

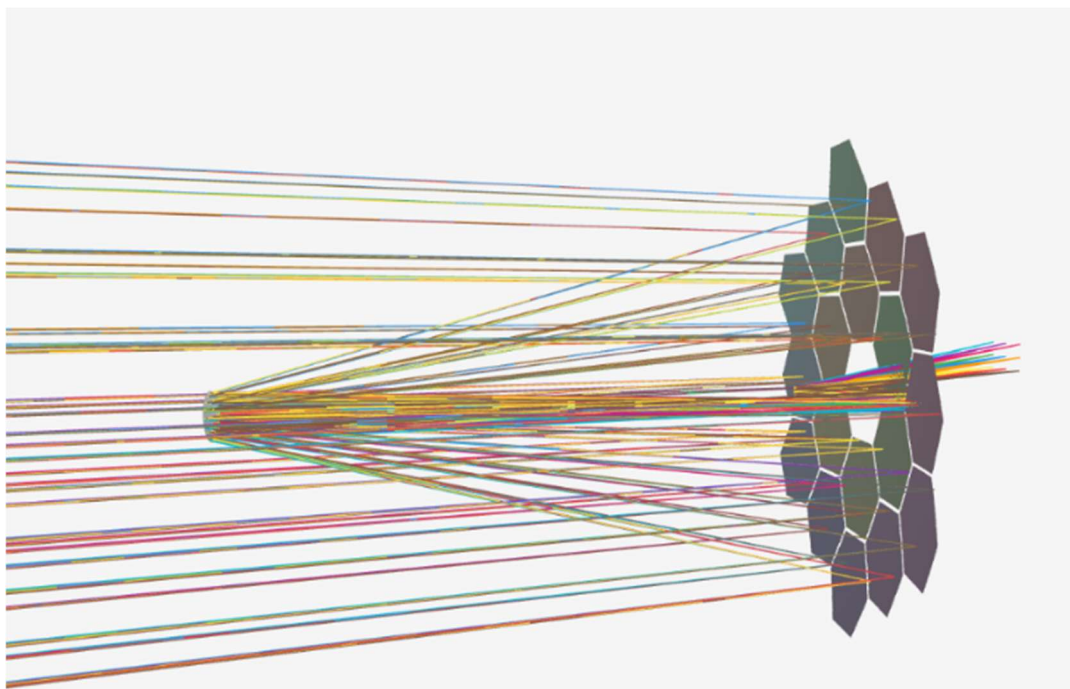
Benchmark : James Webb Space Telescope

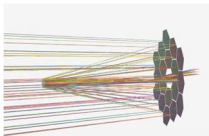
Optimization and spot diagram

This case study is inspired by the tutorial "Modeling & Analysis of the James Webb Space Telescope (JWST)" by Samuel Kim, Prof. Saharnaz Baghdadchi, Prof. Nicholas Antipa from the University of California San Diego.

The objective of this benchmark is to reproduce the optimization workflow described in the source material and validate the resulting spot diagram at the image plane against the reference.

Key results: The optimization algorithm produces very good results in 2 minutes, with most spot sizes smaller than the Airy Disk. Agreement with reference metrics is within <1% relative difference throughout the workflow.





System prescription:

The simulated setup is a simplified representation of the James Web Telescope, as per the source material from the University of California San Diego.

A quick overview of the prescription:

#	Surface	Comment	Type	Radius	Thickness	Semi-Ø	Material	Stop
0	Object	Object plane (source) - tilted	Object Plane	inf	inf	auto	air	
JWST 18 seg	M1	M1 Primary - 18 hexagonal seg	Segmented	-15880	-7169	auto	mirror	
2	S2	M2 Secondary - convex hype	Standard	-1778.9	7965.3	auto	mirror	

GEOMETRY

Standard Parameters

Aperture

Conic Constant (k)

Aperture Type

r_max (mm)

r_min (mm)

-1.6598

Radial (Circular)

370

0

OPTICS

Coating

Figure Error (INT)

Type

No file loaded

None

Upload .JNT

POSITION / ORIENTATION

Decenter (mm)

Tilt (°)

X

Y

Rx

Ry

Rz

0

0

0

0

0

CONSTRAINTS (0)

No constraints on this surface.

+ Add constraint

GEOMETRY

Standard Parameters

Aperture

Conic Constant (k)

Aperture Type

r_max (mm)

r_min (mm)

-0.6595

Radial (Circular)

350

0

OPTICS

Coating

Figure Error (INT)

Type

No file loaded

None

Upload .JNT

POSITION / ORIENTATION

Decenter (mm)

Tilt (°)

X

Y

Rx

Ry

Rz

0

0

0

0

0

CONSTRAINTS (0)

No constraints on this surface.

+ Add constraint

GEOMETRY

Standard Parameters

Aperture

Conic Constant (k)

Aperture Type

r_max (mm)

r_min (mm)

Radial (Circular)

162

0

OPTICS

Coating

Figure Error (INT)

Type

No file loaded

None

Upload .JNT

POSITION / ORIENTATION

Decenter (mm)

Tilt (°)

X

Y

Rx

Ry

Rz

0

0

0

0

0

CONSTRAINTS (0)

No constraints on this surface.

+ Add constraint

| 5 | Image | Focal plane | Image Plane | inf | 0 | auto | air | |

And more details about the source and segmented surface:

#	Surface	Comment	Type	Radius	Thickness	Semi-Ø	Material	Stop
0	Object	Object plane (source) - tilted	Object Plane	inf	inf	auto	air	

GEOMETRY

Source Parameters

Type

Collimated

Aperture

EPD (mm)

6500

Field Type

Angle (°)

OPTICS

Wavelengths

Field Points

λ (nm)	Weight	X (°)	Y (°)	Weight
2000	1	0	0	1
		-0.152	0	1
		0.152	0	1
		0	-0.076	1
		0	0.076	1
		-0.152	-0.076	1
		-0.152	0.076	1
		0.152	-0.076	1
		0.152	0.076	1

POSITION / ORIENTATION

Decenter (mm)

Tilt (°)

X

Y

Rx

Ry

Rz

0

0

0.16

0

0

GEOMETRY

Segment Configuration

Conic Constant (K)

Segment Layout Preview

SEGMENT LAYOUT PREVIEW

Presets: JWST

Segments: 18

Flat-to-Flat (mm): 1241.48

Gap (mm): 23.51

OPTICS

Coating

Figure Error (INT)

Type

No file loaded

None

Upload .JNT

POSITION / ORIENTATION

Decenter (mm)

Tilt (°)

X

Y

Rx

Ry

Rz

0

0

0

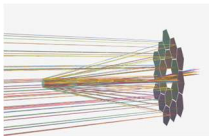
0

0

CONSTRAINTS (0)

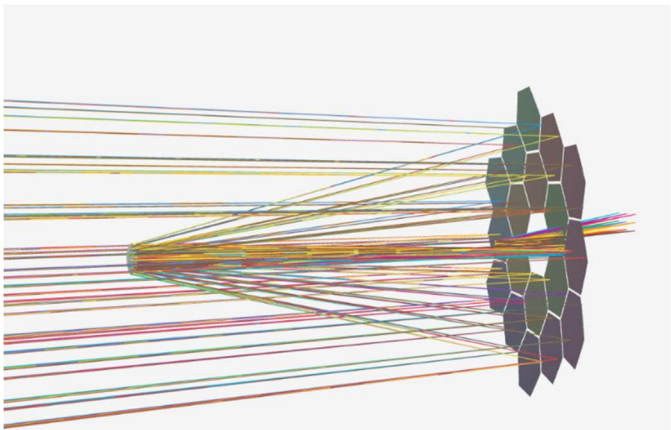
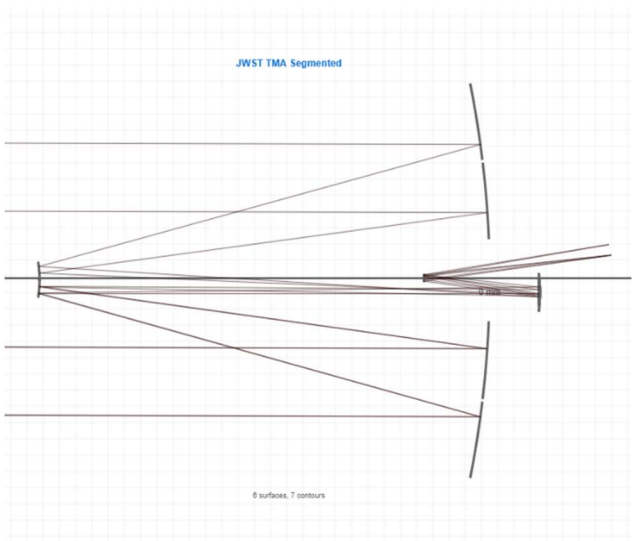
No constraints on this surface.

+ Add constraint



Simulation results:

Before analyzing the simulated values, an initial visual check confirms that the system is properly configured. This step is important, as the setup was reconstructed by the AI based on screenshots from the reference document.



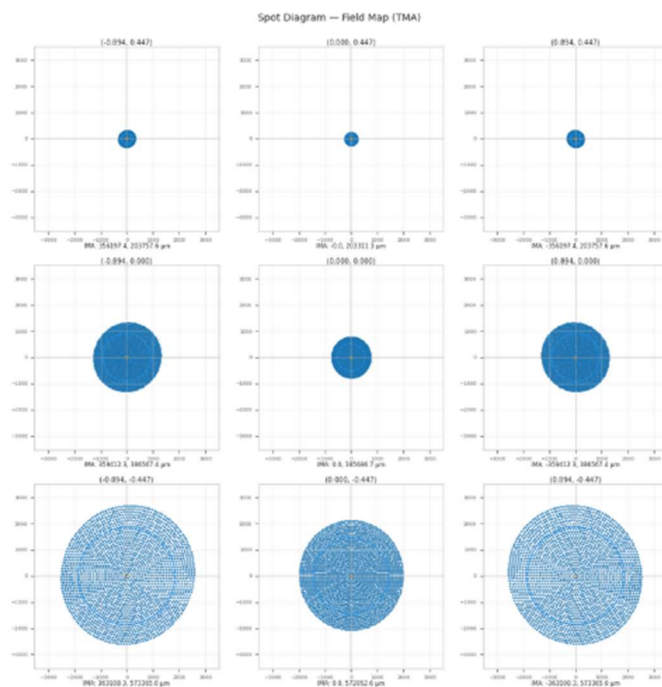
In the reference material, the operator performs a chief ray solve to tilt the image plane; the corrections applied by both software tools are shown below:

	Decenter Y (mm)	Tilt about X (°)
Etendue	-5.424	6.937
Ref software	-3.191	6.941
Relative difference	0.5% ¹	0.06%

¹ normalized by the semi-diameter (delta decenter / semi diameter*100).

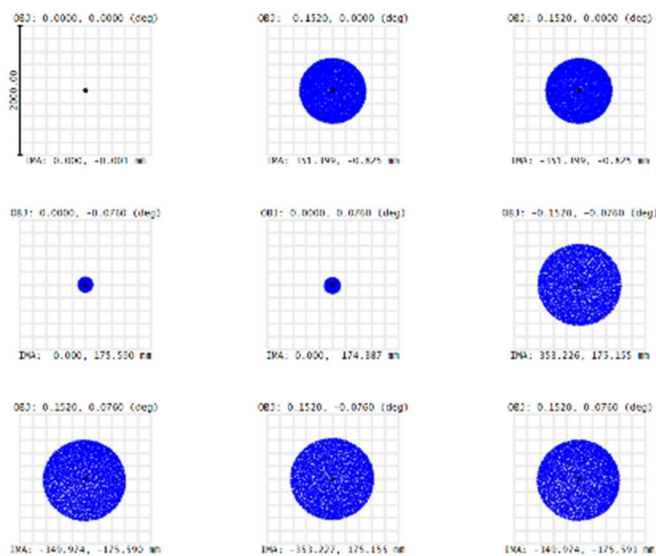


The TMA analysis gives us the following graph²:



a - source : etendue

Which we can compare with the reference:



b - source : ref. software

² Please note that in etendue, fields are spatially sorted by coordinates, that is not the case in the reference software.



The initial spot diagrams being much bigger than the Airy disk, we must perform an optimization.

In etendue it can be done by using the “generic optimization” plugin, with the following parameters:

☰

Optimization Generic

▼ ×

Algorithm Settings

Method

Auto-select best method

Time Budget

2 minutes

Tolerance

0.00001

Auto selects the best algorithm for your problem type.

Parallel Exploration

1

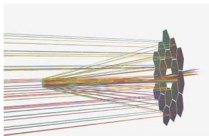
Run multiple optimizations from perturbed starting points. Best result is kept. Perturbation scales automatically with number of starts.

Merit Function (Operands)

9 operands, 4 variables

✎ Merit Function Editor

And the following merit function:



Merit Function Editor

Merit Function: -

X

Optimization Function

Image Quality:
RMS Spot

Spatial Frequency:
50

S Weight:
1

T Weight:
1

Type:
RMS

Reference:
Centroid

☐ Max Distortion (%): 1

☐ Ignore Lateral Color

Optimization Goal
☒ Best Nominal Performance
☐ Improve Manufacturing Yield
Weight: 1

Pupil Integration

☒ Gaussian Quadrature
☐ Rectangular Array

Rings: 3

Arms: 6

Obscuration: 0

Boundary Values

☐ Glass
Min: 0
Max: 1000
Edge Thickness: 0

☐ Air
Min: 0
Max: 1000
Edge Thickness: 0

Merit Function — Operands (9)

Optimization: Spot (RMS) | Start At: SS — Foc | Generate

#	TYPE	SURFACE	FIELD	WAVELENGTH	TARGET	WEIGHT	MIN	MAX	ACTIONS
4	RMS Spot Radius (Most Common)	SS — Focal plar	F4 (0°, -0.076°)	2000 nm	0	100	—	—	
5	RMS Spot Radius (Most Common)	SS — Focal plar	F5 (0°, 0.076°)	2000 nm	0	100	—	—	
6	RMS Spot Radius (Most Common)	SS — Focal plar	F6 (-0.152°, -0.076°)	2000 nm	0	100	—	—	
7	RMS Spot Radius (Most Common)	SS — Focal plar	F7 (-0.152°, 0.076°)	2000 nm	0	100	—	—	
8	RMS Spot Radius (Most Common)	SS — Focal plar	F8 (0.152°, -0.076°)	2000 nm	0	100	—	—	
9	RMS Spot Radius (Most Common)	SS — Focal plar	F9 (0.152°, 0.076°)	2000 nm	0	100	—	—	

+ Add Operand

Optimization Variables (4)

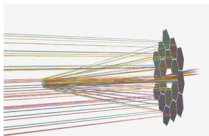
#	TYPE	SURFACE	CURRENT	MIN	MAX	ACTIONS
1	Thickness [mm]	S4 — FSM - Fir	3027.434	2724.68	3330.17	
2	1/R [mm ⁻¹]	SS — Focal plar	-0.0003	-0.001	0.001	
3	Tilt X [deg]	SS — Focal plar	0.0357	-10	10	
4	Tilt Y [deg]	SS — Focal plar	-0	-10	10	

+ Add Variable

Overall Weight: 1 | Configuration: All | Field: All

Cancel | Apply

In the reference software the workflow is slightly different and involves marking some of the surface properties as variables, which is handled automatically by etendue’s plugin depending on selected options.



After reaching the time budget of 2 minutes, we get the following results:

3 Optimization Generic

2 min 06 s

Optimization Complete

122s — Local

Merit Before

1.69e+5

Merit After

18.11

Improvement

99.99%

Convergence: Time budget reached

Variables Changed: (4)

Variable	Surface	Initial	Final	Δ	% Change
position_along_beam	4	3027.4388	3067.9490	+40.5103	+1.34%
radius	5	—	-3039.9445	0.0000	0.00%
tilt	5	0.1211	6.24e-4	-0.1205	-99.48%
tilt	5	0.0000	-1.84e-9	-1.84e-9	0.00%

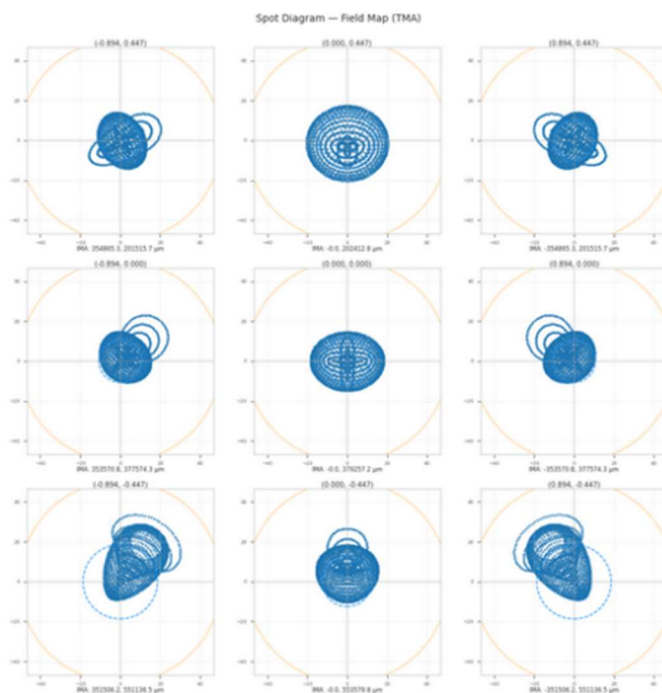
Operands Performance: (9)

Operand	Target	Current	Error
rms_spot_size	0.0000	0.0119	0.0119
rms_spot_size	0.0000	0.0124	0.0124
rms_spot_size	0.0000	0.0124	0.0124
rms_spot_size	0.0000	0.0120	0.0120
rms_spot_size	0.0000	0.0130	0.0130
rms_spot_size	0.0000	0.0186	0.0186
rms_spot_size	0.0000	0.0134	0.0134
rms_spot_size	0.0000	0.0186	0.0186
rms_spot_size	0.0000	0.0134	0.0134

Execution time: 2 min 06 s

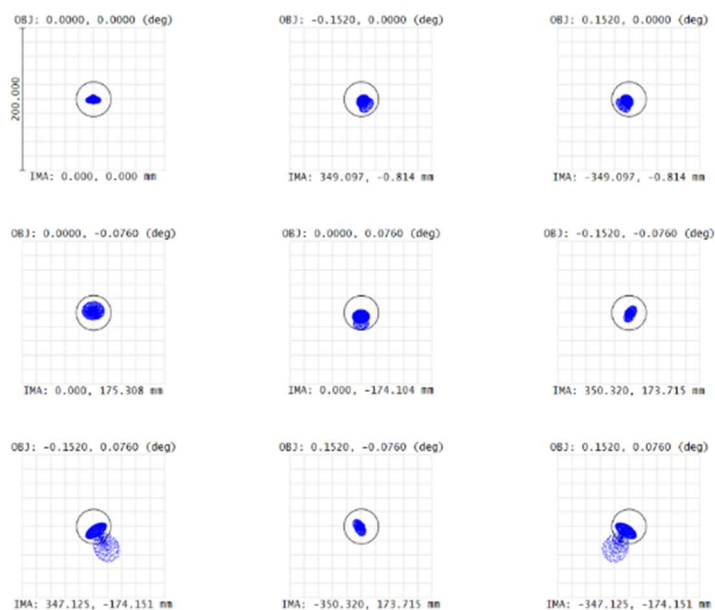


And let's look at the TMA maps:

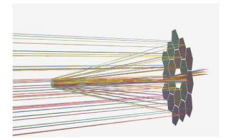


c - source : etendue

Which we can compare with the reference:



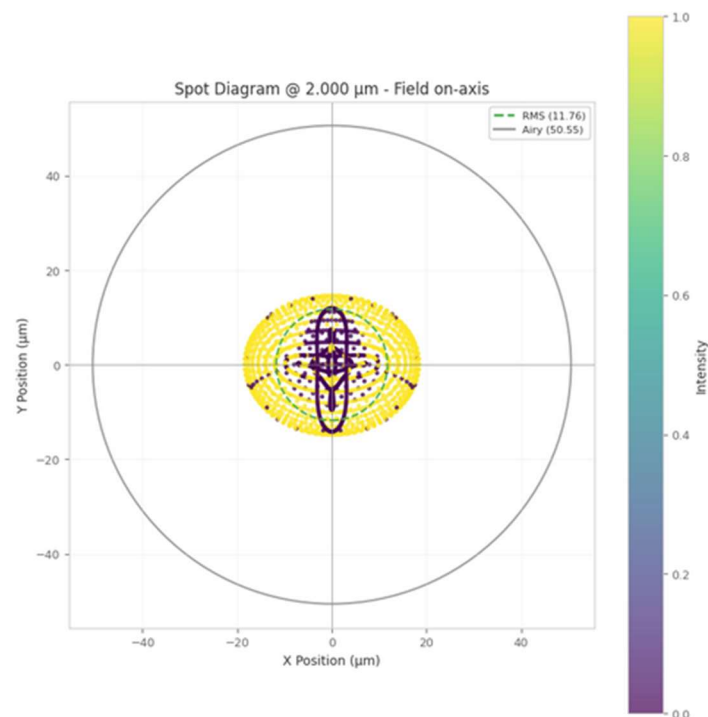
d - source : ref. software



Conclusion:

Etendue demonstrates simulation and optimization capabilities comparable to the reference software, with negligible deviation.

The workflow in Etendue is fast and easy to set up, largely thanks to the AI assistant, which successfully reconstructed the system from scratch by analyzing screenshots from the source material.



*On axis spot diagram after optimization
source: etendue*