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Automated Multidisciplinary Optimization of a Space-based Telescope (OptiOpt™ Part 2)

TFAWS 2002

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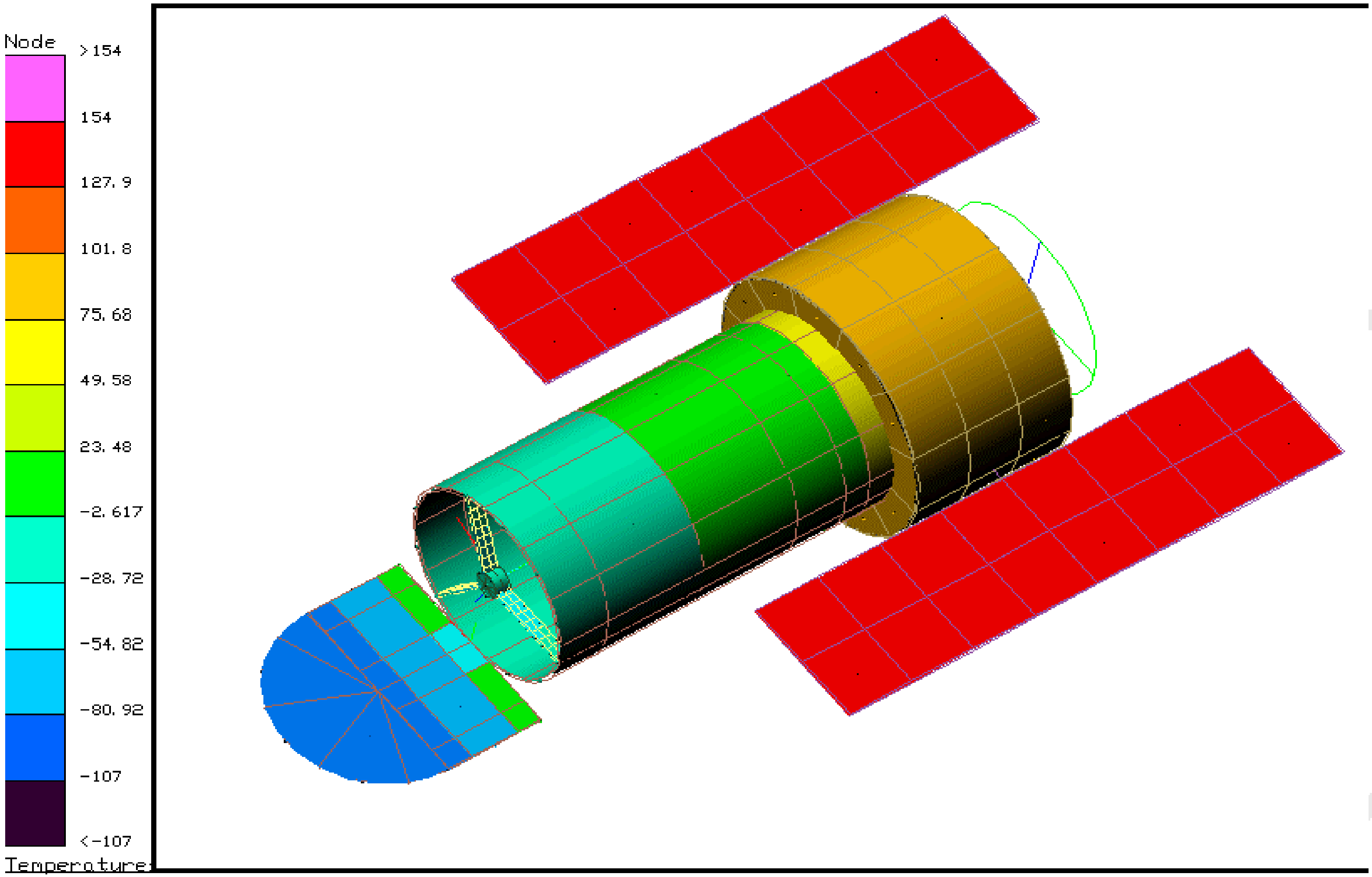
Automated Design Synthesis: Part 2

- Part 1: Analysis codes were integrated, bottlenecks removed, and APIs added to enable external commands
- Final step: Integration with optimization engine
  - Engineous' iSIGHT® selected
- Other possible automated analyses:
  - Worst-case scenario searching
  - Calibration to test data
  - DOE/Sensitivity
  - Statistical design (reliability, tolerancing)

Example: Space-based Telescope Design

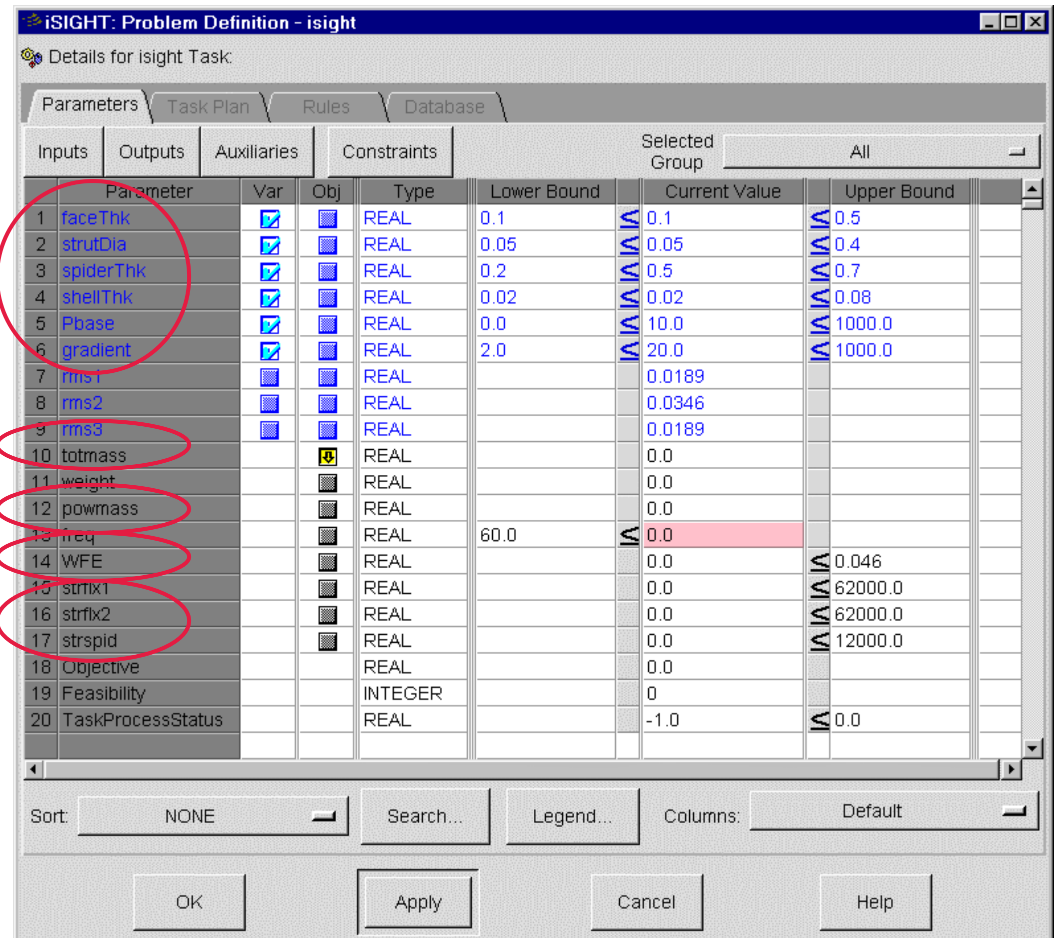


Summary of Optimization

- Objective
  - Minimize structural mass plus thermal power penalty
- Design Variables
  - Stuctural: shell thickness, spider thickness, PM facesheet thickness, flex strut diameters
  - Thermal: shell heater power, isothermality
- Constraints
  - Optical: wave front error less than $0.046\lambda_v$
  - Structural: fund freq. (<60Hz), cap launch stresses
  - Thermal: $66°F < T_{detector} < 70°F$

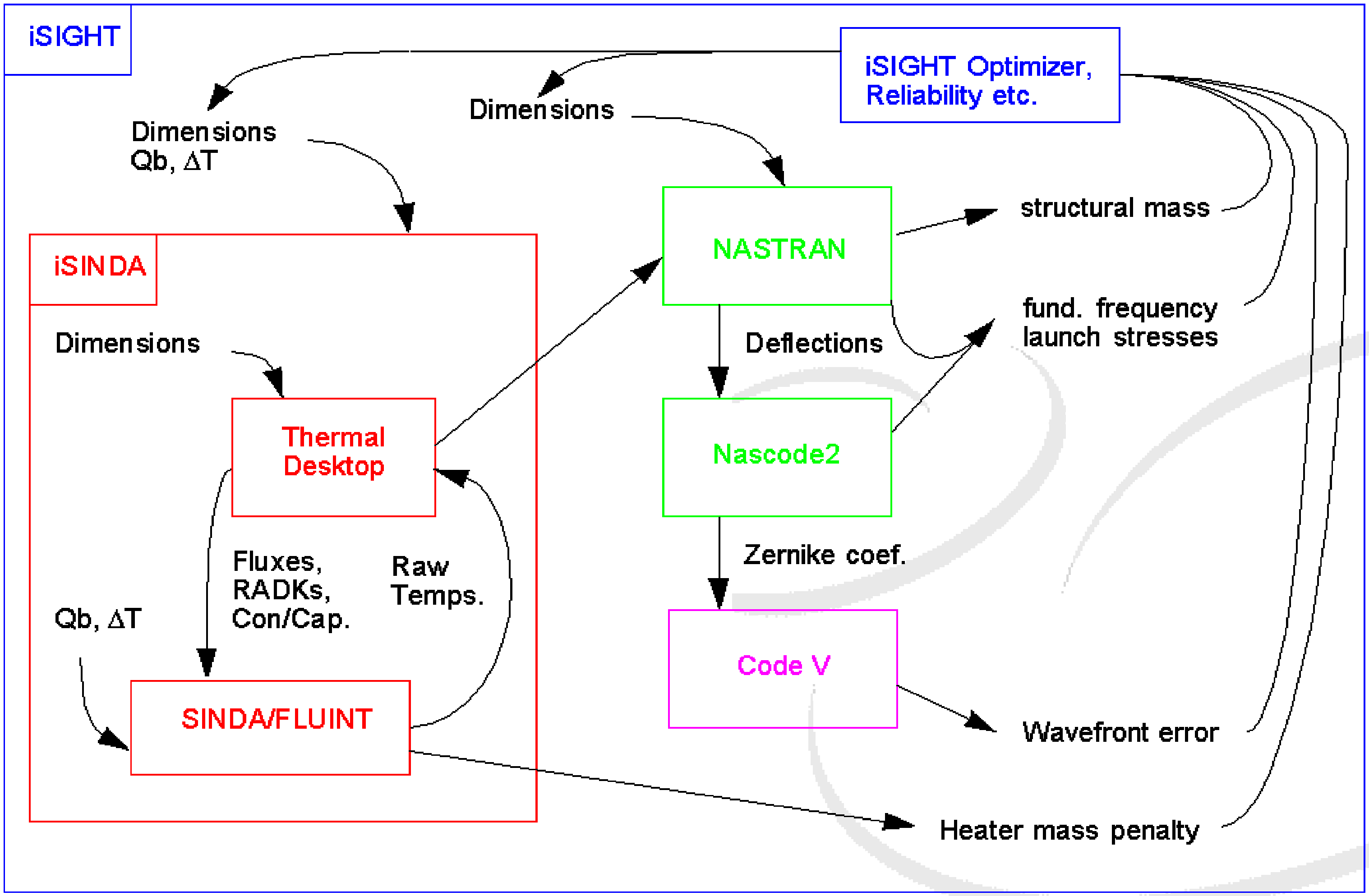
Design Variables, Constraints, Objectives

- 4 dimensions and 2 thermal design parameters varied simultaneously
- Mass minimized; mass penalty for heater power
- Optical wavefront error constrained
- Freq. of structural modes and launch stresses constrained



	Parameter	Var	Obj	Type	Lower Bound		Current Value		Upper Bound
1	faceThk			REAL	0.1	≤	0.1	≤	0.5
2	strutDia			REAL	0.05	≤	0.05	≤	0.4
3	spiderThk			REAL	0.2	≤	0.5	≤	0.7
4	shellThk			REAL	0.02	≤	0.02	≤	0.08
5	Pbase			REAL	0.0	≤	10.0	≤	1000.0
6	gradient			REAL	2.0	≤	20.0	≤	1000.0
7	rms1			REAL			0.0189		
8	rms2			REAL			0.0346		
9	rms3			REAL			0.0189		
10	totmass			REAL			0.0		
11	weight			REAL			0.0		
12	powmass			REAL			0.0		
13	freq			REAL	60.0	≤	0.0		
14	WFE			REAL			0.0	≤	0.046
15	strfix1			REAL			0.0	≤	62000.0
16	strfix2			REAL			0.0	≤	62000.0
17	strspid			REAL			0.0	≤	12000.0
18	Objective			REAL			0.0		
19	Feasibility			INTEGER			0		
20	TaskProcessStatus			REAL			-1.0	≤	0.0

Design Evaluation Procedure: *All Performed Automatically*



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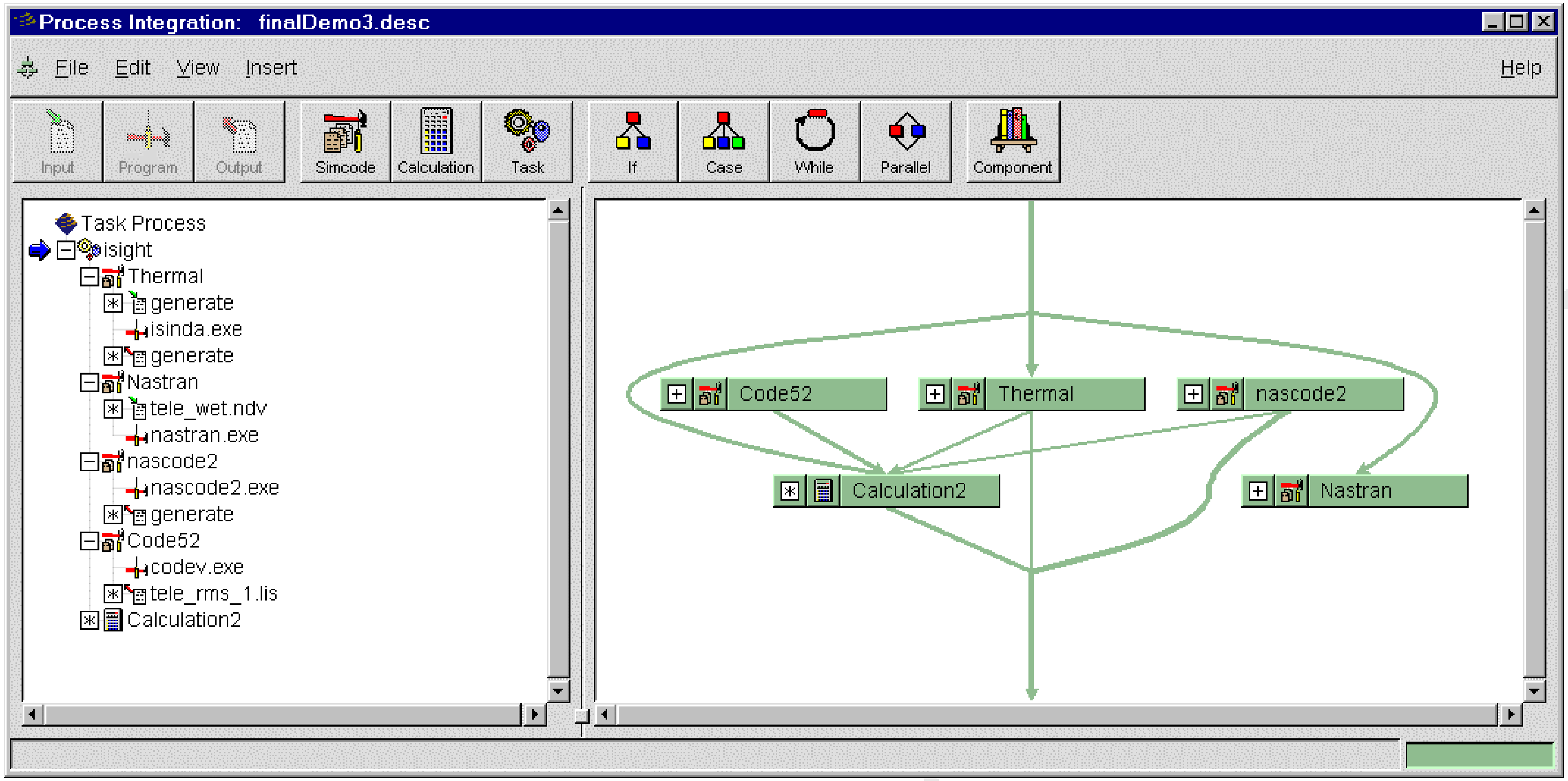
Evaluation Procedure as depicted in iSIGHT



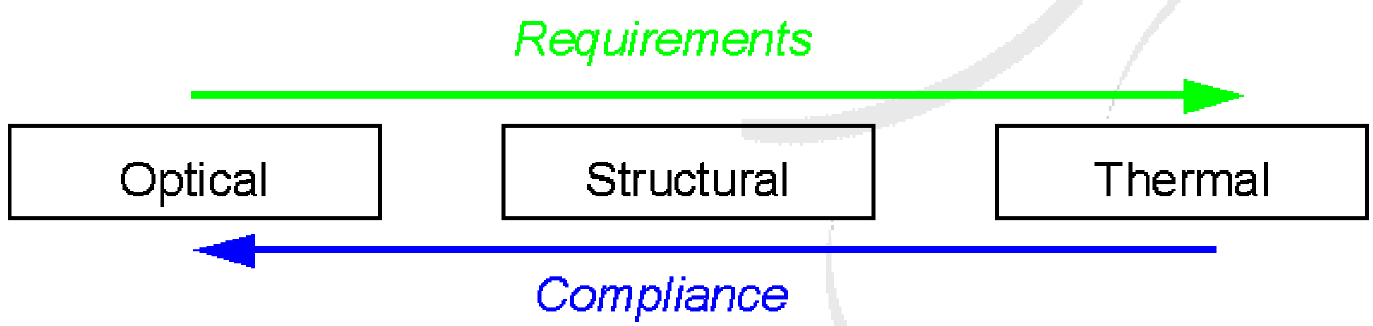
Results

- Two reasonable designs found (80 evaluations)
  - Baseline: Invar shell/spider and ULE ceramic optics
  - Alternative: cheaper, lighter aluminum structure and silica optics (usually difficult to achieve due to thermal distortions)

Parameter	Invar/ULE Design		Aluminum/Silica Design	
	value	comment	value	comment
PM facesheet thickness	0.1 in	lower limit	0.1 in	lower limit
PM strut diameter	0.05 in	lower limit	0.05 in	lower limit
Spider thickness	0.453 in	limited by fund freq.	0.451 in	
Shell thickness	0.02 in	lower limit	0.02 in	lower limit
Base shell heater power	0 W	lower limit	152 W	
Gradient required	>60 °F	essentially infinite	2 °F	lower limit
Total mass	155 lb	all structural, no thermal	189 lb	66 lb structural 123 lb thermal
Fundamental frequency	60 Hz	constraining	75 Hz	not constraining
Total RMS WFE	0.0404 λ_v	not constraining	0.046 λ_v	constraining

Lessons Learned

- A one-time flow-down of requirements is still needed to generate the initial design
- Care is required to avoid an explosion of design variables for the specialty furthest from the requirements (thermal in this case):



Other Multidisciplinary Integration Environments

- ModelCenter® (Phoenix Integration)
- MSC/RD (MSC)
- Pointer® (Synapse)
- Visual DOC® (VR&D)
- DAKOTA (Sandia National Lab)
- Optimus® (LMS)
- BossQuattro (Samtech)

Conclusions

- An means of automatically searching for an optimal thermal/structural/optical design has been demonstrated
  - derived requirements and margin stack-up thereby avoided
- The resulting capability augments but doesn’t replace specialists