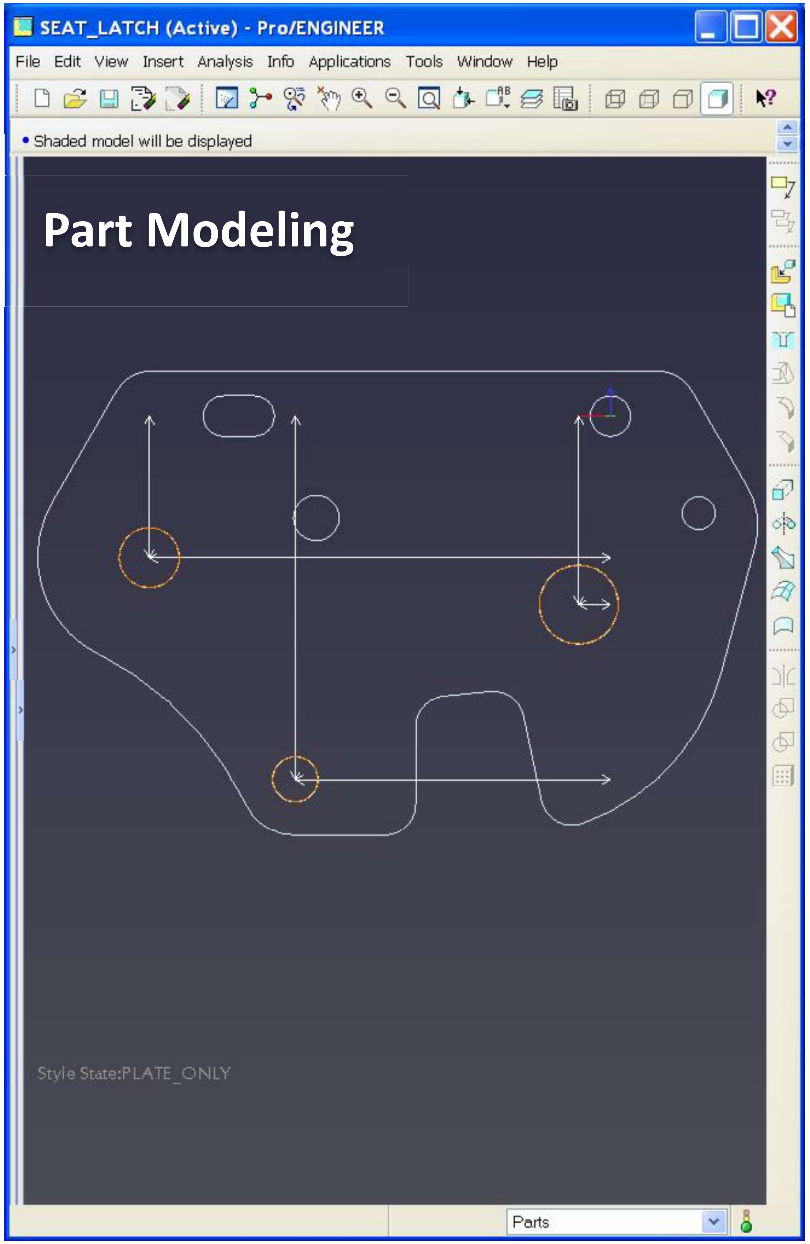

Claw
Locking Cam
Striker
Mid Cam

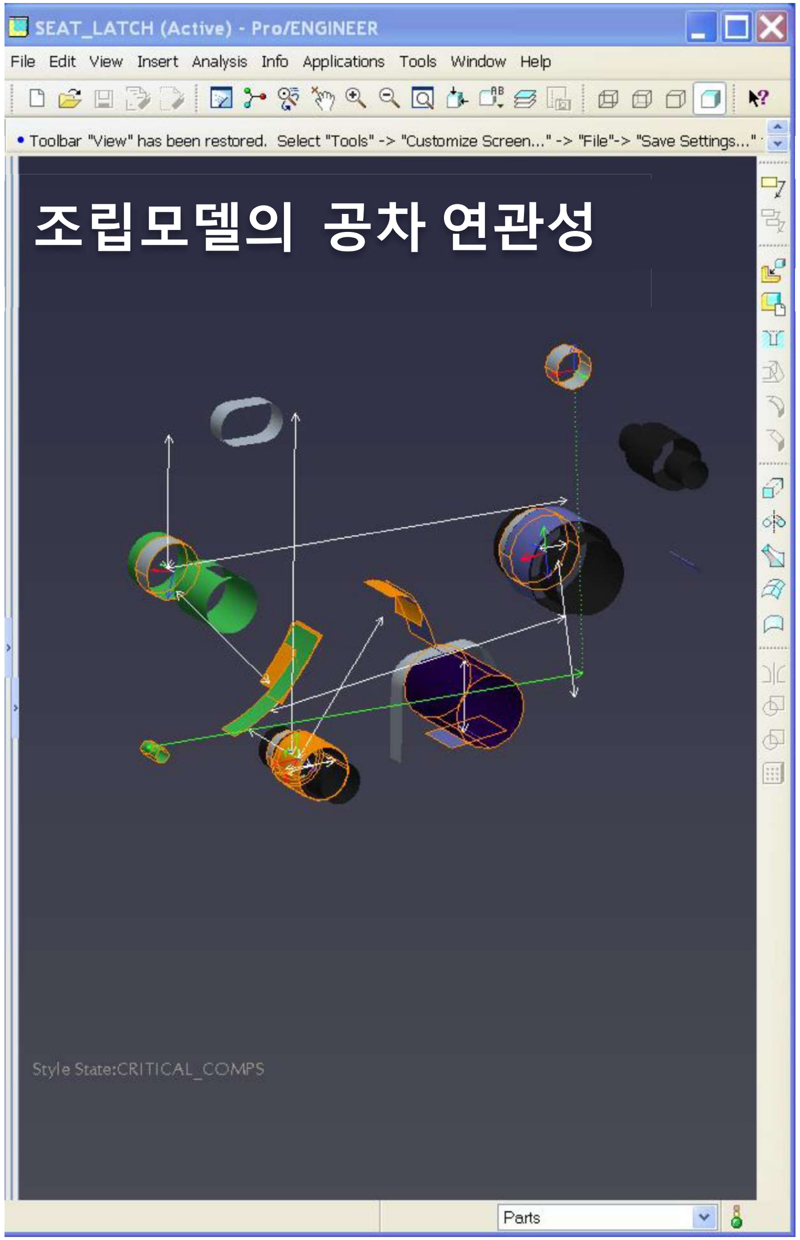

Locking Cam
Mid Cam
Claw
Striker
spring

Tolerance Analysis Procedure



Tolerance Analysis Procedure

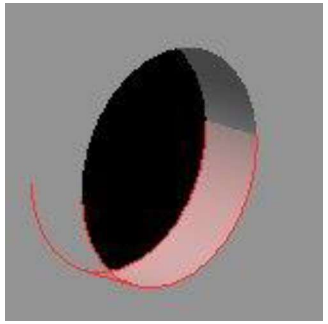


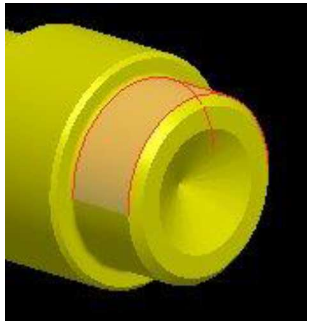


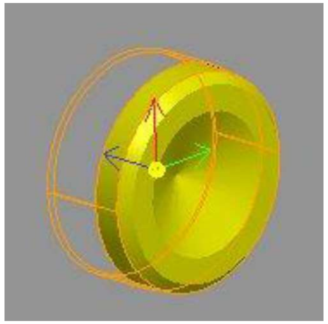
Assembly Modeling

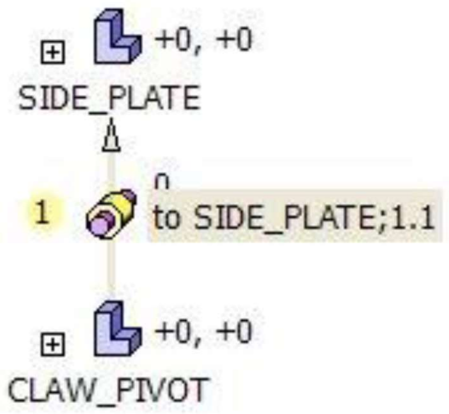
CETOL 6σ™

Step 1: 조립구속조건 설정

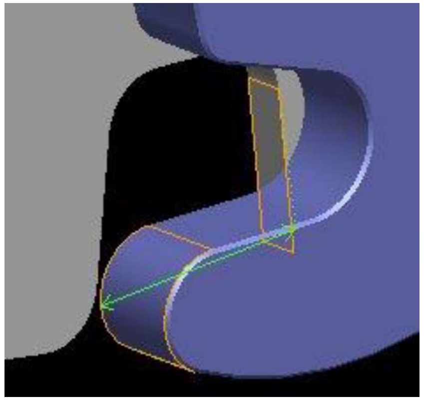


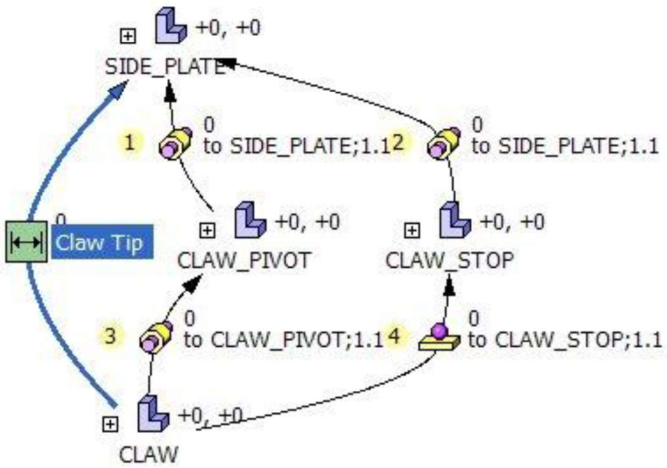


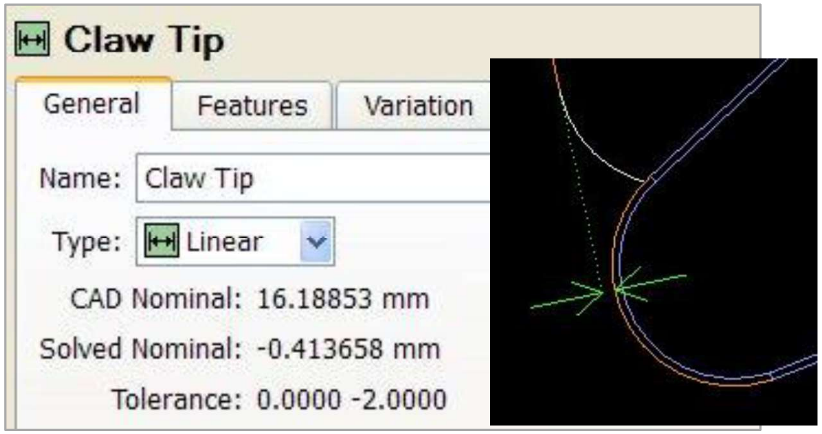




Step 2: 누적공차 측정지점 설정



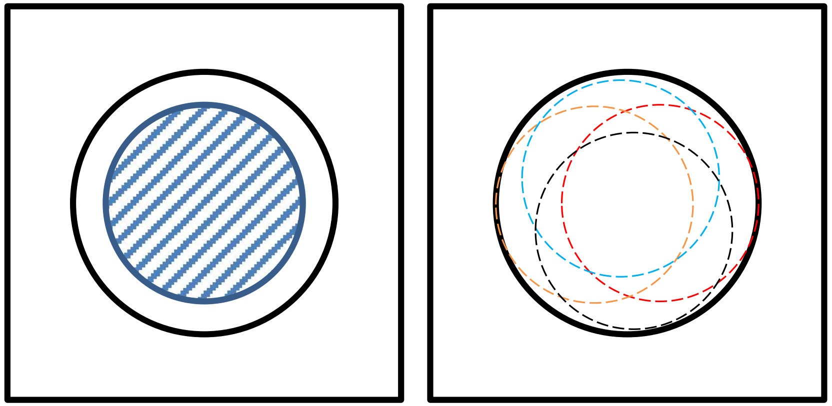


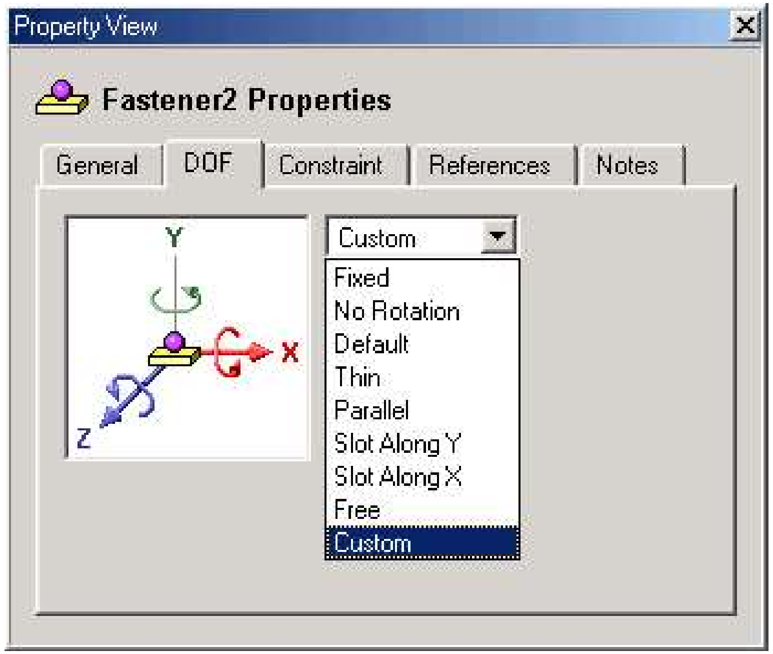


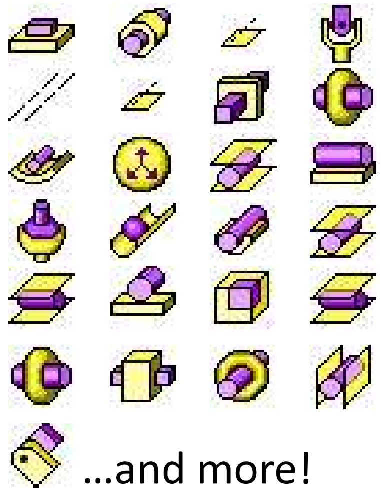
Precise Constraint Technology

CETOL 6σ

- CAD 곡면정보를 기반으로 폭넓은 설정 지원
- CAD 곡면에서의 실제 물리적인 접촉 거동 지원
- 250개 이상의 조립조건에 대한 설정 제안
- 모델 조립 거동에 대한 고차원 움직임 제어 지원
  - Center, Tangent contact, Floating, Hinge axis position…
- 조립 공차 적용에 대한 유연성 확보





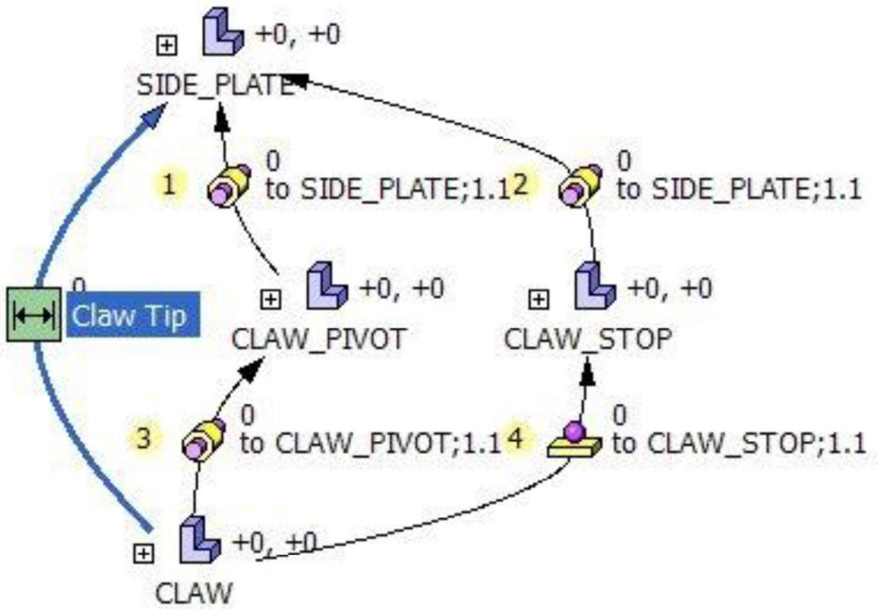


…and more!

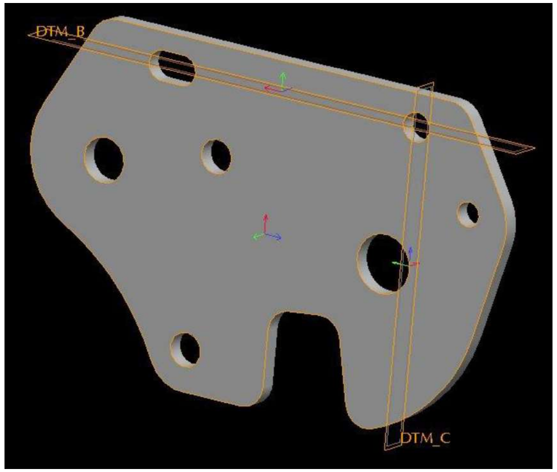
Precise Constraint Technology

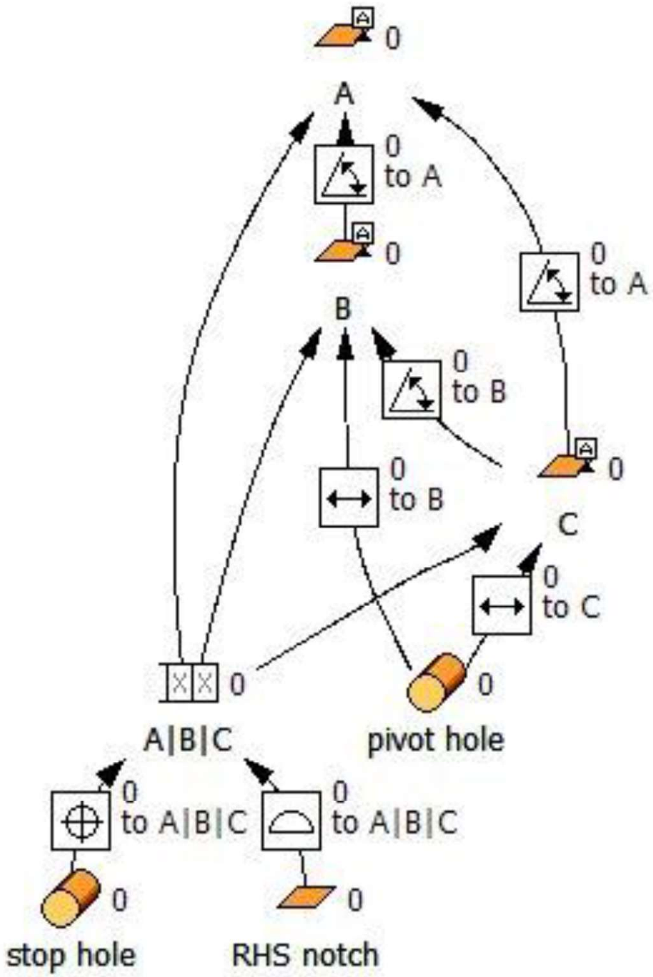
CETOL 6σ

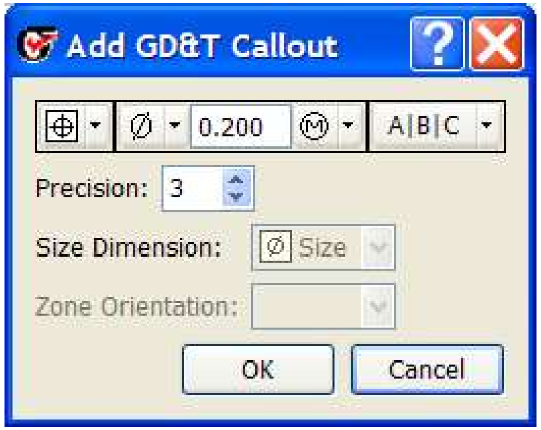
- Automatically Status Identify
  - 기구학적 Closed Loop Solver 사용
  - 복잡한 Mechanism을 가지는 모든 부품의 조립 위치를 자동으로 계산
  - 조립 시, 부품의 구속조건 상태를 즉시 계산
  - 공차 변경 시, 조립품 및 단품의 공차 변경 상태를 즉시 계산
  - 탁월한 Sensitivity 분석 기능



Step 3: 단품 치수구속조건 설정



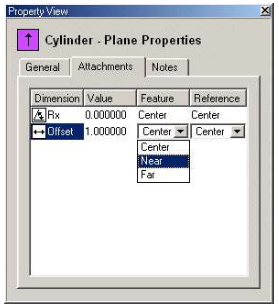


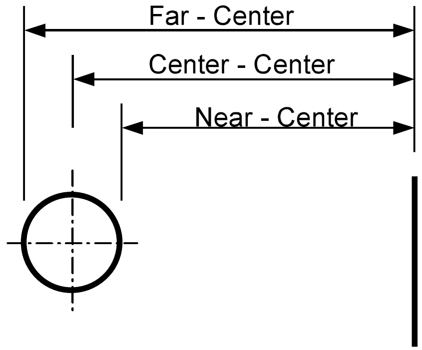


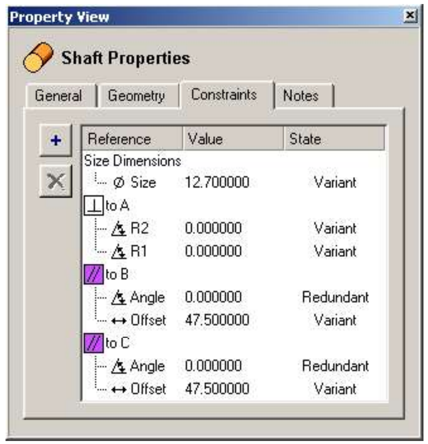
Part Modeling

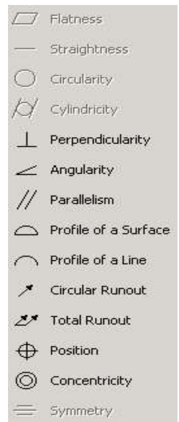
CETOL 6σ

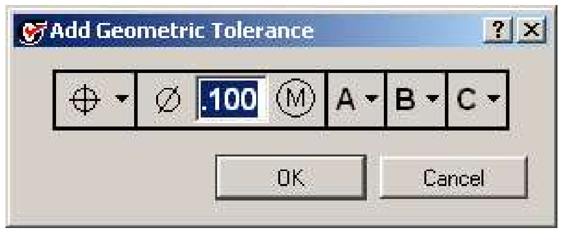
- Dimension Scheme
  - Parametric Mode & OverLay Mode 모두 지원하며 혼용 사용 가능
  - Parametric Mode는 CAD Modeling Scheme을 인식
  - OverLay Mode는 Feature Constraint를 통해 CAD와 독립적으로 Manufacturing Step 정의
- 형상 공차
  - Datum Reference Frame 설정
  - 2개 이상의 형상공차 간 우선순위 정의
  - CAD 공차 정보 Import 및 자체 생성 가능
  - 설정 오류에 대한 Advisor 기능 지원







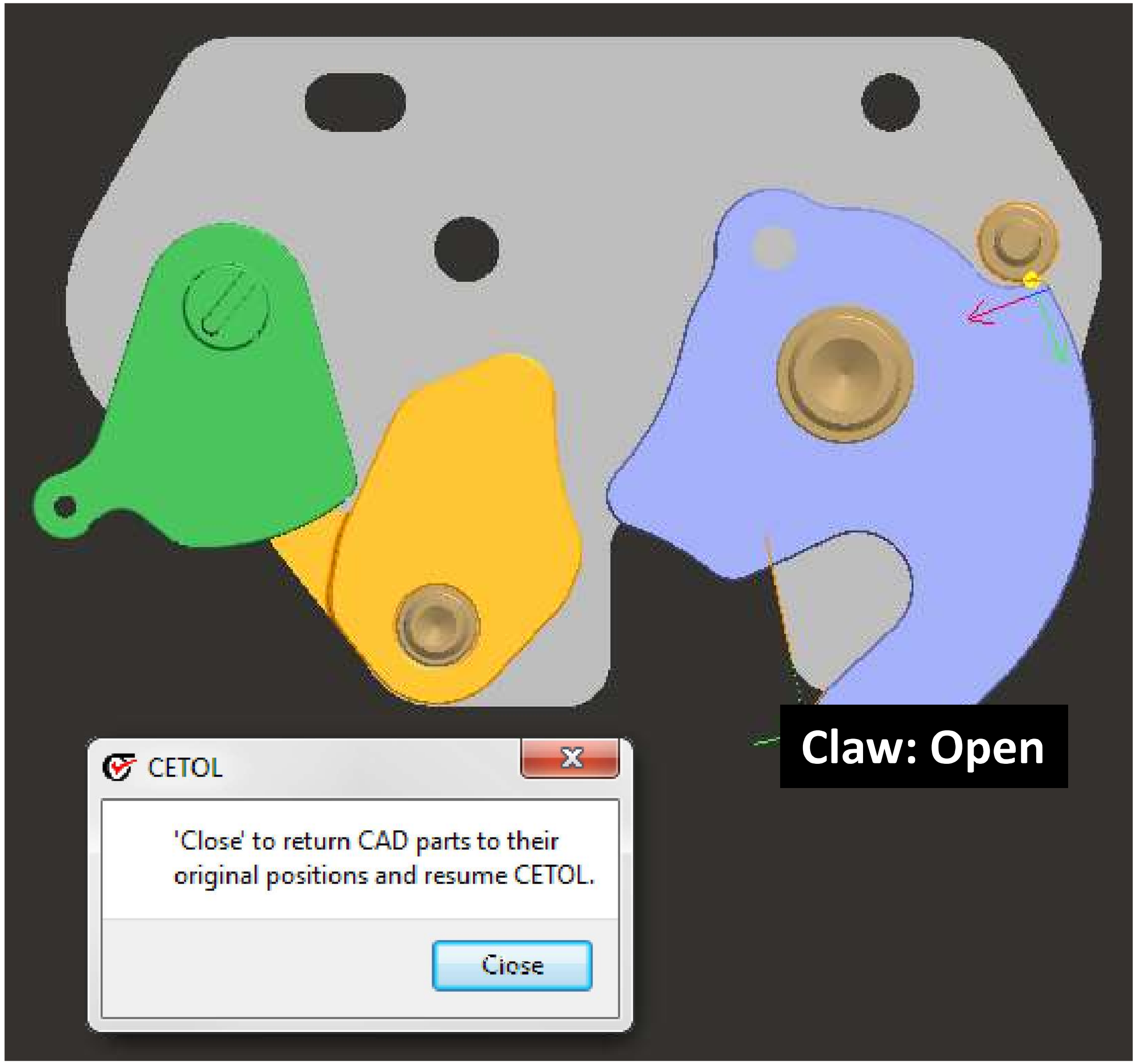




Modeling Verification

CETOL 6σ

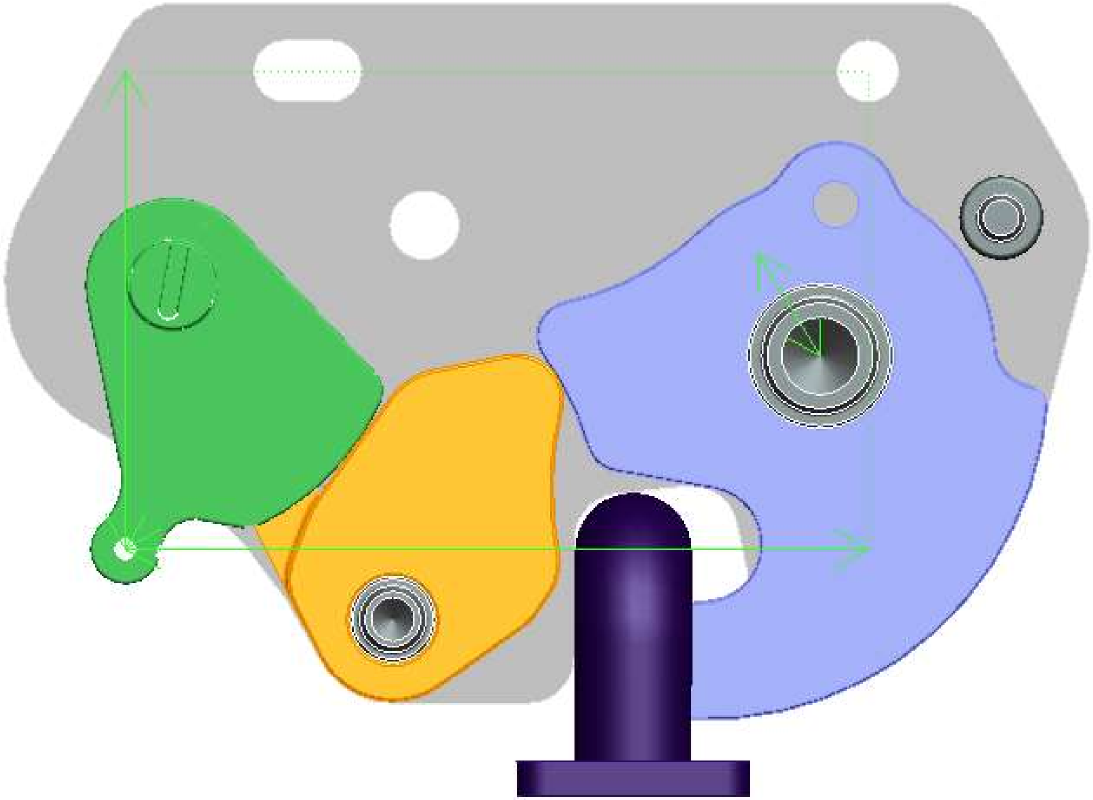
Show Part Location

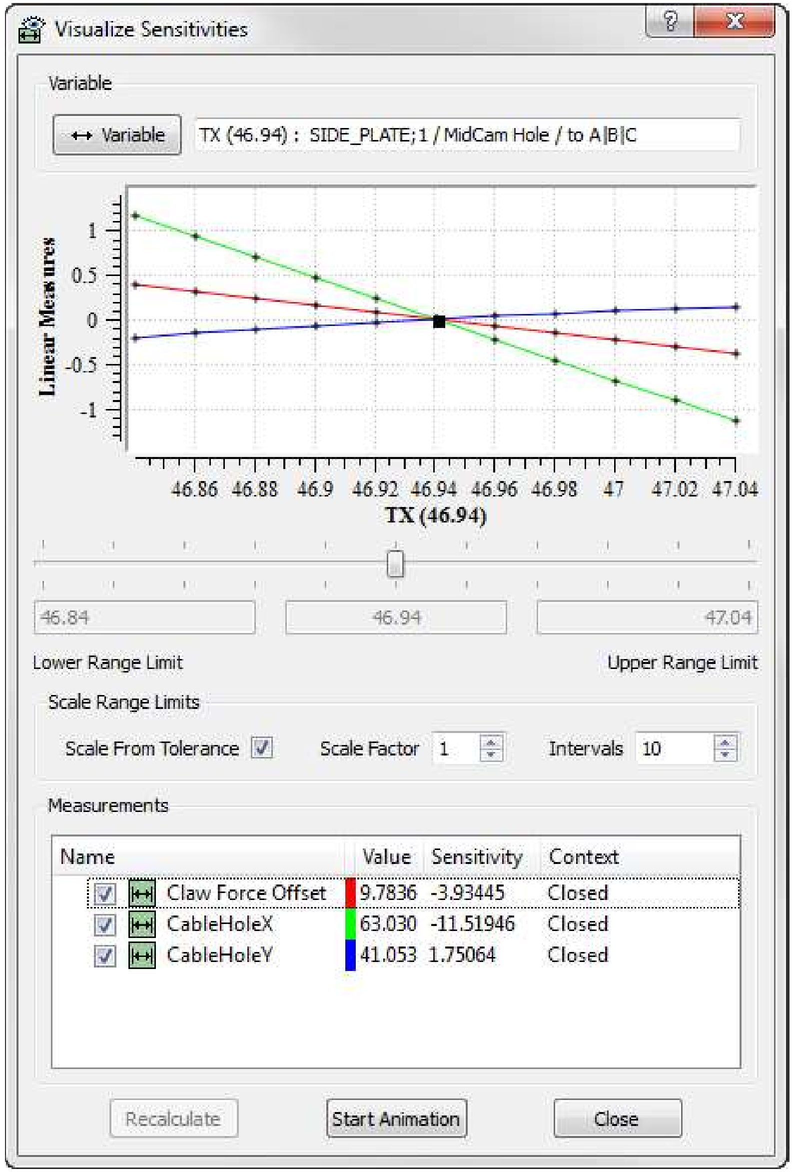


Modeling Verification

CETOL 6σ™

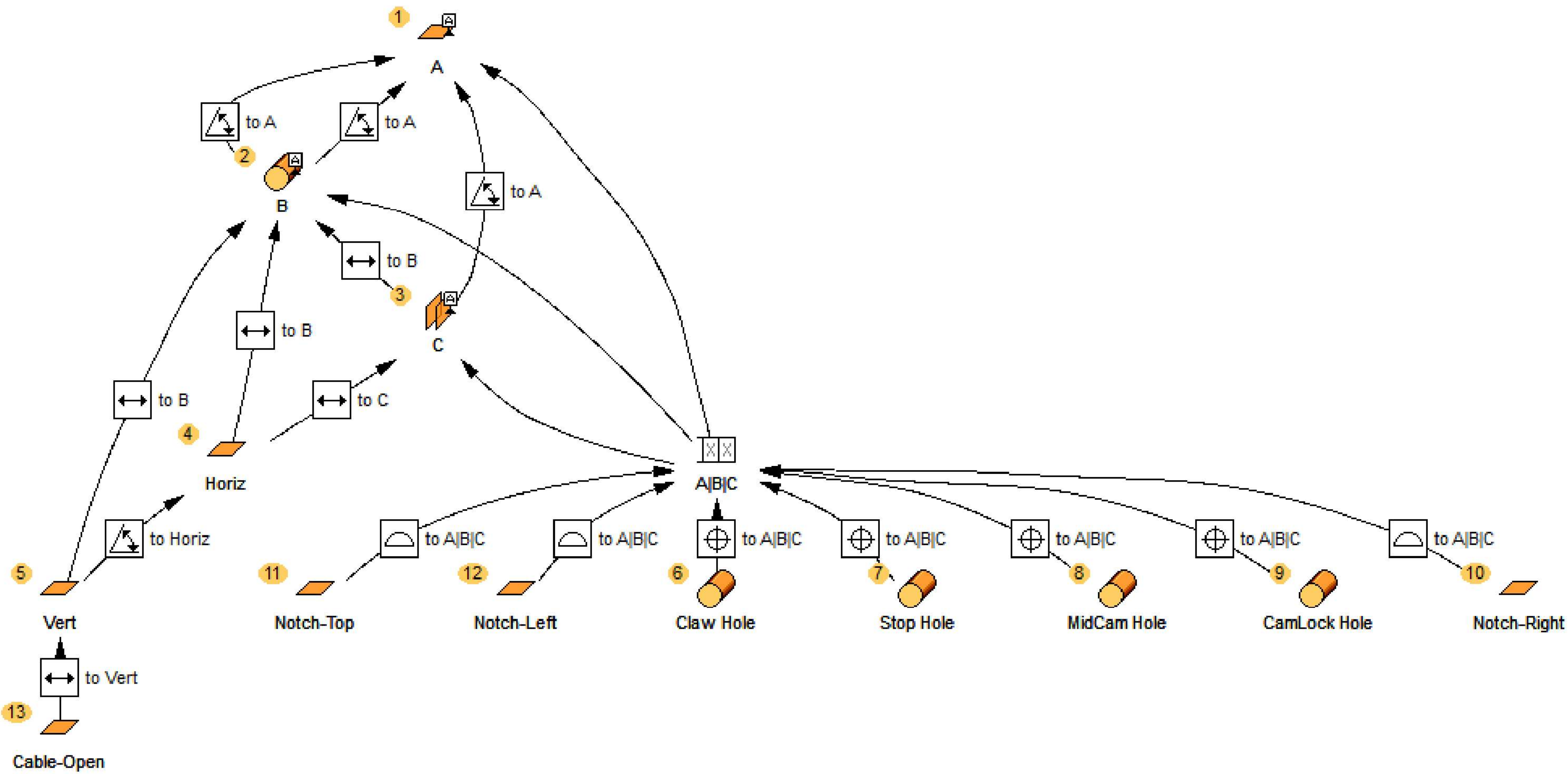
Sensitivity Animation





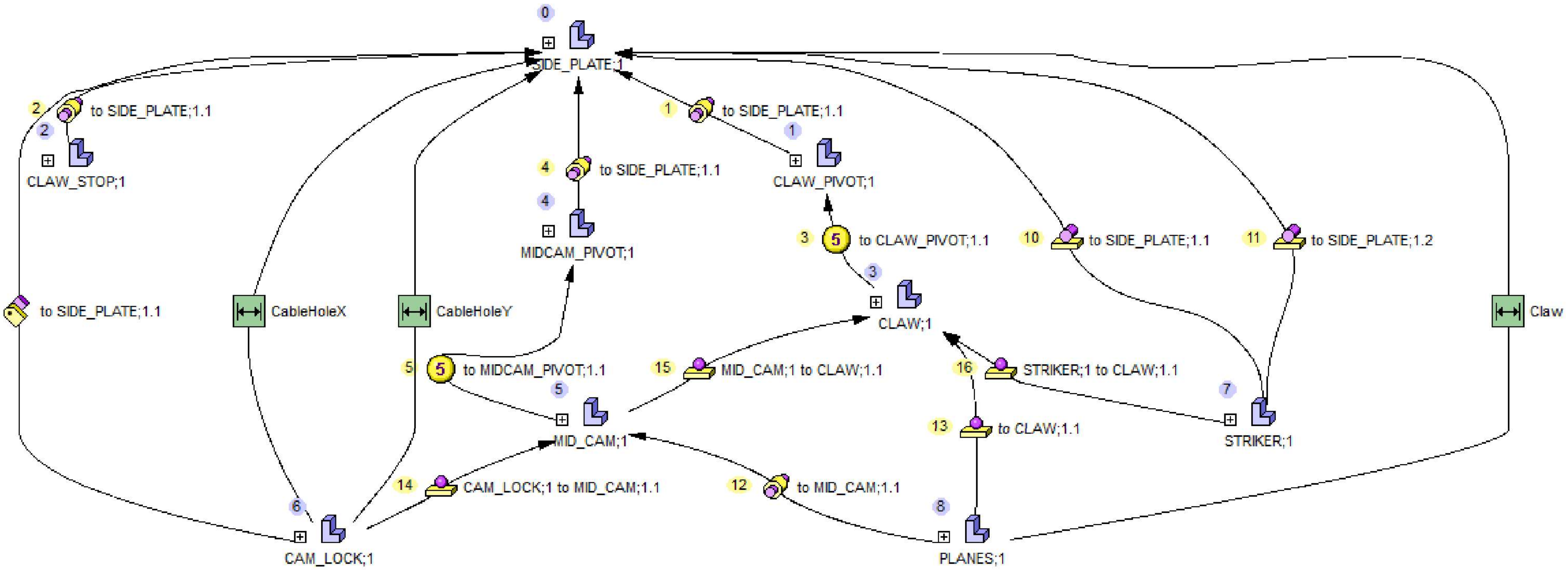
Dimension Constraints

CETOL 6σ



Assembly Constraints

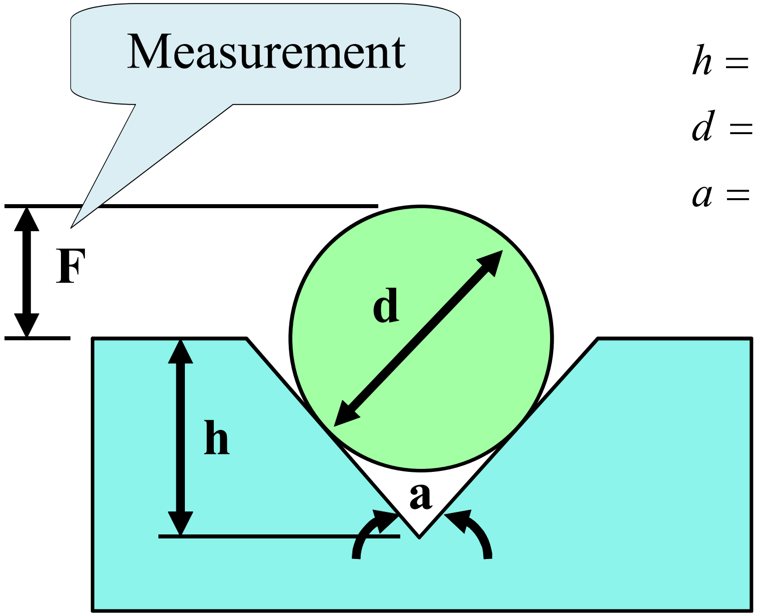
CETOL 6σ



Closed Loop Simulation
Not Block Box!!

Calculating Sensitivities

CETOL 6σ



$$h = 30\ mm$$
$$d = 30\ mm$$
$$a = 90°$$

$$F(h,d,a) = \frac{d}{2} + \frac{d}{2}\csc\left(\frac{a}{2}\right) - h$$

$$\frac{\partial F}{\partial h} = -1$$

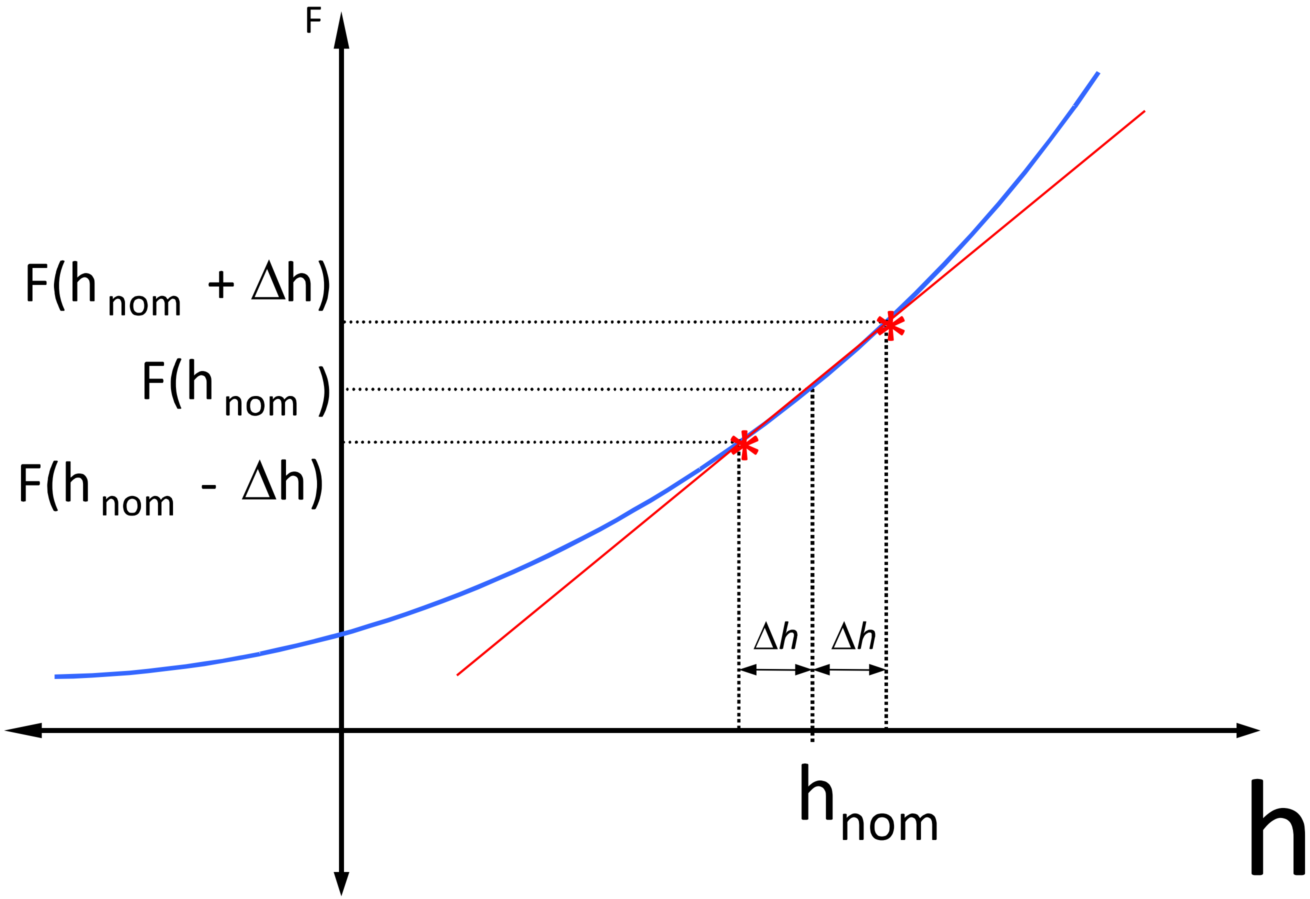
$$\frac{\partial F}{\partial d} = \frac{1}{2} + \frac{1}{2}\csc\left(\frac{a}{2}\right) \approx 1.207$$

$$\frac{\partial F}{\partial a} = -\frac{d}{4}\csc\left(\frac{a}{2}\right)\cot\left(\frac{a}{2}\right) \approx -10.607$$

Calculating Sensitivities

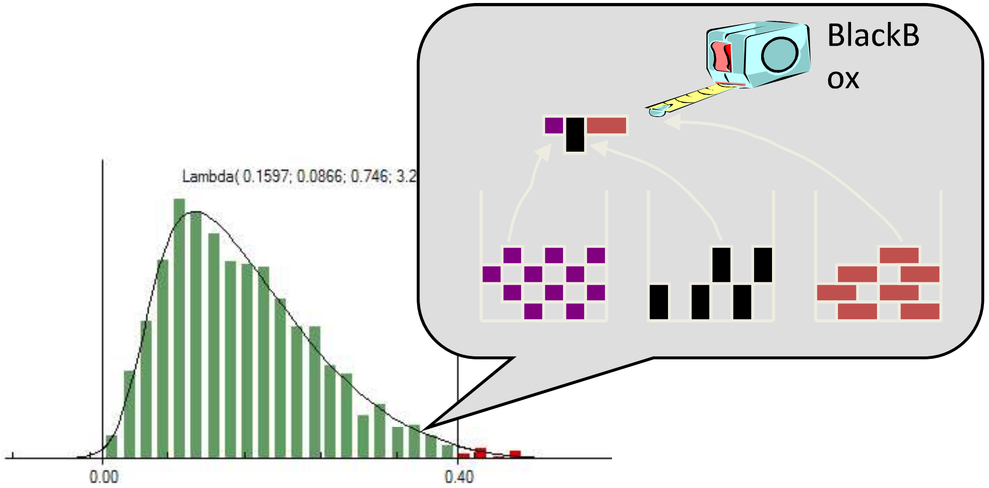
CETOL 6σ

– 민감도는 nominal variable에서 커브의 기울기 입니다.

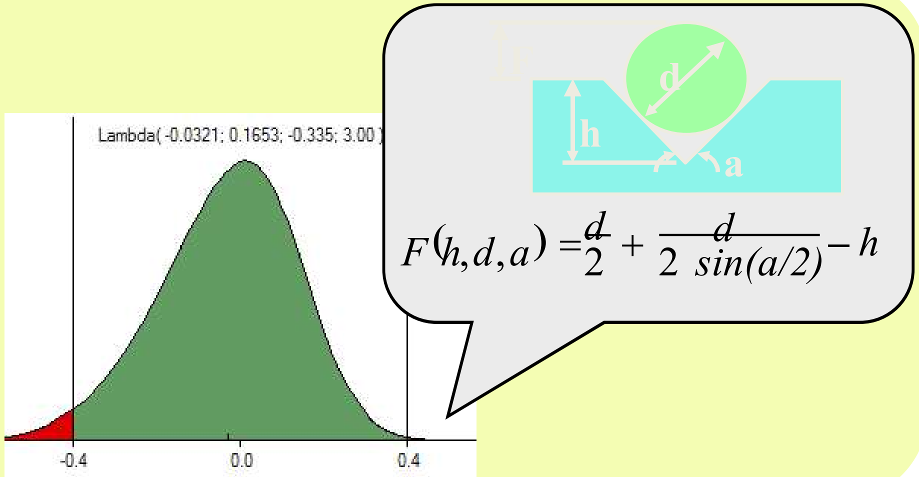


System moment method [CETOL original]

- Monte-Carlo Method
  - Substitute solution
  - 결과의 정확성은 계산에 사용된 sampling number에 의존적임

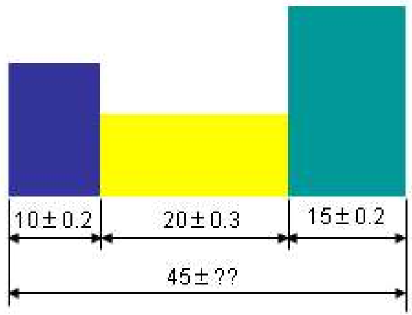


- System Moment Method
  - 유도함수에 기반한 계산 방법
  - 2차(비선형) 응답 계산 가능



Tolerance Analysis Method

[Worst Case]

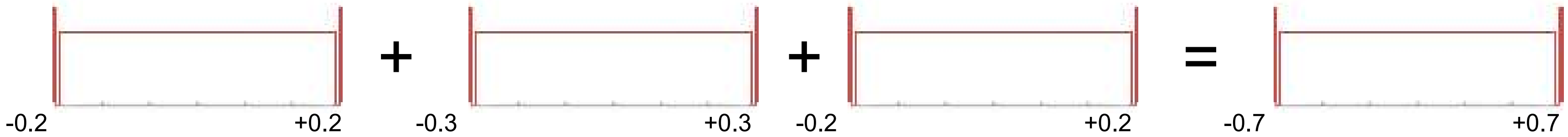


Adding to tolerance values;

$$0.2 + 0.3 + 0.2 = 0.7$$

Big variation!

(image)



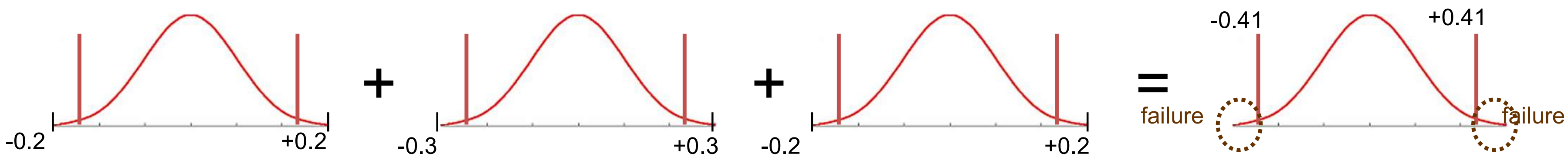
[RSS (Root Sum Square)]

Square root of added square tolerance values;

$$\sqrt{0.2^2 + 0.3^2 + 0.2^2} = 0.41$$

Allow few% failure!

(image)



Tolerance Analysis Method

❑ Worst Case

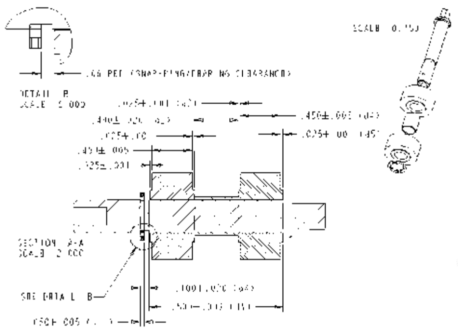
단순 누적 공차 분석

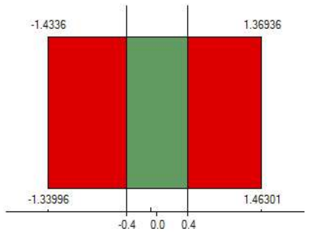
Benefits

- 100%의 제품이 기능적 조건을 만족
- 공정 능력 Data가 불필요

Problems

- 기능에 비해 엄한 공차 결과로 제조원가 상승 여지가 큼
- 실제 제조 상태를 고려 하지 않음
- 부품의 100% 검사가 전제 조건





높은 신뢰성이 요구되거나 Failure Risk가 큰 경우 선택적으로 사용되어 짐

❑ 통계적 공차 분석

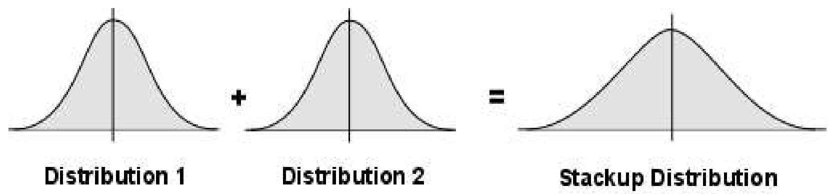
6시그마 통계 기법 이용

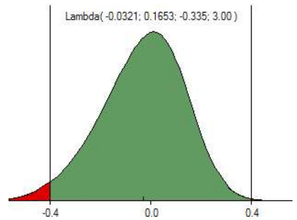
Benefits

- 신뢰도 기반의 품질(not 100%)
- 실제 제조 현상을 구현할 수 있음
- 넓은 범위의 허용공차로 인해 제품 원가 절감

Problems

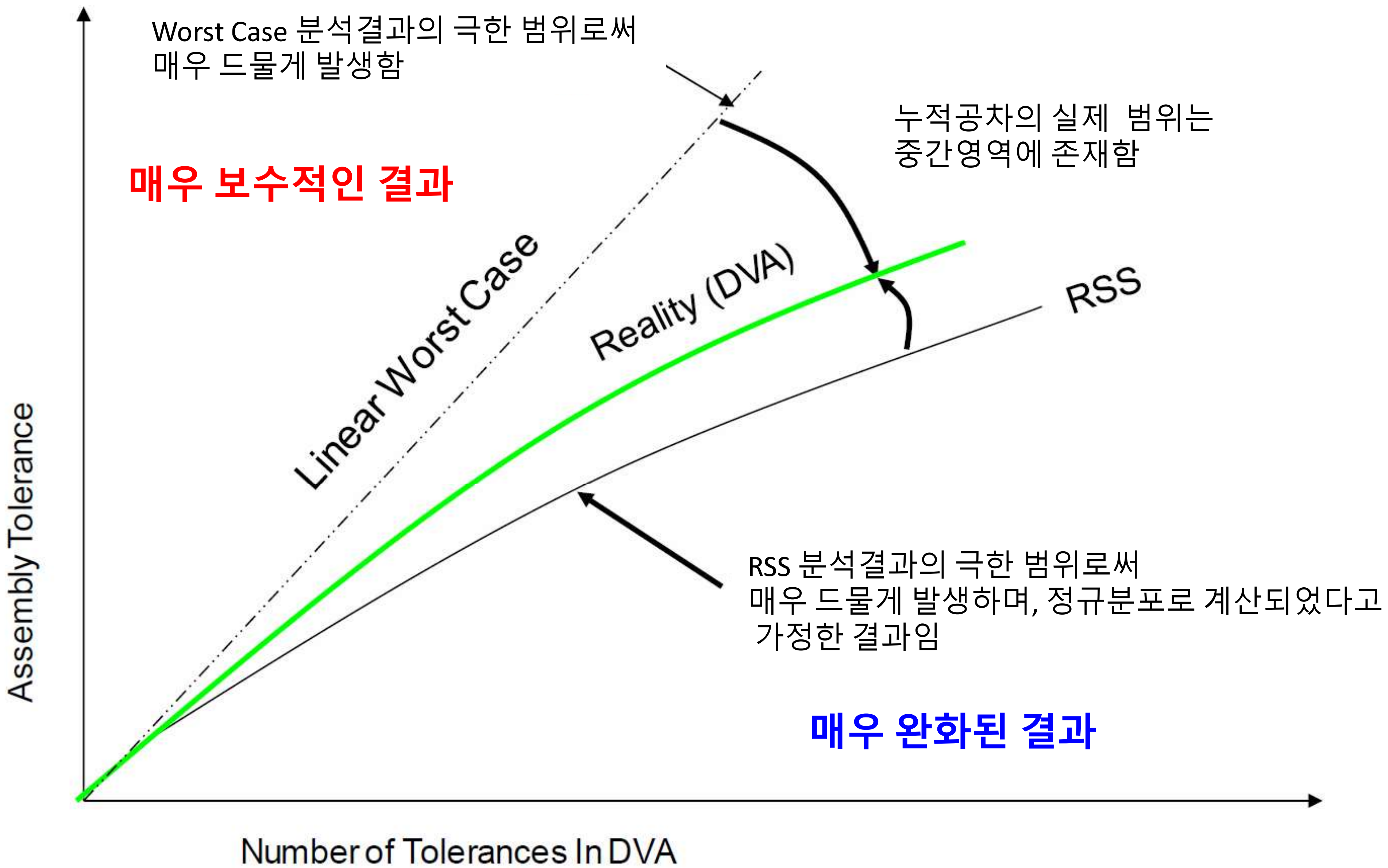
- 생산 공정 능력 데이터가 필요(혹은 추정치)
- Worst Case보다 복잡한 Concept





대부분의 공차 문제를 해결할 수 있는 체계적인 방법임.

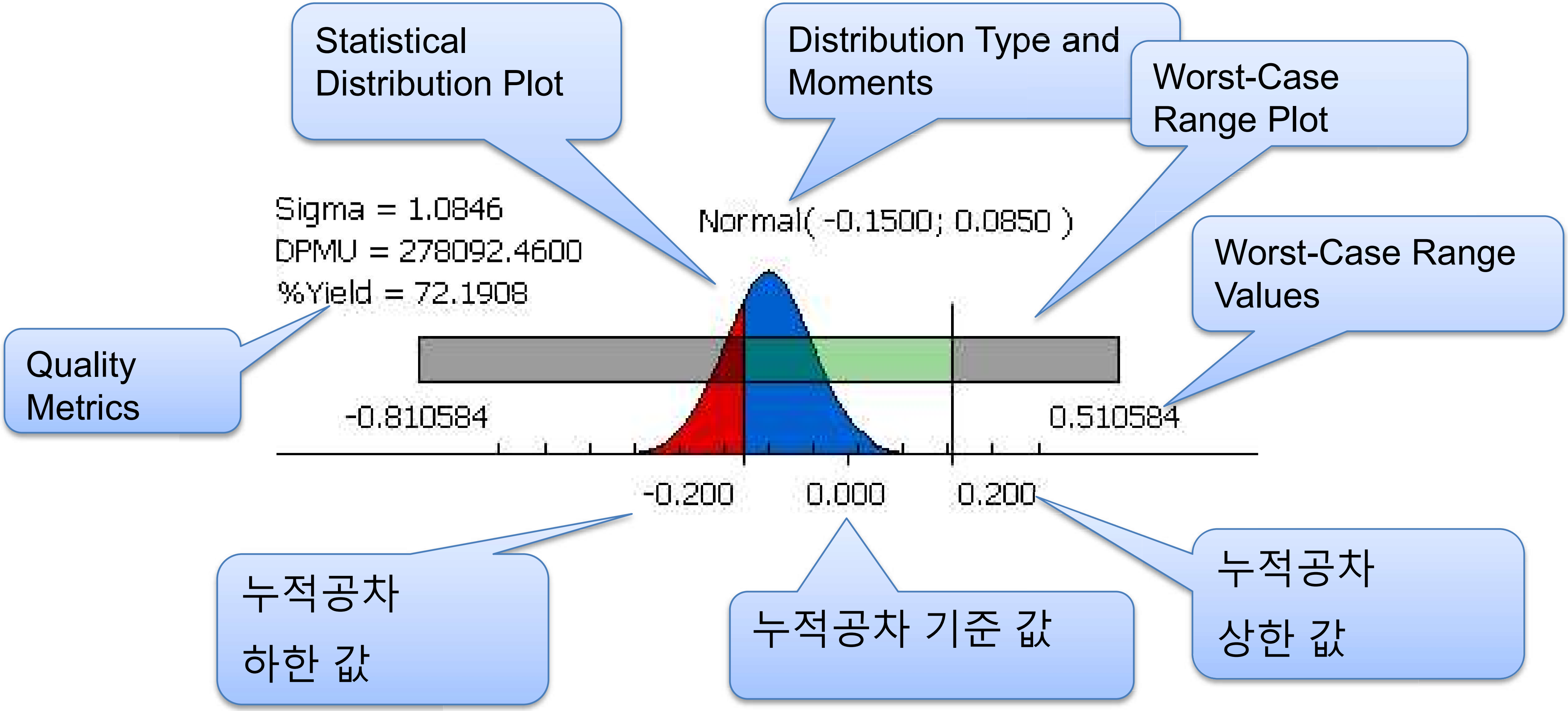
Worst Case vs. RSS



Analysis

Result Review

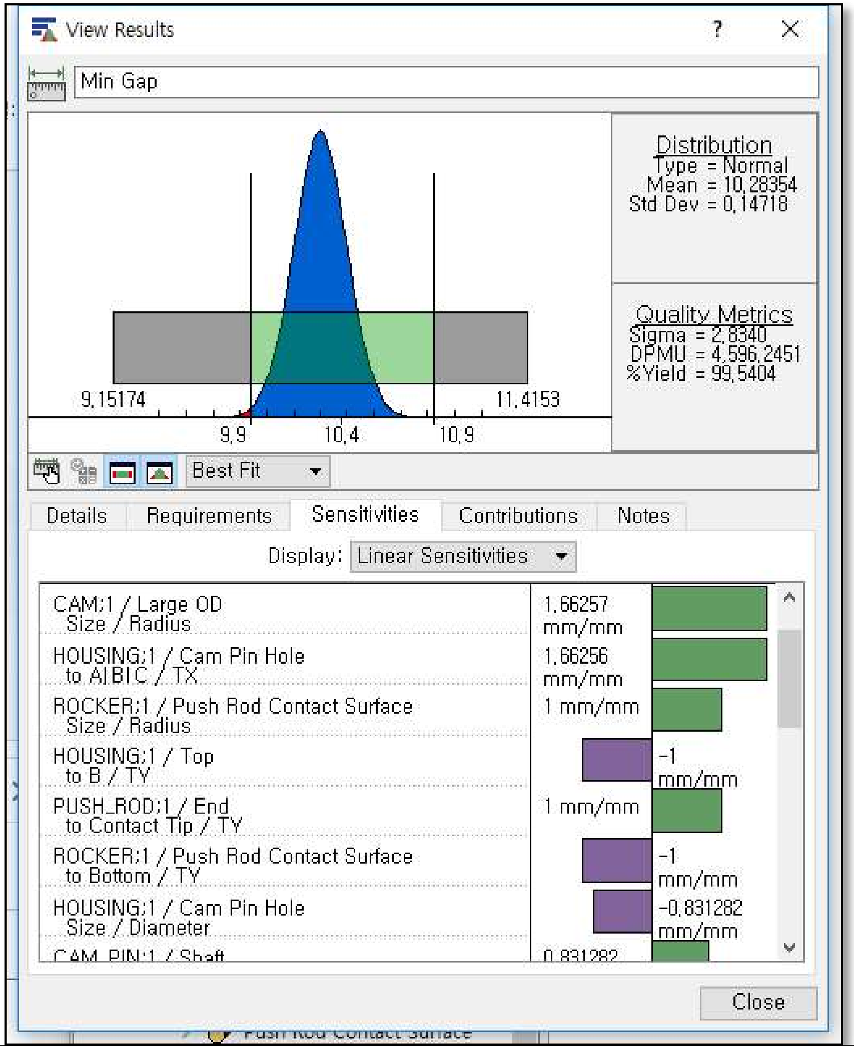
Statistical and Worst case results.

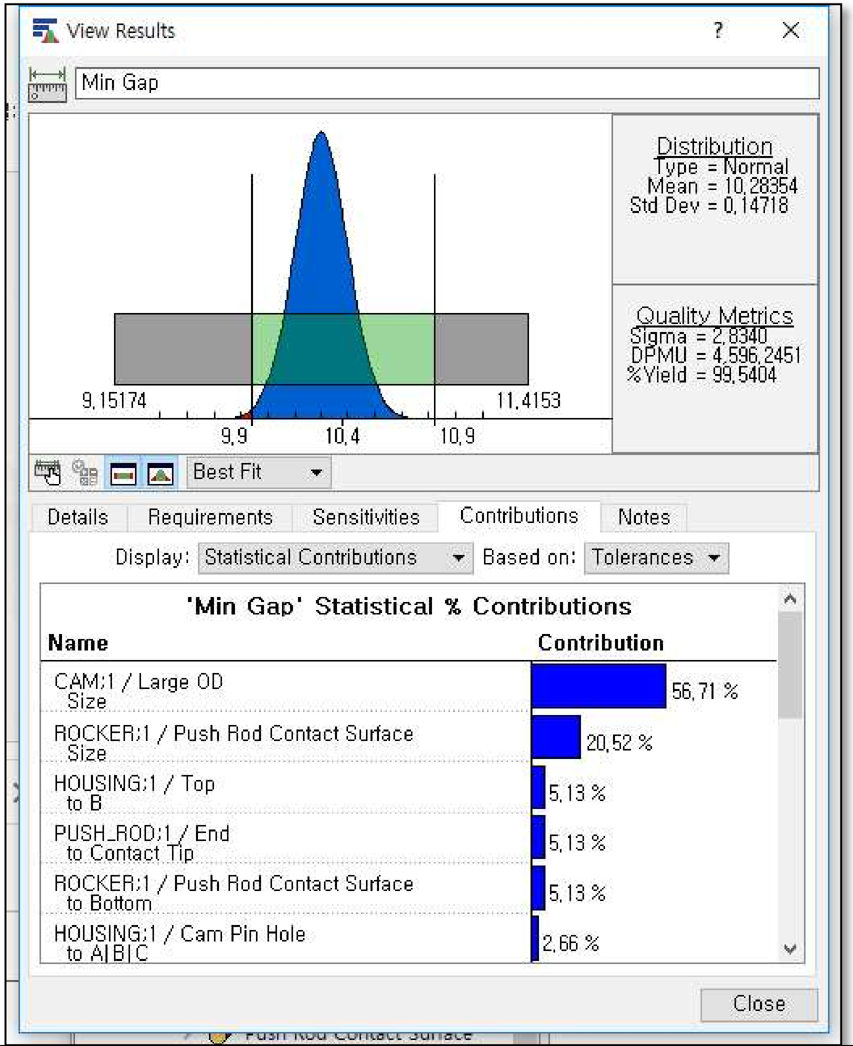


Analysis

Result Review

공차 별 민감도 및 기여도 결과항목

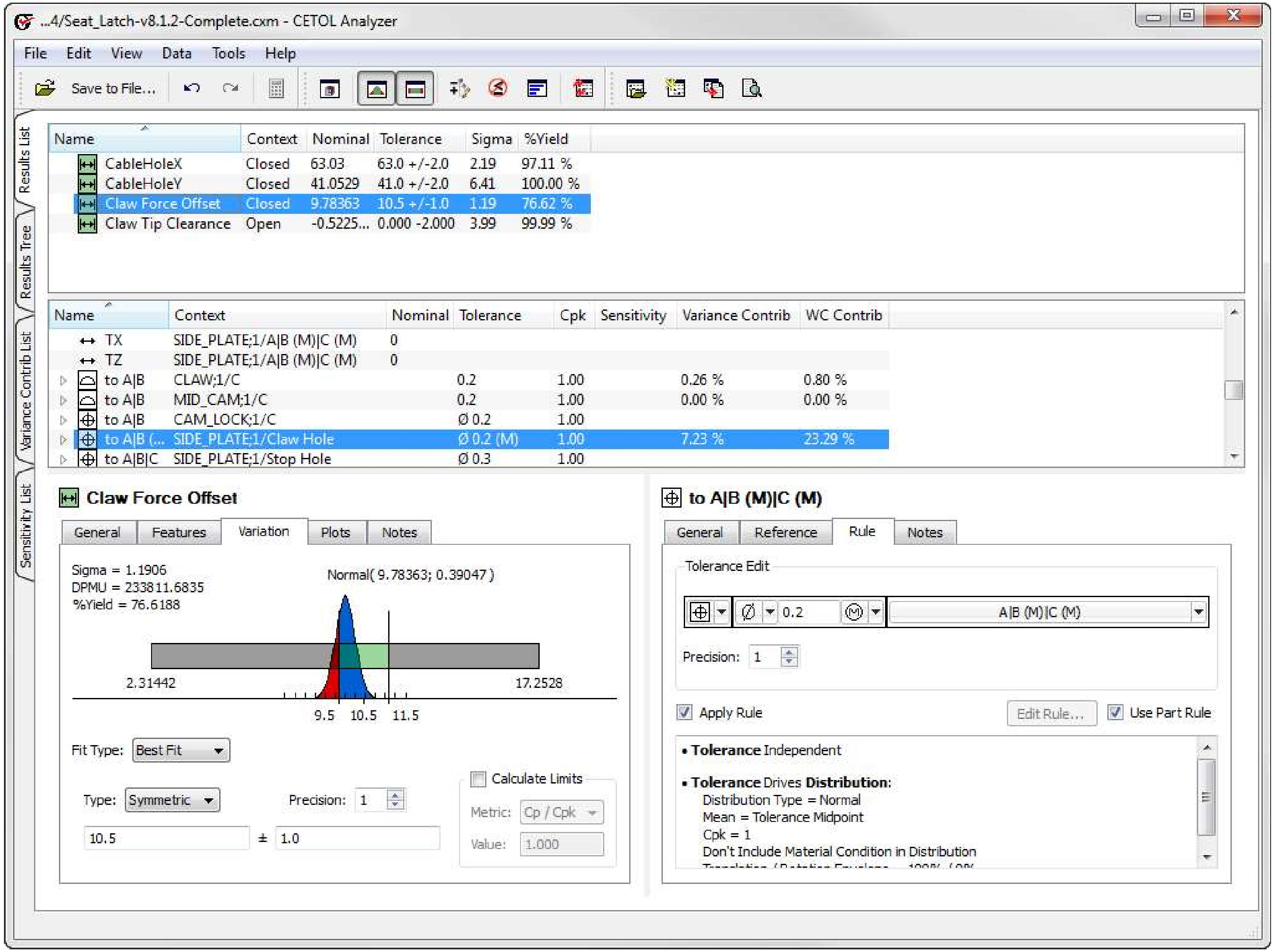




Design Analyzer

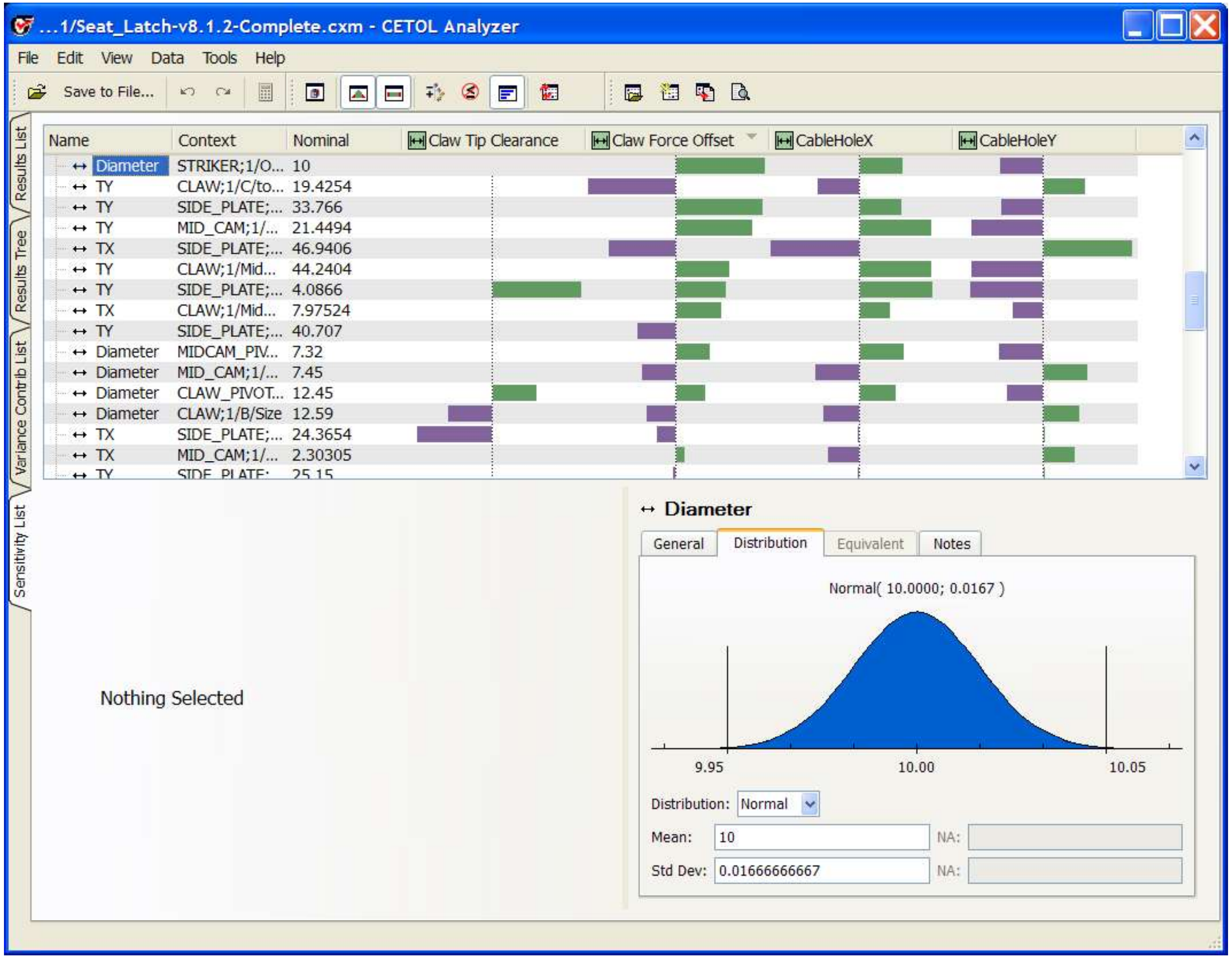
CETOL 6σ

CETOL Analyzer - 통합 분석환경



Design Analyzer

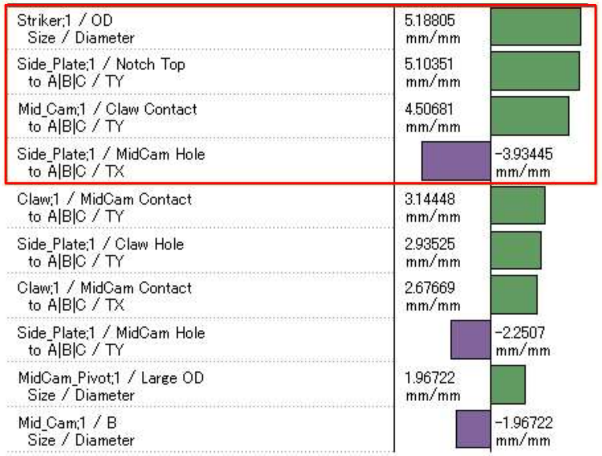
CETOL Analyzer - 통합 분석환경



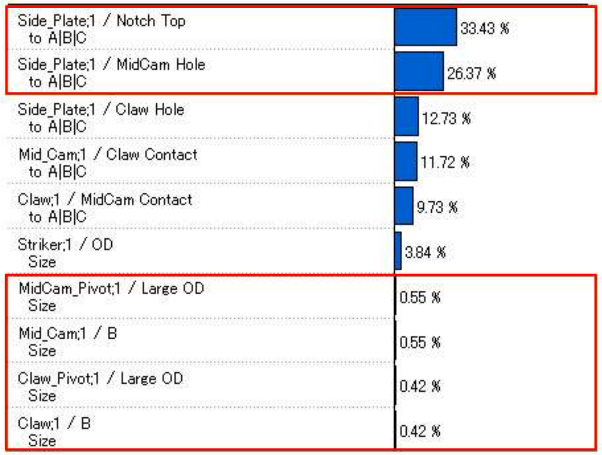
Using Data to Make Decisions

CETOL 6σ

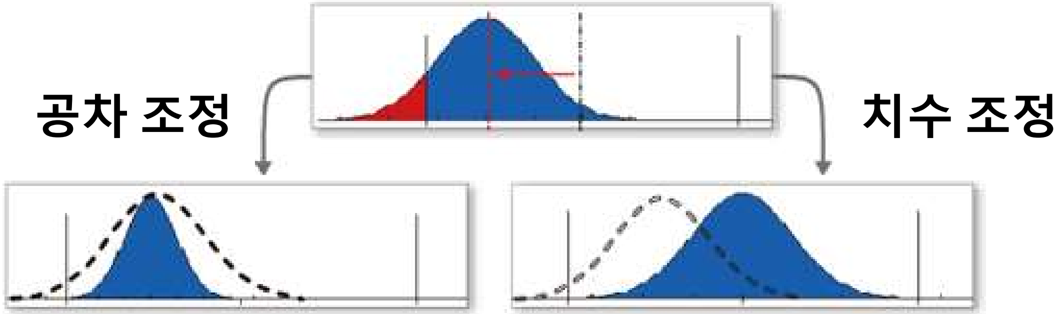
- **공차 민감도**
  공차 제어의 방향성 검토



- **공차 기여도**
  성능·품질에 대한 기여도 검토

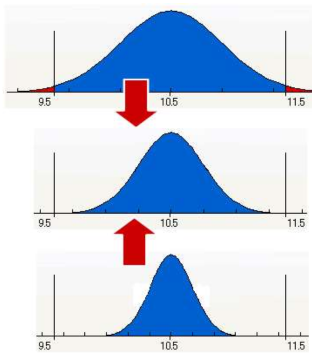


- **치수의 재검토**
  공차의 제어 방향으로부터 낮은 비용으로
  품질을 개선하는 방안 검토



제조비용 상승 **저비용 개선 방안**

- **공차의 재검토**
  공차 기여도로부터 품질 불균형에 대한
  개선방안을 검토



품질부족

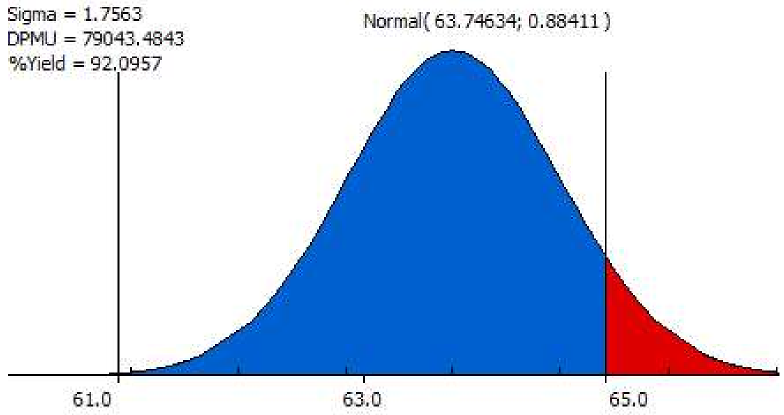
적정품질

과잉품질

Using Data to Make Decisions

CETOL 6σ™

- Design Centering
  - The Math
    - 중심 편차 계산
      - (63.0 – 63.74634 = **- 0.74634**)
    - 민감도 상위 공차항목 확인
      - SIDE_PLATE/CamLockHole-Ty = **-7.87014**
    - 민감도 값을 사용하여 nominal value change 값 계산
      - Nominal change = (-0.74634 / -7.87014) = **0.094831**
    - 공차항목의 nominal value 수정(= 치수 값 변경)
      - 59.575 + 0.094831 = **59.6698**



Name	Context	Nominal	Sensitivity
to A|B|C	SIDE_PLATE;1/CamLock Hole		
TY		59.575	-7.87014 ...
RY		0	0.572838 ...
TX		18.3139	6.3388 m...
RX		0	0.719566 ...

Report Generation

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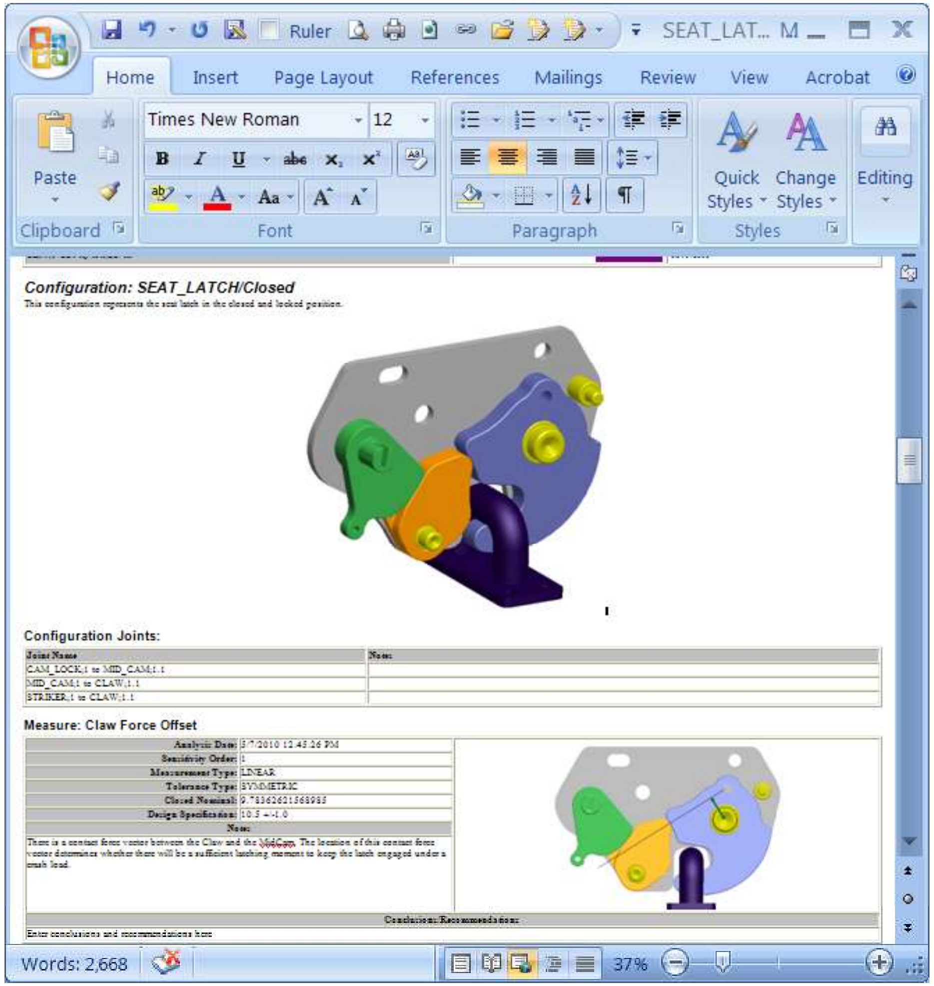
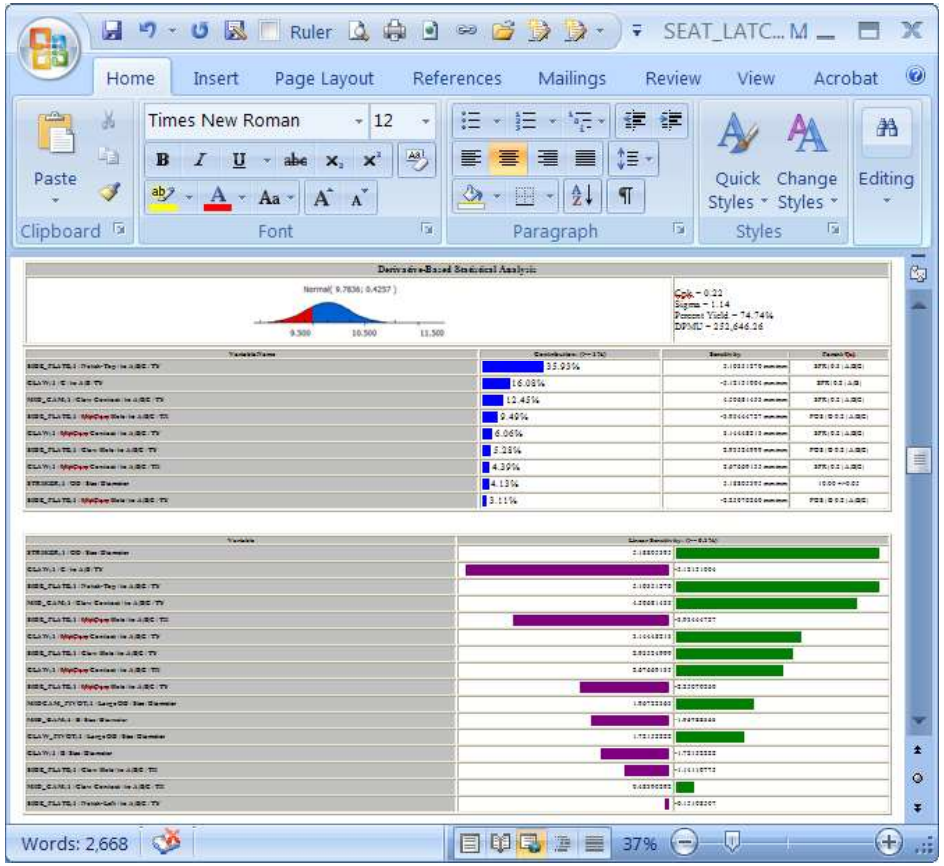
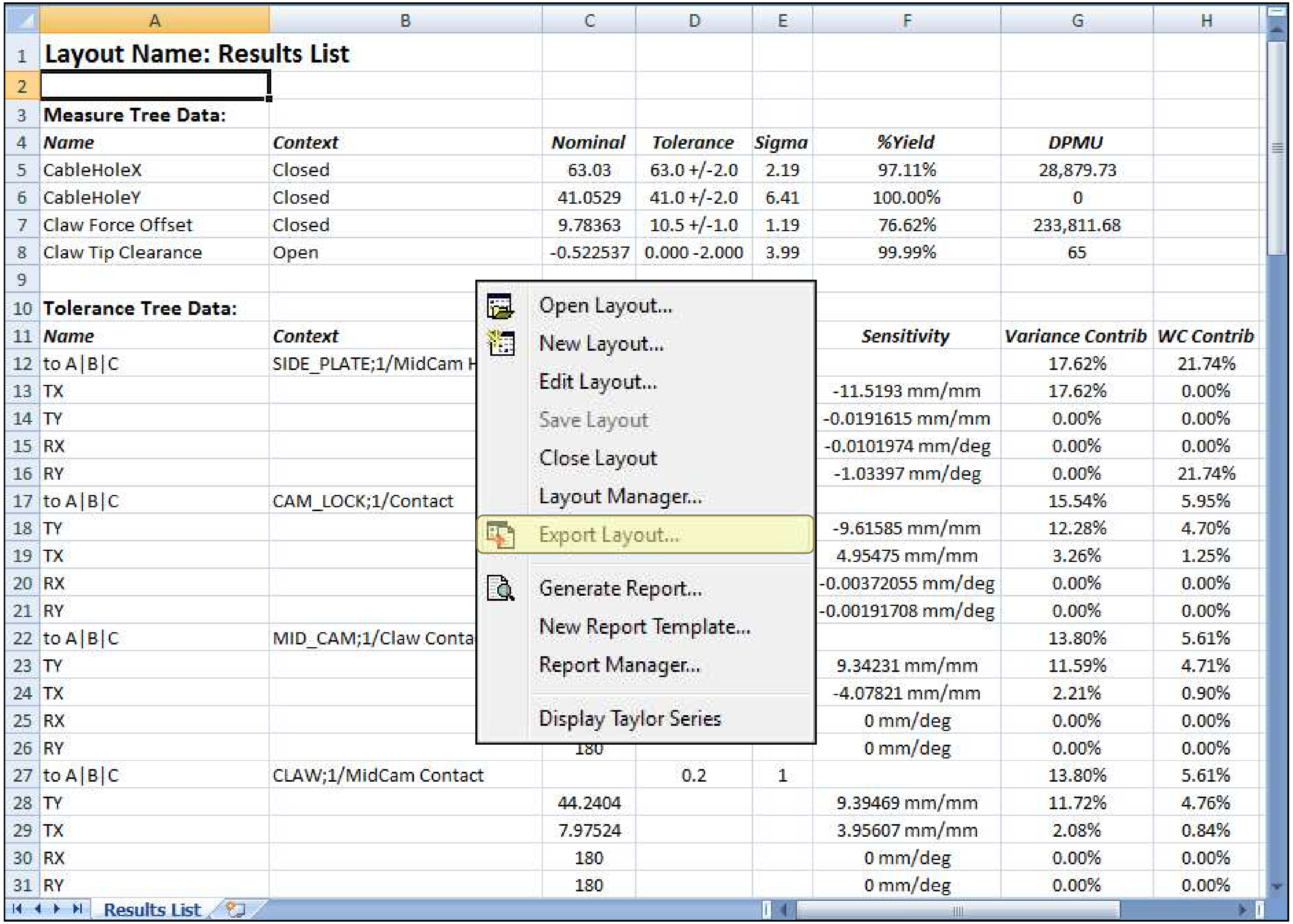
Reporting

표준 양식 또는 사용자 양식 기준으로 자동보고서 생성기능 지원





Export Wizard



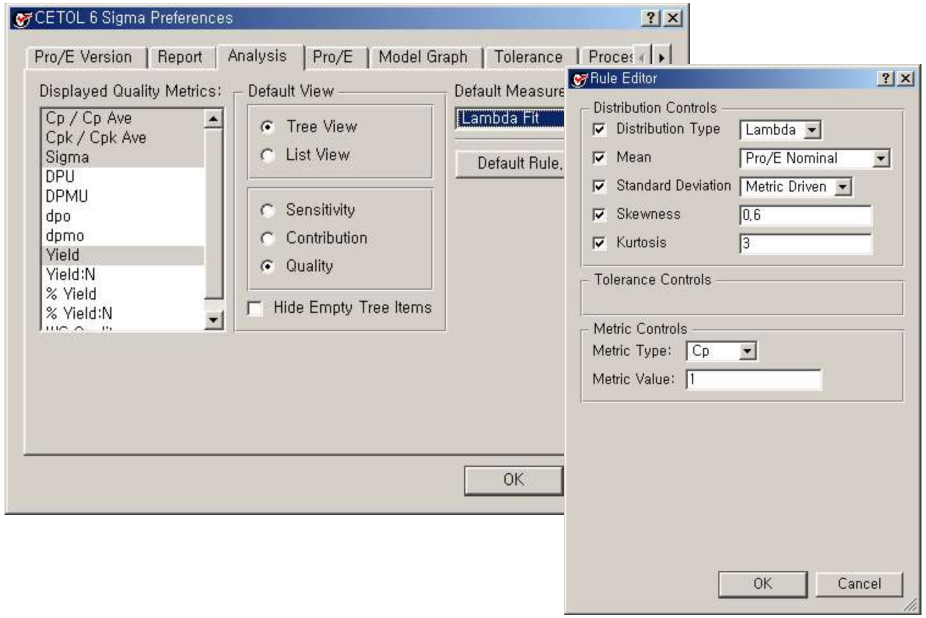
	A	B	C	D	E	F	G	H
1	**Layout Name: Results List**							
2								
3	**Measure Tree Data:**							
4	***Name***	***Context***	***Nominal***	***Tolerance***	***Sigma***	***%Yield***	***DPMU***	
5	CableHoleX	Closed	63.03	63.0 +/-2.0	2.19	97.11%	28,879.73	
6	CableHoleY	Closed	41.0529	41.0 +/-2.0	6.41	100.00%	0	
7	Claw Force Offset	Closed	9.78363	10.5 +/-1.0	1.19	76.62%	233,811.68	
8	Claw Tip Clearance	Open	-0.522537	0.000 -2.000	3.99	99.99%	65	
9								
10	**Tolerance Tree Data:**							
11	***Name***	***Context***				***Sensitivity***	***Variance Contrib***	***WC Contrib***
12	to A|B|C	SIDE_PLATE;1/MidCam H					17.62%	21.74%
13	TX					-11.5193 mm/mm	17.62%	0.00%
14	TY					-0.0191615 mm/mm	0.00%	0.00%
15	RX					-0.0101974 mm/deg	0.00%	0.00%
16	RY					-1.03397 mm/deg	0.00%	21.74%
17	to A|B|C	CAM_LOCK;1/Contact					15.54%	5.95%
18	TY					-9.61585 mm/mm	12.28%	4.70%
19	TX					4.95475 mm/mm	3.26%	1.25%
20	RX					-0.00372055 mm/deg	0.00%	0.00%
21	RY					-0.00191708 mm/deg	0.00%	0.00%
22	to A|B|C	MID_CAM;1/Claw Conta					13.80%	5.61%
23	TY					9.34231 mm/mm	11.59%	4.71%
24	TX					-4.07821 mm/mm	2.21%	0.90%
25	RX					0 mm/deg	0.00%	0.00%
26	RY		180			0 mm/deg	0.00%	0.00%
27	to A|B|C	CLAW;1/MidCam Contact		0.2	1		13.80%	5.61%
28	TY		44.2404			9.39469 mm/mm	11.72%	4.76%
29	TX		7.97524			3.95607 mm/mm	2.08%	0.84%
30	RX		180			0 mm/deg	0.00%	0.00%
31	RY		180			0 mm/deg	0.00%	0.00%

다양한 Output

CETOL 6σ

❑ Output Type

- Preference를 통한 환경 설정 및 저장
- Cp, Cpk, Sigma, 수율, DPMU(백만개당 불량 개수), DPU 등의 다양한 형태로 결과 분석 가능



❑ Automatic Report

- Xml, xsl 기반 Customizing 가능
- Html, doc 생성 가능
- 자동화된 생성 및 회사 표준 양식화 가능