Metrology as a Mindset

What This Means for Our Customers

- Reduce Risk Early and Often
- Measurement You Can Trust
- Metrology Across the Full Lifecycle
- Access When You Need It



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Senior Manager, Optical Engineering at Optikos Corporation

- 20+ years of optical engineering experience, out of which 14+ years tenure at Optikos;
- PhD in Optics from the University of Rochester;
- :https://www.linkedin.com/in/davidbiss/



I will be your host

Because I’ve experienced first-hand why metrology matters

If you cannot measure it, you haven’t made it.
- unknown

The blue or the red pill, Neo?

Little to No Metrology

- You can only speculate about problems!!
- You need to develop a testing plan!!
- You may need to create tooling!!
- **You will lose time and money**

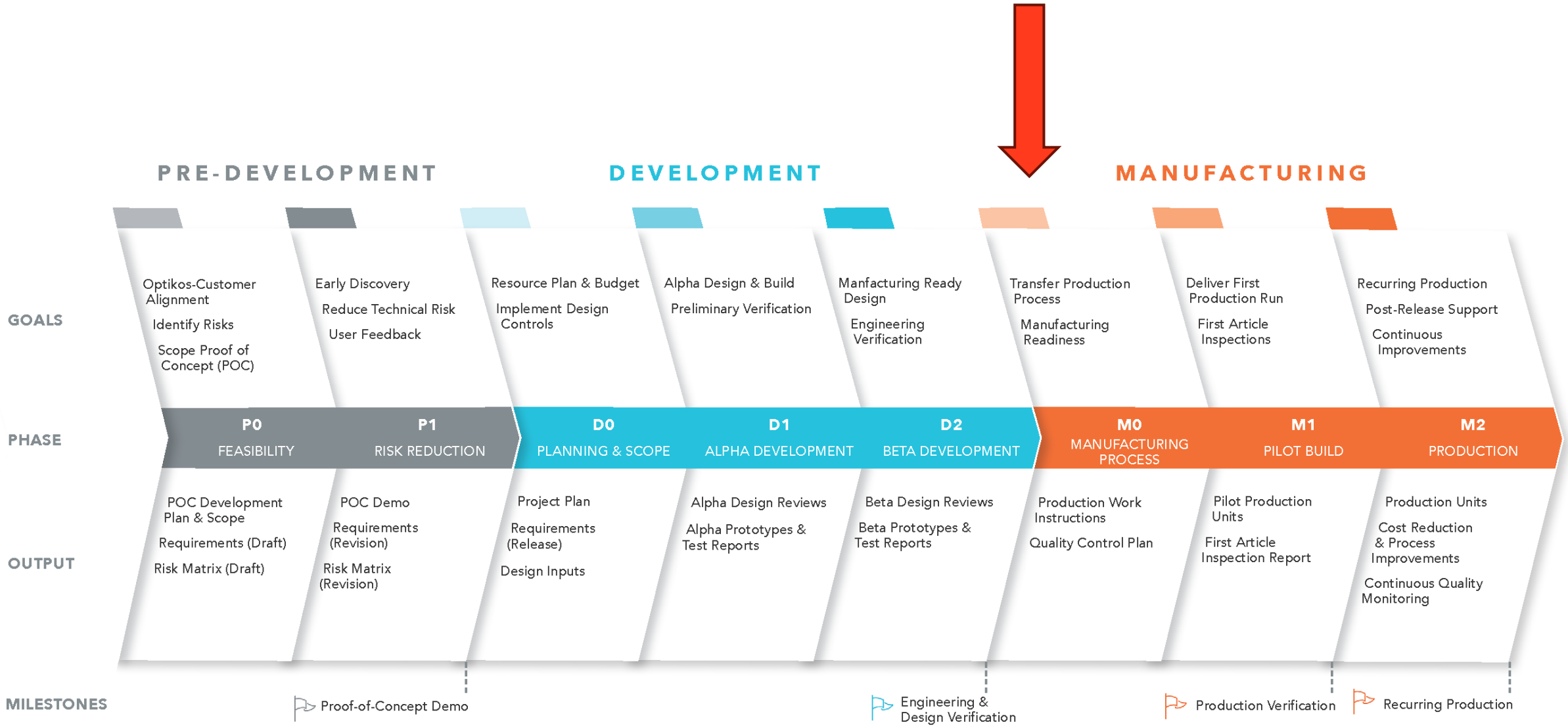


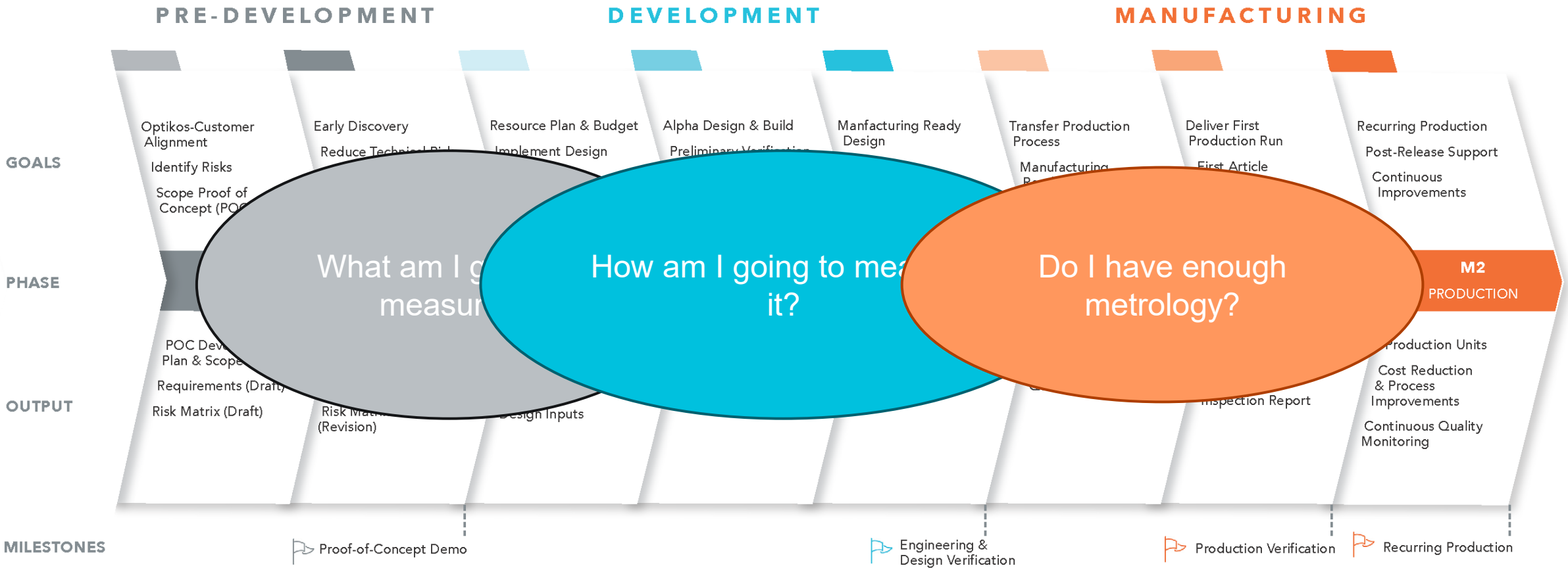
With Robust Metrology

- **Existing metrology will help you troubleshoot faster**
- **Provides more consistent outcomes**
- **This saves time and money**

Bottom line: a metrology mindset saves projects

- You reduce (enormous amounts of) confusion during the build process
- You get more consistent prototype and production outcomes
- Less downtime
- Saving **$$$+++** doesn't sound that bad, right?


PRE-DEVELOPMENT
DEVELOPMENT
MANUFACTURING
GOALS
PHASE
OUTPUT
MILESTONES
Optikos-Customer Alignment
Identify Risks
Scope Proof of Concept (POC)
Early Discovery
Reduce Technical Risk
User Feedback
Resource Plan & Budget
Implement Design Controls
Alpha Design & Build
Preliminary Verification
Manfacturing Ready Design
Engineering Verification
Transfer Production Process
Manufacturing Readiness
Deliver First Production Run
First Article Inspections
Recurring Production
Post-Release Support
Continuous Improvements
P0
FEASIBILITY
P1
RISK REDUCTION
D0
PLANNING & SCOPE
D1
ALPHA DEVELOPMENT
D2
BETA DEVELOPMENT
M0
MANUFACTURING PROCESS
M1
PILOT BUILD
M2
PRODUCTION
POC Development Plan & Scope
Requirements (Draft)
Risk Matrix (Draft)
POC Demo
Requirements (Revision)
Risk Matrix (Revision)
Project Plan
Requirements (Release)
Design Inputs
Alpha Design Reviews
Alpha Prototypes & Test Reports
Beta Design Reviews
Beta Prototypes & Test Reports
Production Work Instructions
Quality Control Plan
Pilot Production Units
First Article Inspection Report
Production Units
Cost Reduction & Process Improvements
Continuous Quality Monitoring
Proof-of-Concept Demo
Engineering & Design Verification
Production Verification
Recurring Production


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Implement Design
Alpha Design & Build
Preliminary Verification
Manfacturing Ready Design
Transfer Production Process
Manufacturing
Deliver First Production Run
First Article
Recurring Production
Post-Release Support
Continuous Improvements
M2
PRODUCTION
POC Dev
Plan & Scope
Requirements (Draft)
Risk Matrix (Draft)
Risk Matrix (Revision)
Design Inputs
Inspection Report
Production Units
Cost Reduction & Process Improvements
Continuous Quality Monitoring
What am I g
measur
How am I going to mea
it?
Do I have enough metrology?
Proof-of-Concept Demo
Engineering & Design Verification
Production Verification
Recurring Production

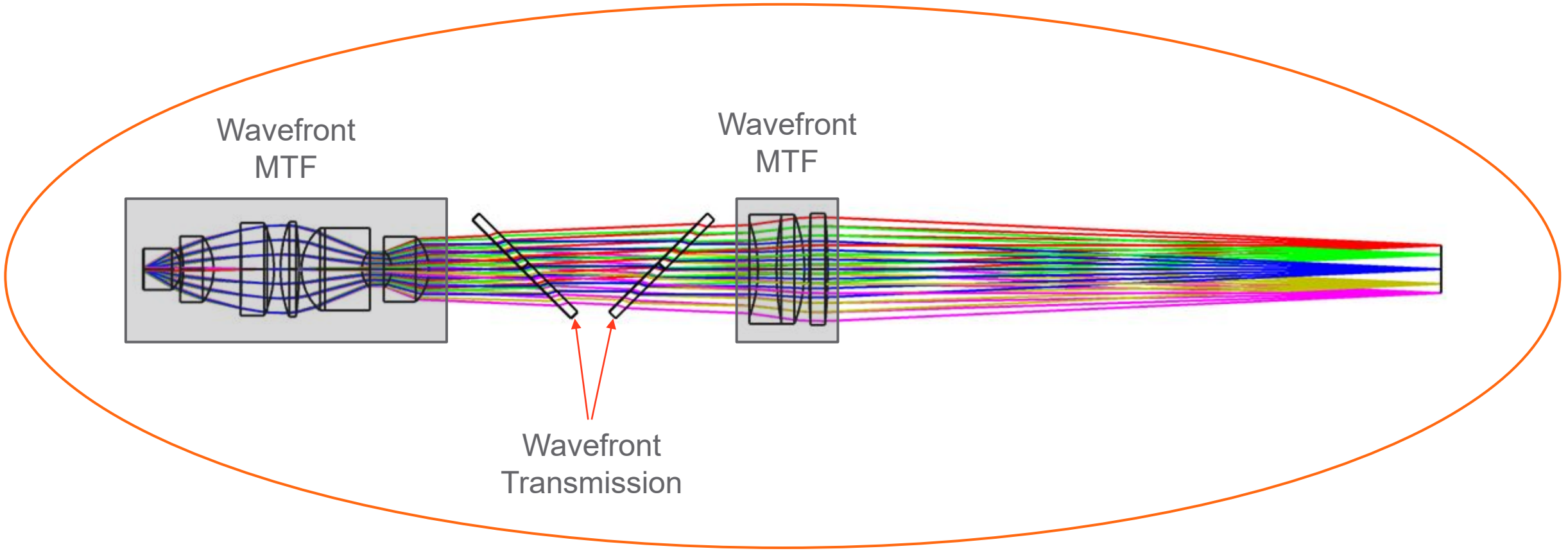

What am I going to measure?

“We have run into a problem **multiple times** where we build and test a system, the system performance is lousy and find out a sub-assembly we assumed should work isn’t performing to our expectation.”

- uncredited

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Resolution





Final system performance!

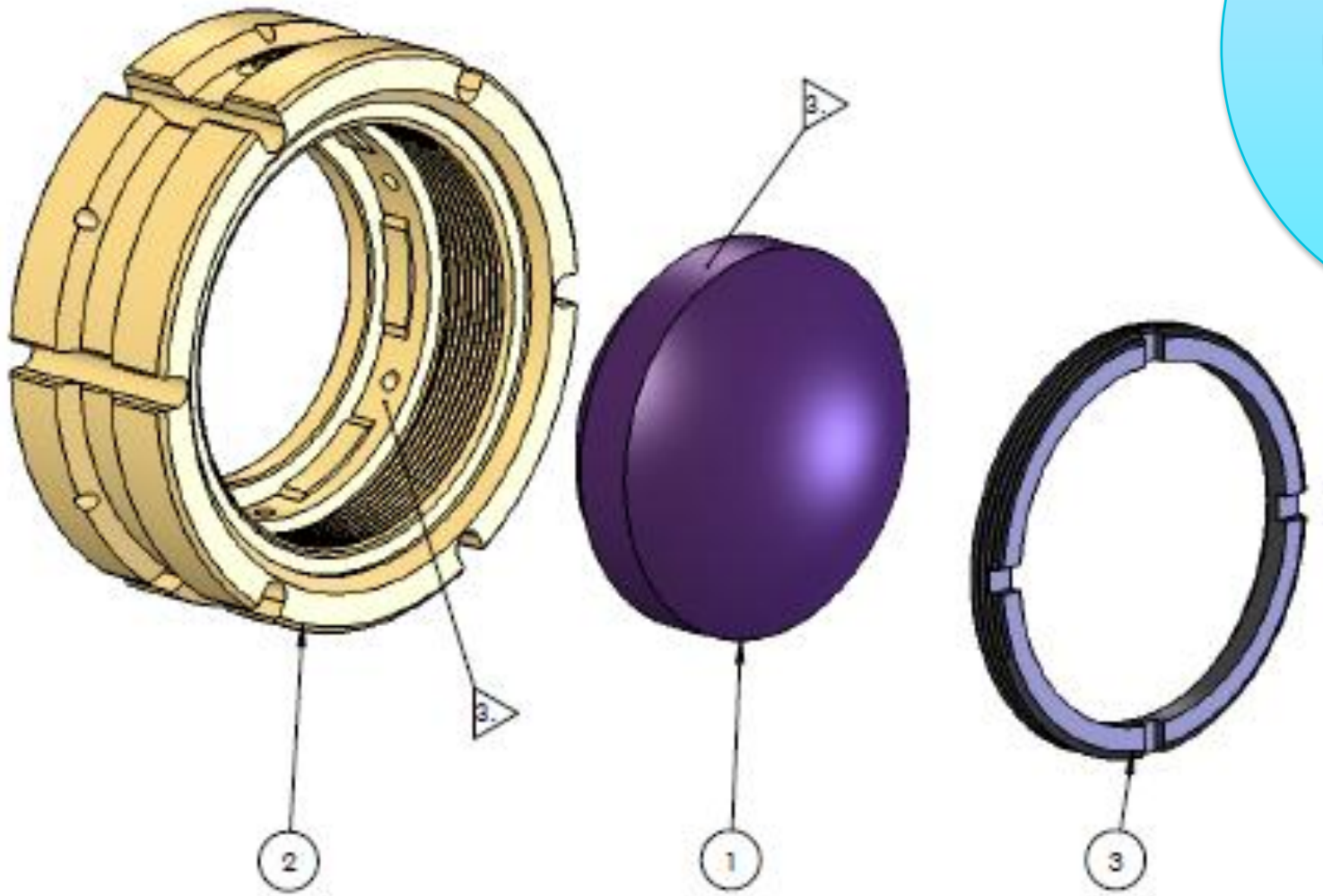
Simple

Diameters
Thicknesses
Radii of Curvature
Irregularity
Etc…

Complex

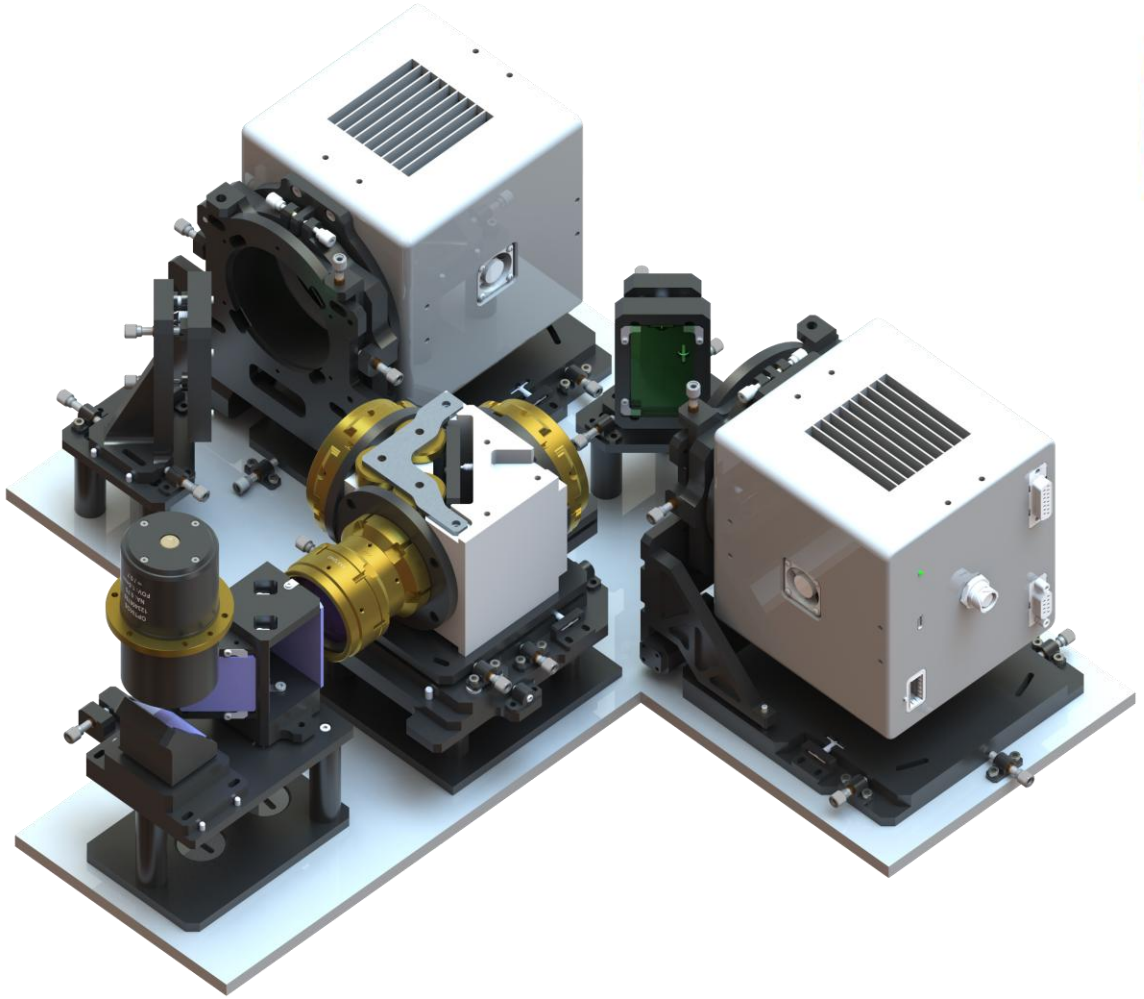
Component wavefront
Sub-assembly performance
What tolerance?
Others?

Simple

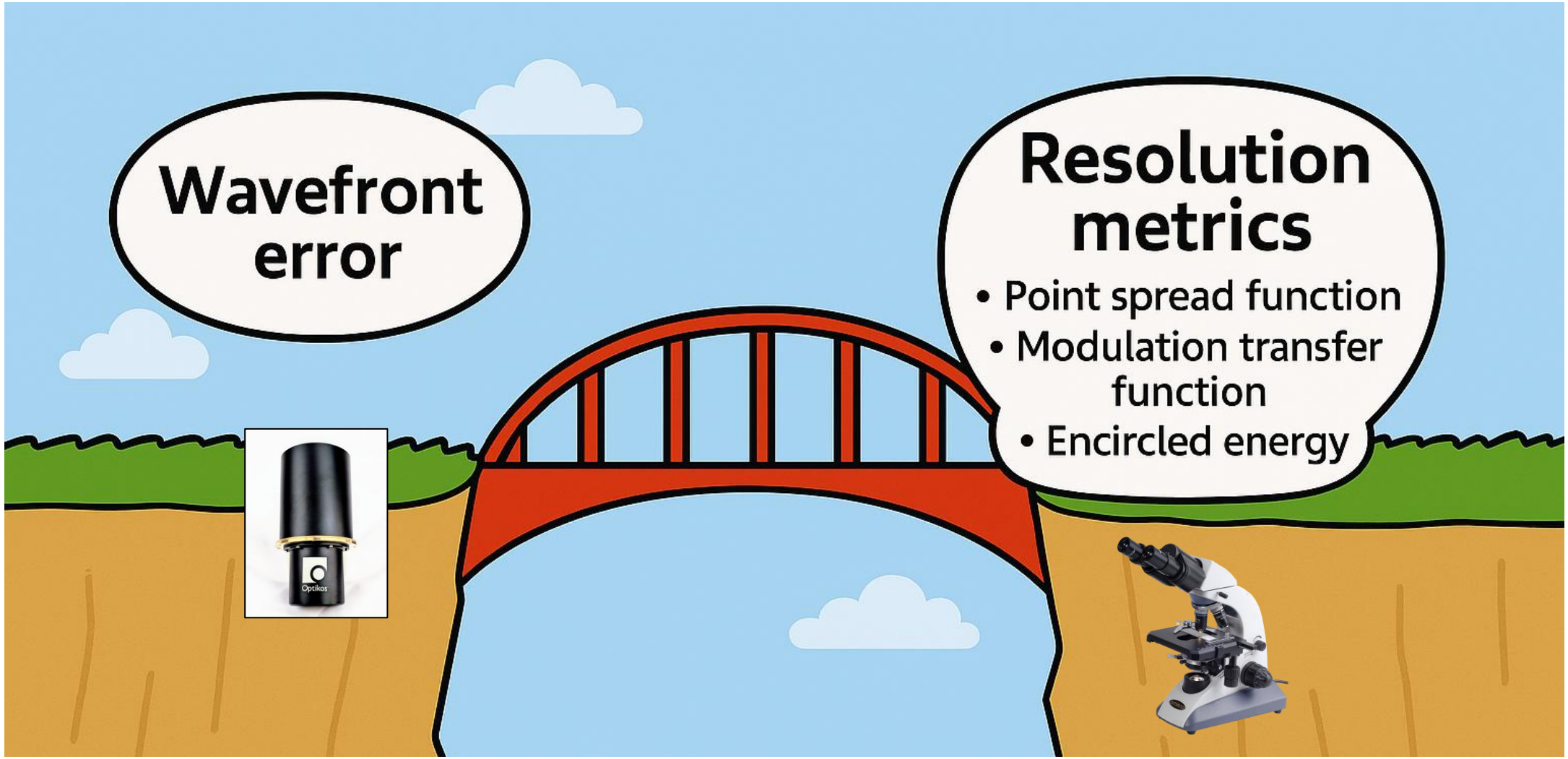


Diameters
Thicknesses
Radii of curvature
Irregularity
Etc.

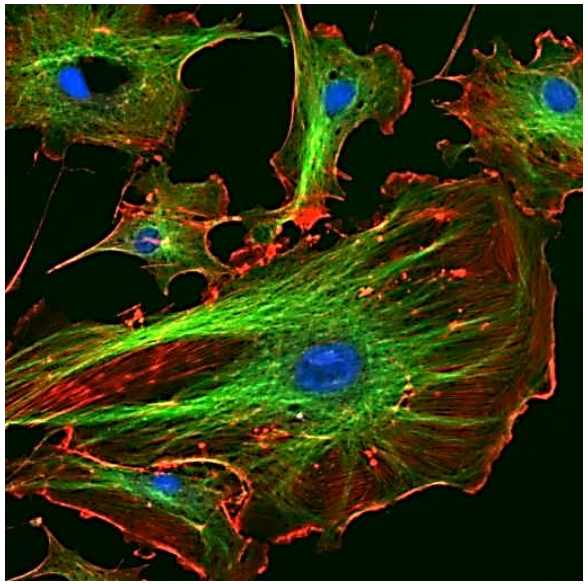
Complicated



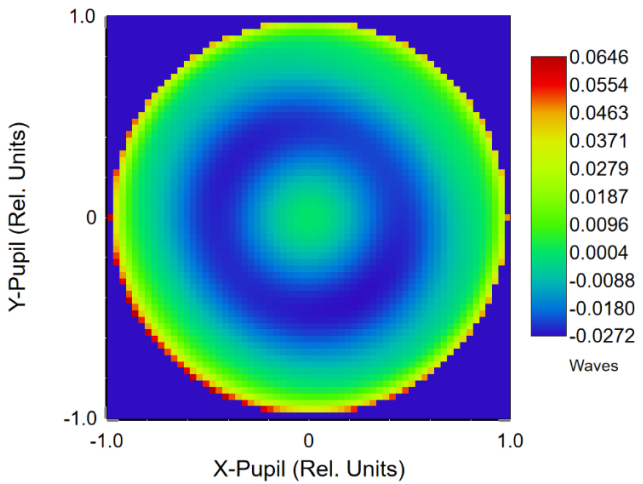
Component wavefront
Sub-assembly
performance
What tolerance?
Others?


Wavefront error
Resolution metrics
• Point spread function
• Modulation transfer function
• Encircled energy
Optikos

How do you figure out sub-assembly performance?





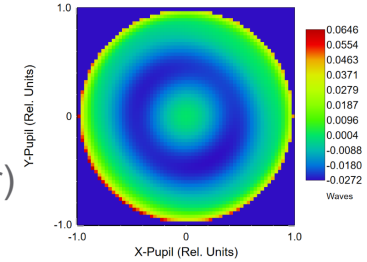


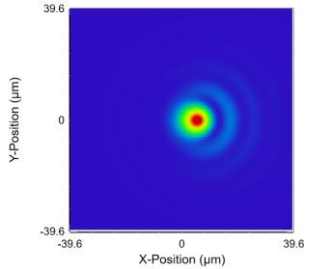




$$P(x,y)$$

pupil function
(wavefront and wavefront error)





$$PSF(x,y) = \mathcal{F}\{OTF(f_x, f_y)\}$$

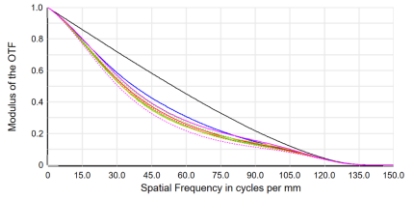
Point Spread Function
(FWHM, radius, etc)

$$OTF(\xi,\eta) = \iint_{-\infty}^{\infty} P(x,y)P^*(x-\xi, y-\eta)dx\,dy$$

Optical transfer function
Autocorrelation of the pupil function

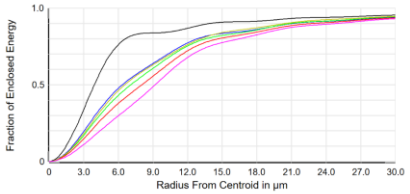
$$MTF = \left|OFT(f_x, f_y)\right|$$

Modulation Transfer Function
(Contrast at a spatial frequency)

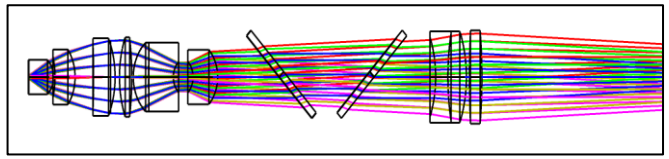


$$EE(r) = \int_0^r PSF(r)dr$$

Encircled (or ensquared) Energy



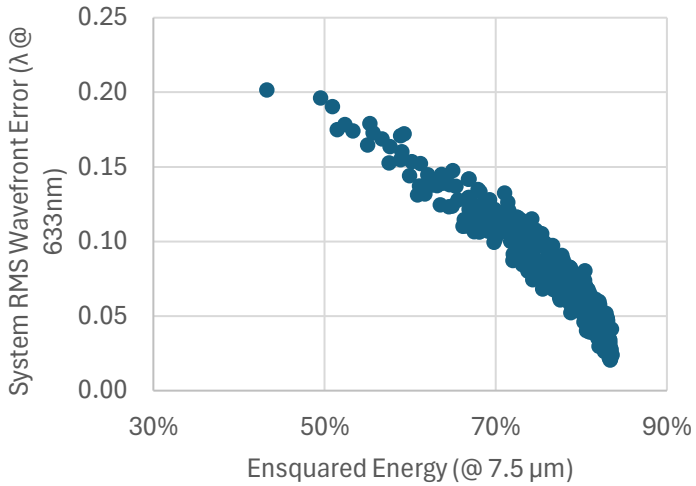
INPUTS!



Tolerance 1	± 10 µm
Tolerance 2	± 2%
Tolerance 3	± 30 nm
Tolerance 4	1 fr
And so on…	

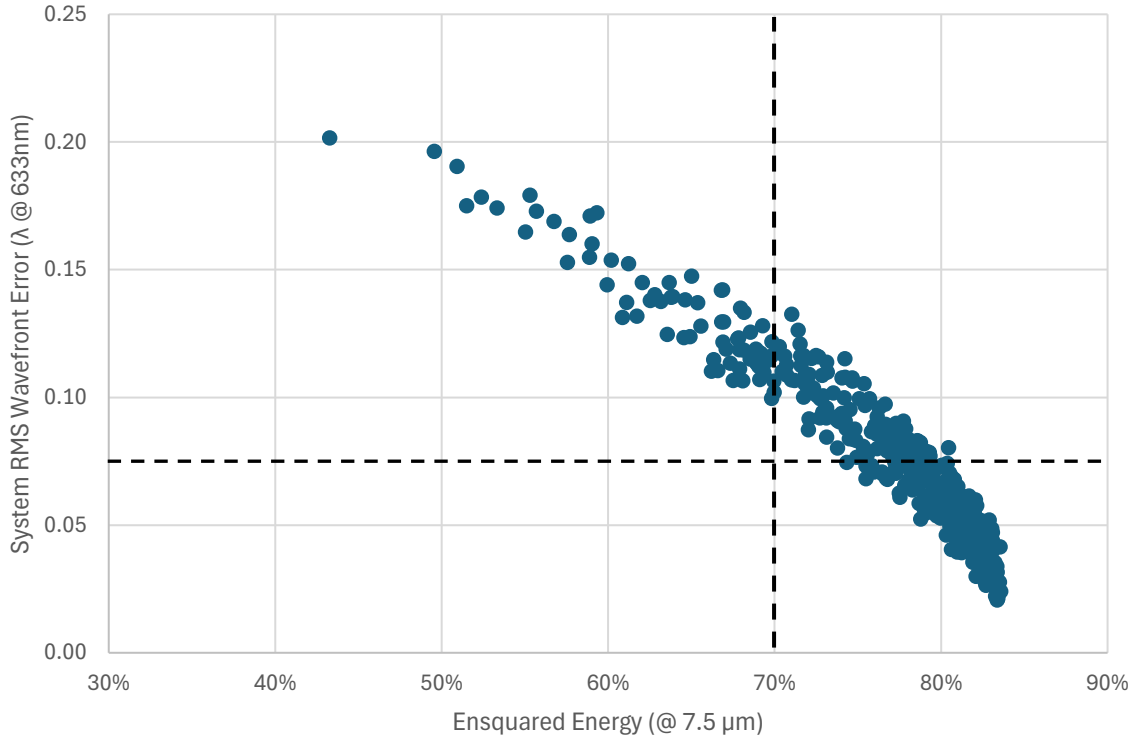


OUTPUTS!



How does this data help?

- You can identify (and monitor) process yield for subassemblies!!
- Identify poor performing components before they reach the end of line!
  - Saves time and $$$



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What am I going to measure? - Summary

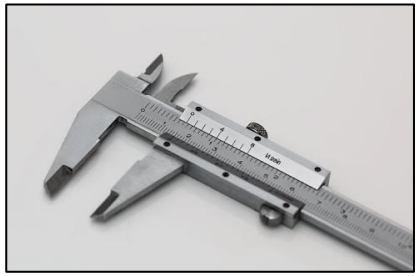
- Identifying what you want to measure helps determine:
  - Creates a metrology foundation that will support a well-performing system.
  - What tools you need
- Determining what you want to measure isn't usually as straightforward as you expect.
  - It's simple to think it is just measurable specifications of components
  - You will care about sub-assembly performance, expected performance requirements, allowable variation (tolerance) in these specifications
- Design and modeling work bridges the gap between different component metrology target.
  - Tolerance analysis helps you understand the relationship between variation of different performance metrics.


How am I going to measure it?

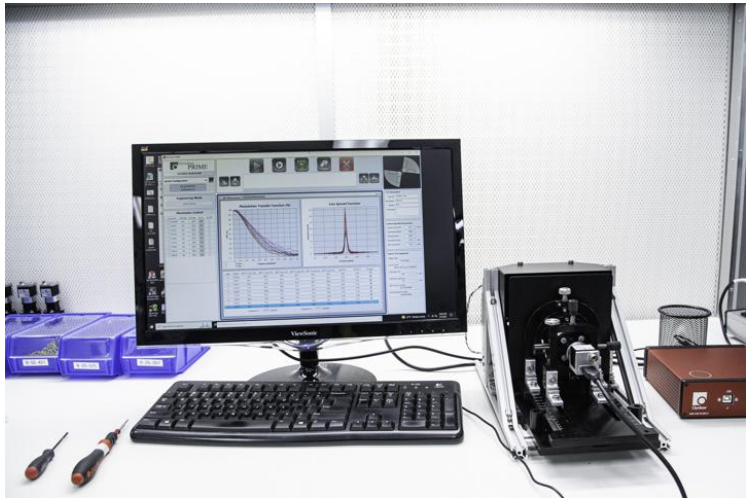

Mitutoyo


LensCheck LWIR
LWIR
Optikos

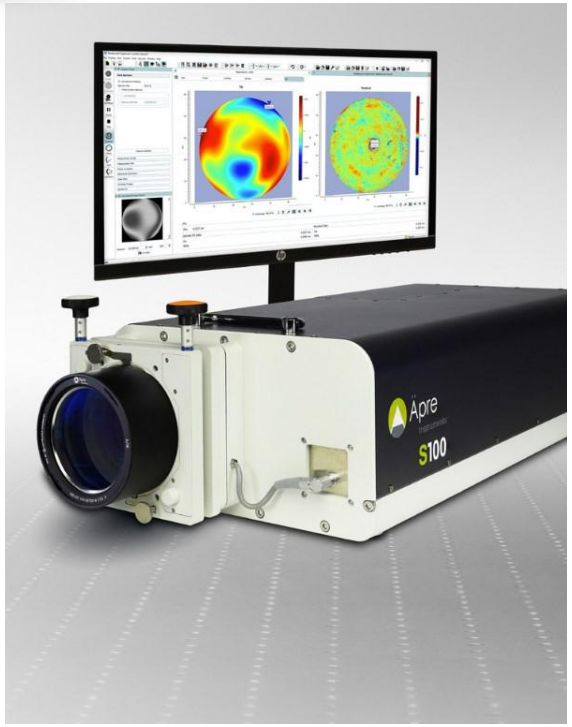

onto
IVS 220



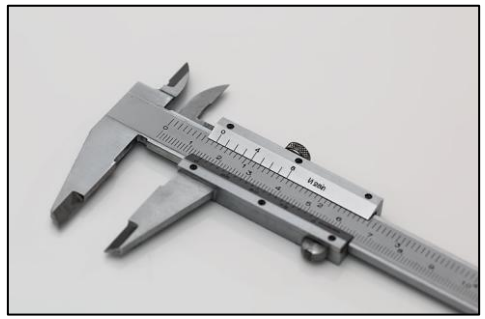

R-FLEX



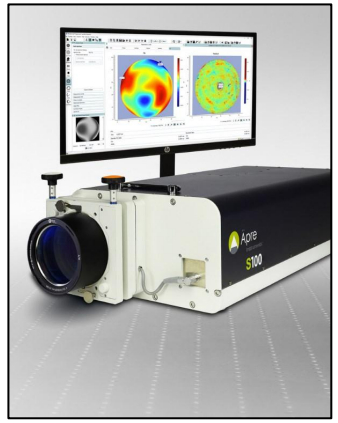


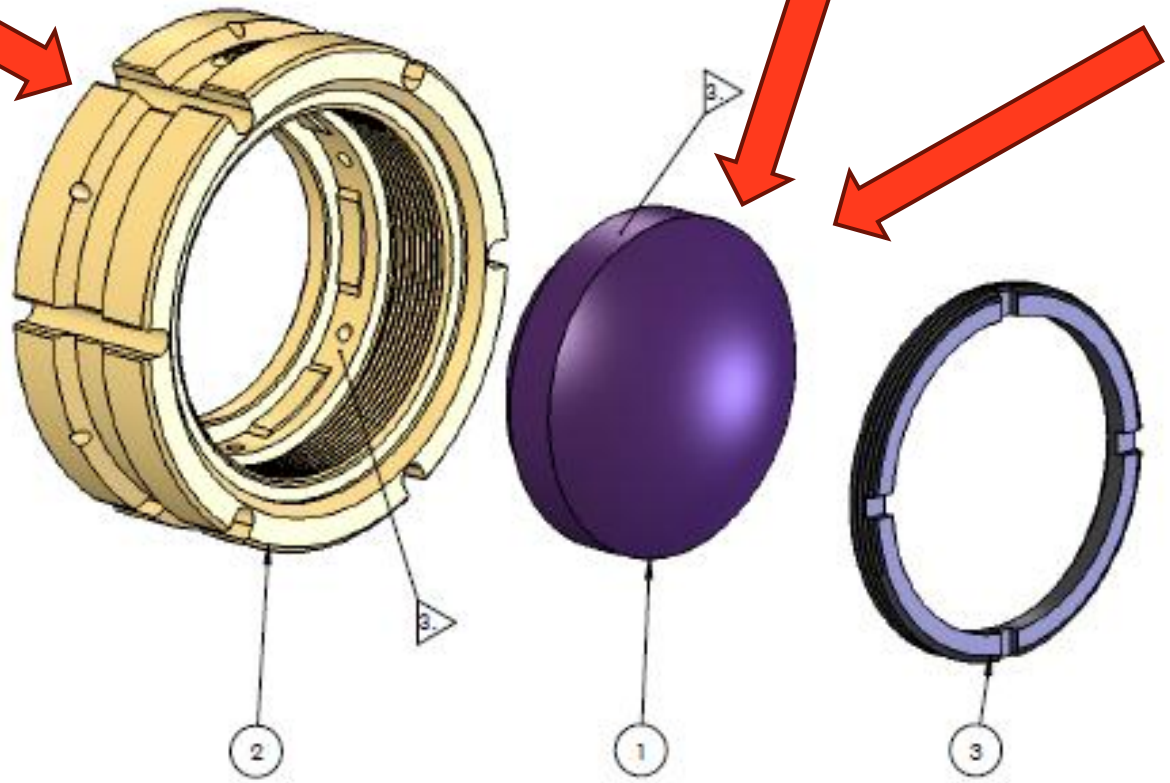

Apre
S100





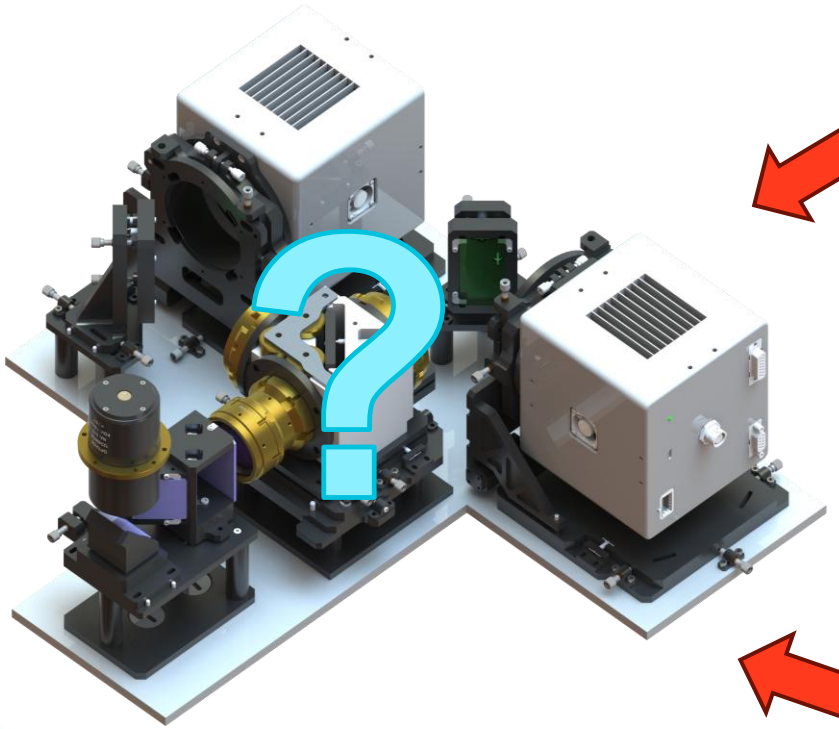

R-FLEX


Apre
S100

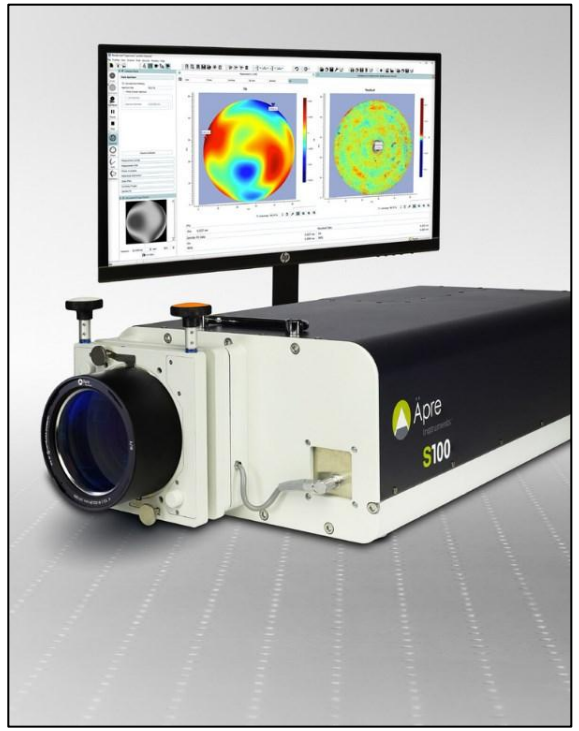

2
1
3


R-FLEX

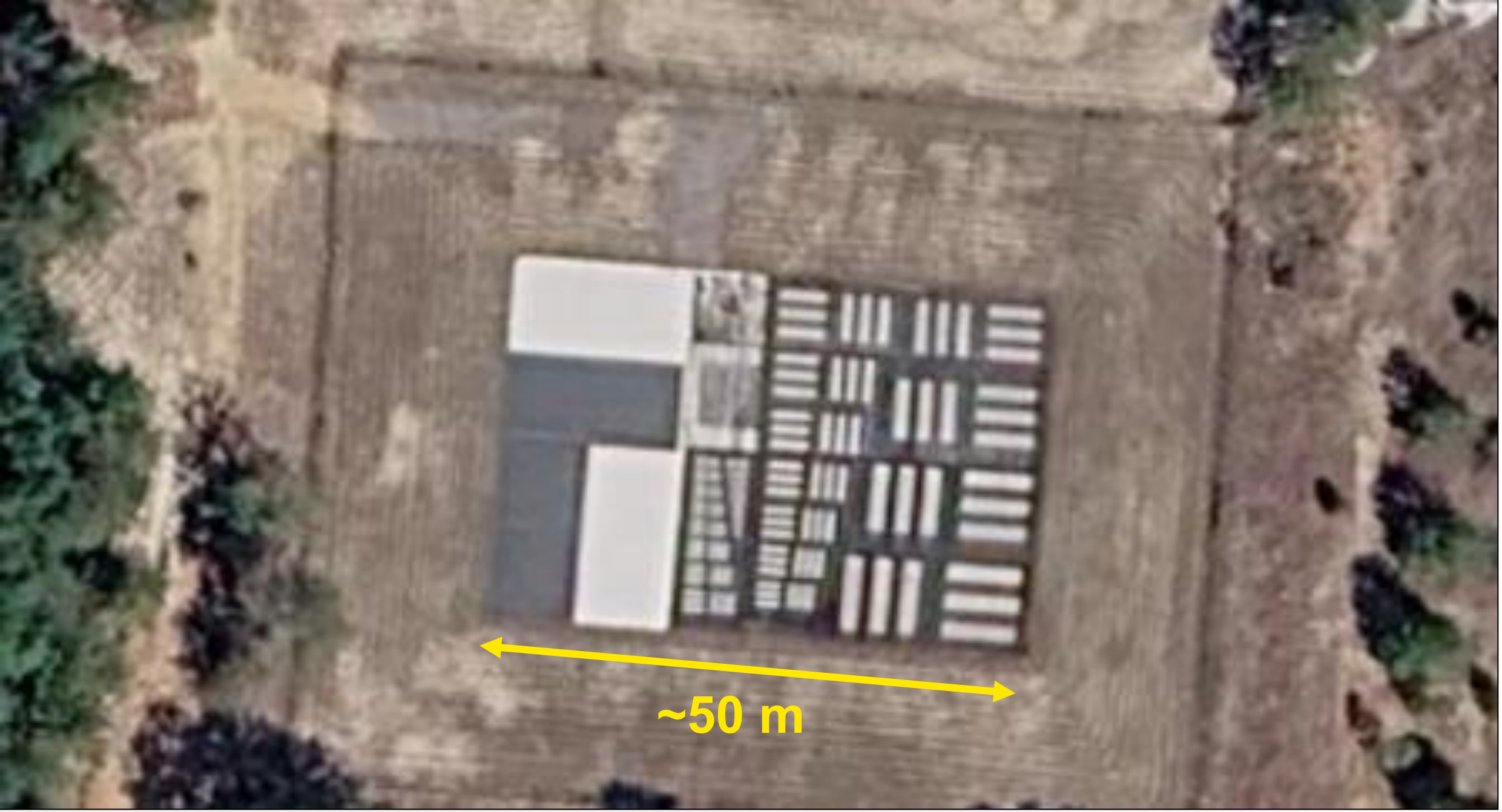




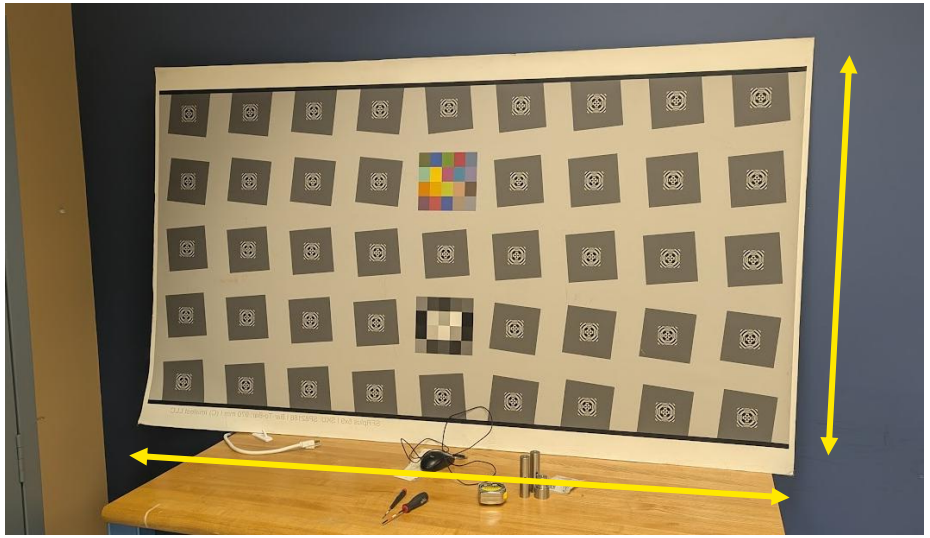

LensCheck LWIR
LWIR
Optikos


Apre
S100

For many applications you'll want a custom metrology setup for some portion of testing!


~50 m





~1 m

~2 m

- More compact
  - less facility space = less $$$
- Easier to integrate into line

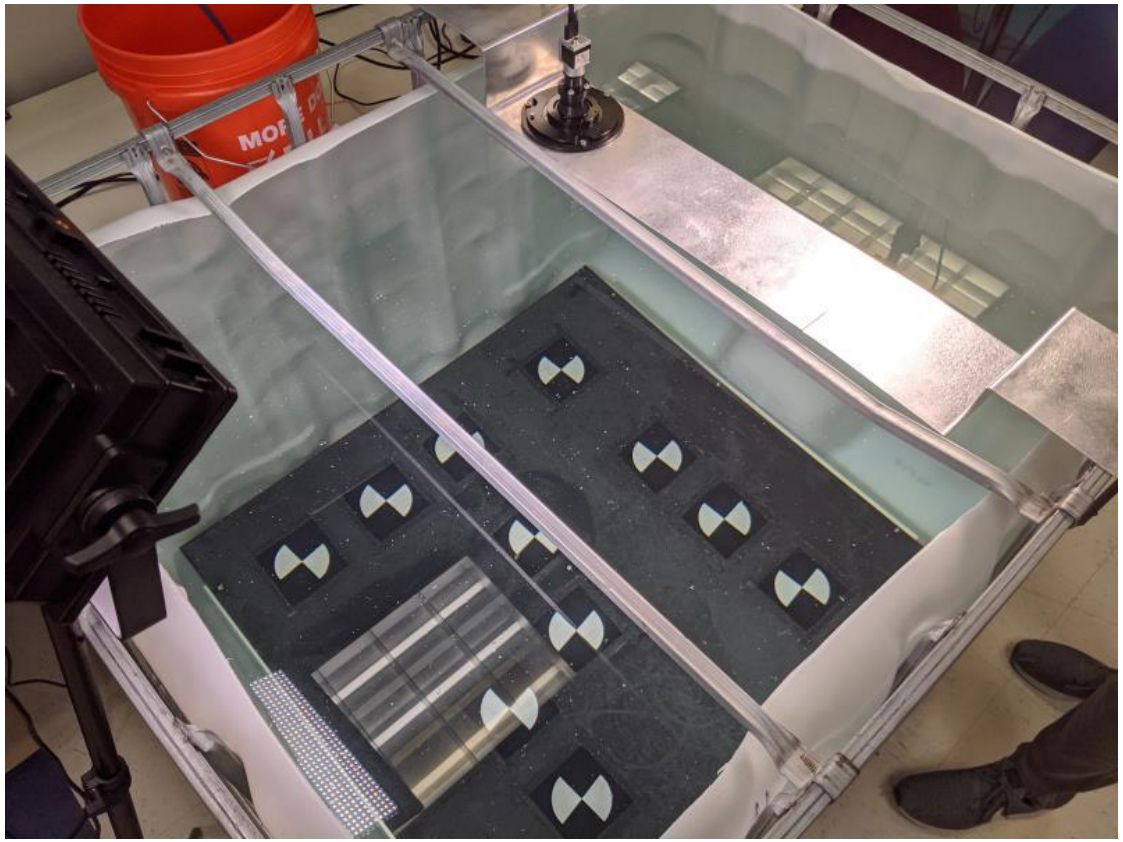


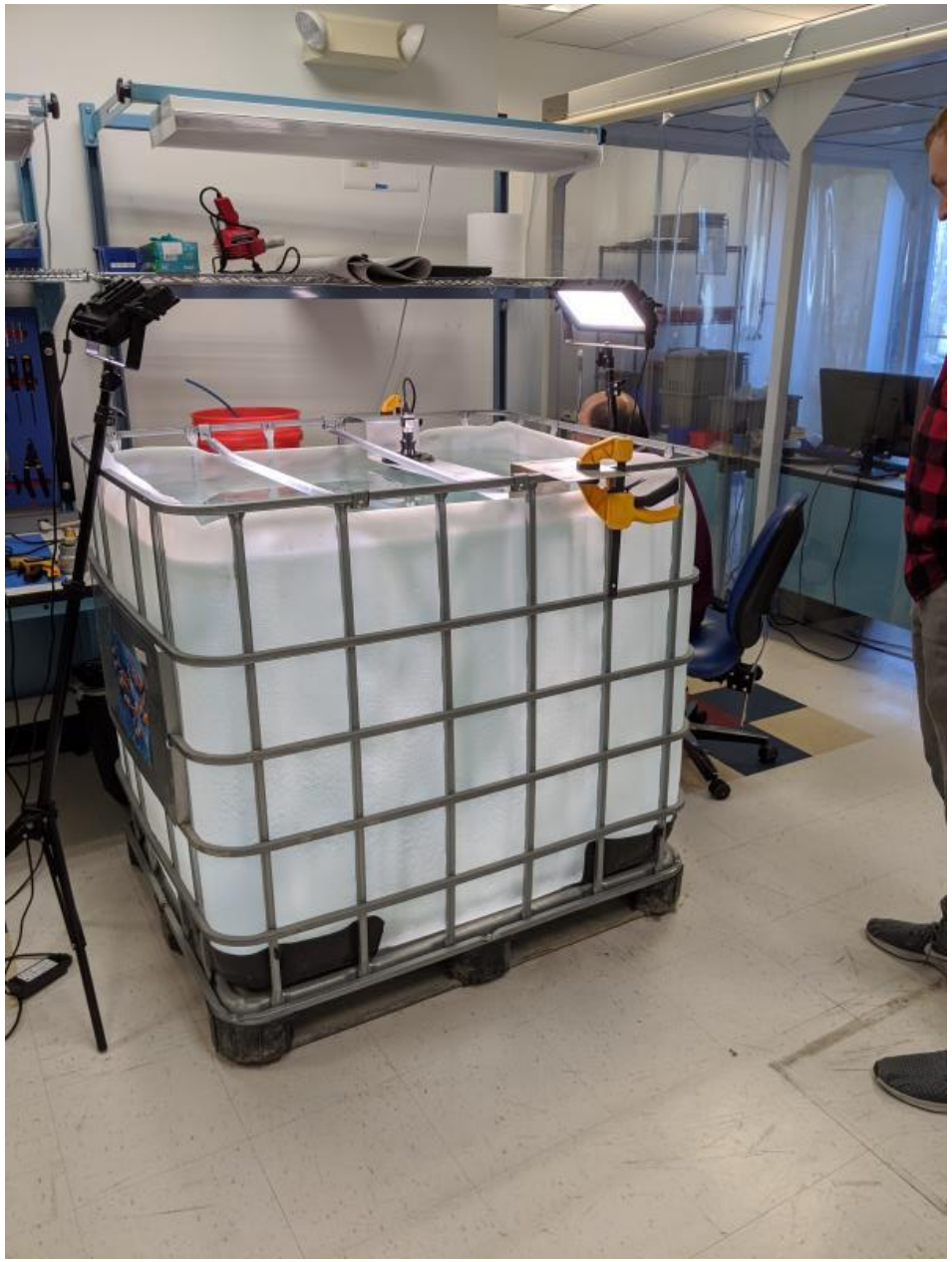


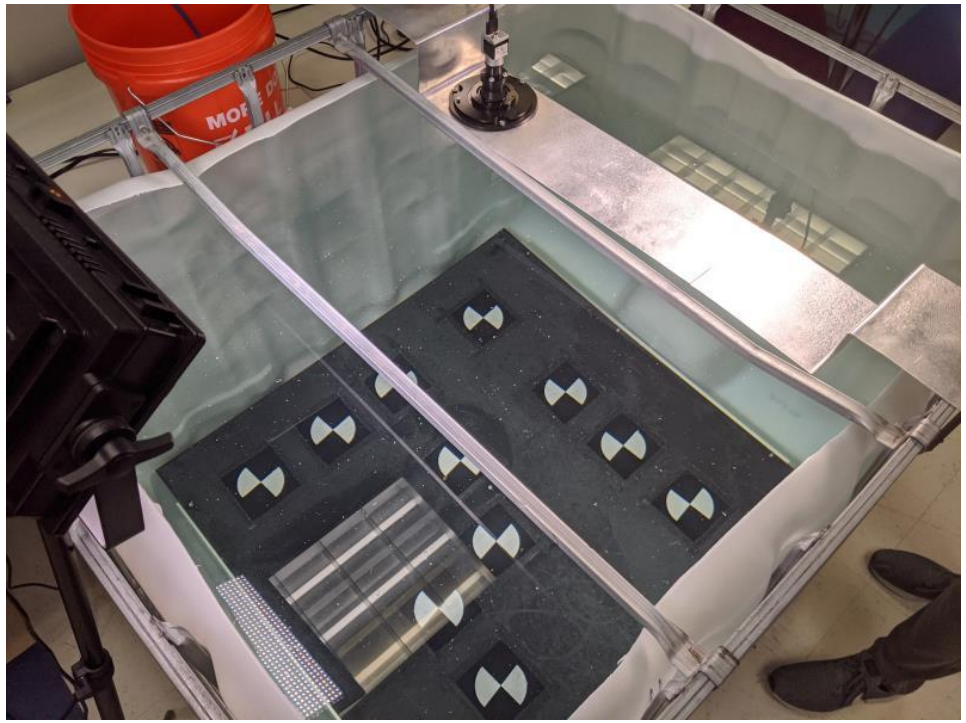
~0.3 m

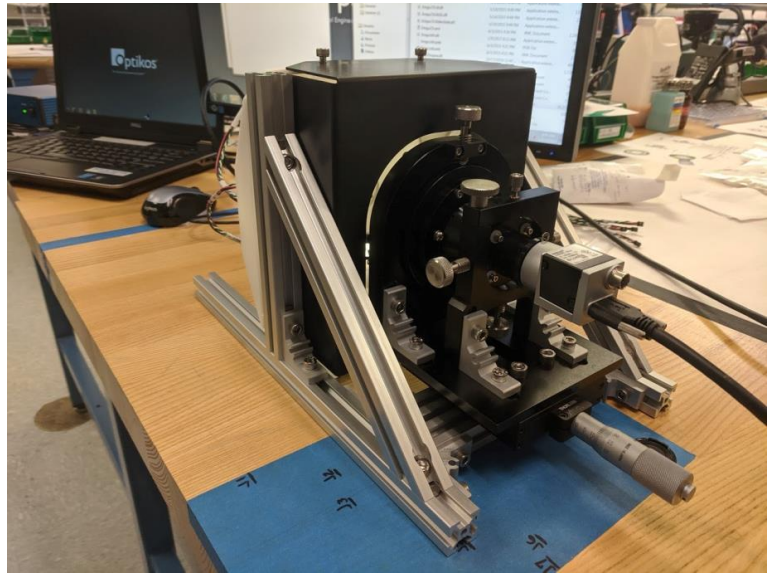
~0.3 m


How do you test this?





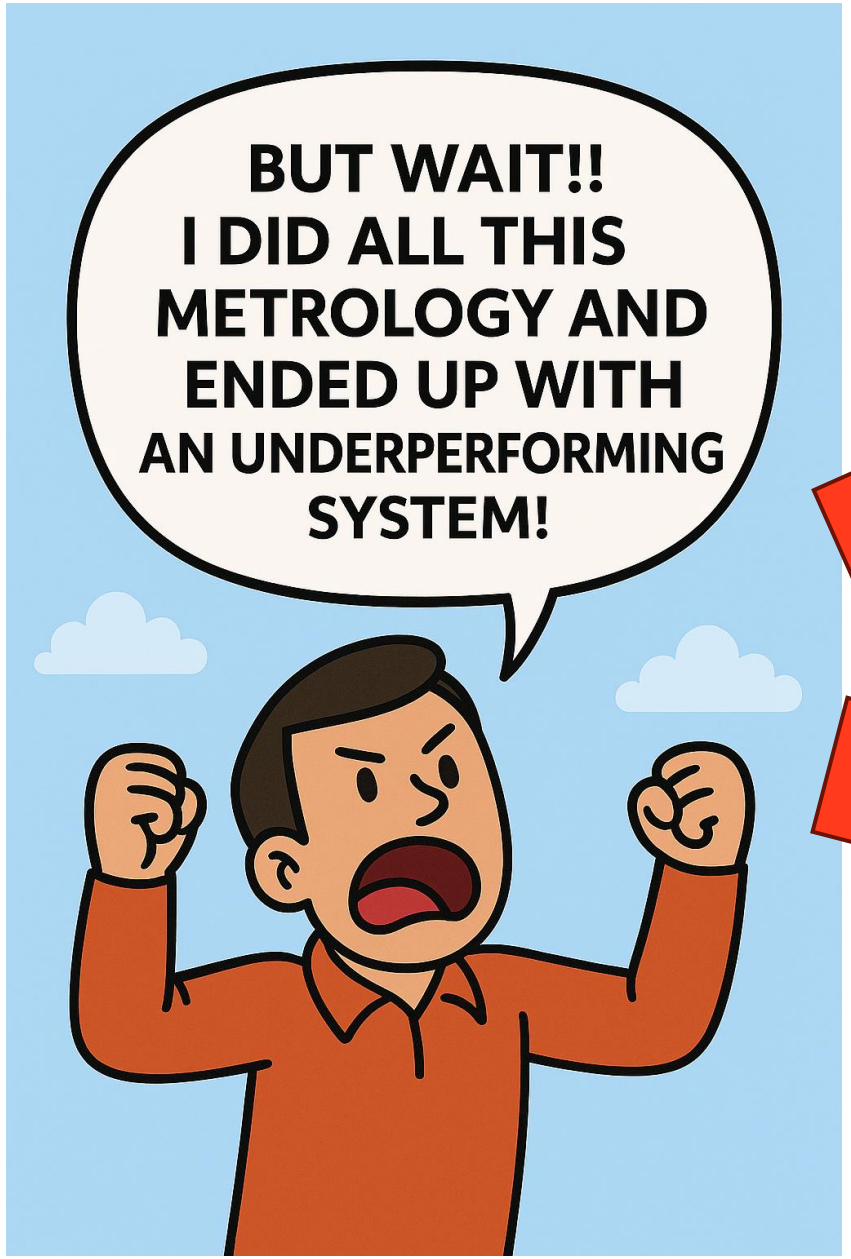




- Fully custom
- Minimal space
- Easy to use
- Lowest risk of flood

How am I going to measure it? - Summary

- Specifications and requirements will guide how you are going to measure
- Component metrology is often straightforward.
  - Lots of off the shelf tools exist.
- Fixturing is your friend!
  - Think about fixturing during the design phase, it'll save you time.
- Sub-assembly and full system testing often requires some form of customization
  - This could be just fixturing to use an existing piece of test equipment.
  - Other times it requires fully custom metrology equipment; you need to design and create your own form of test equipment!!



Robust Metrology

- Existing metrology will help you troubleshoot faster!!
- **This saves time and money!!**

Little to No Metrology

- You can only speculate about problems!!
- You need to develop a testing plan!!
- You may need to create tooling!!
- **You will lose time and money!!**


Do I have enough metrology?

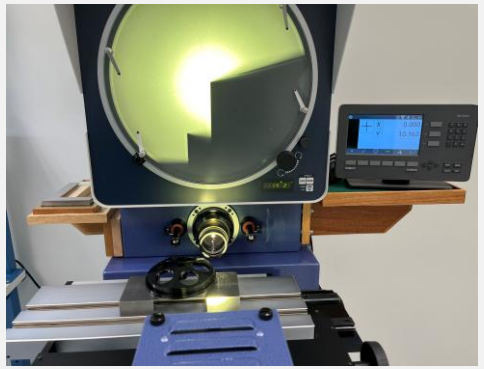


https://www.optikos.com/webinars/metrology-in-manufacturing/

Optical Metrology Integration in the Assembly Workflow

Incoming Inspection

- Confirm component parts are good
- Earliest point to avoid defects before adding value



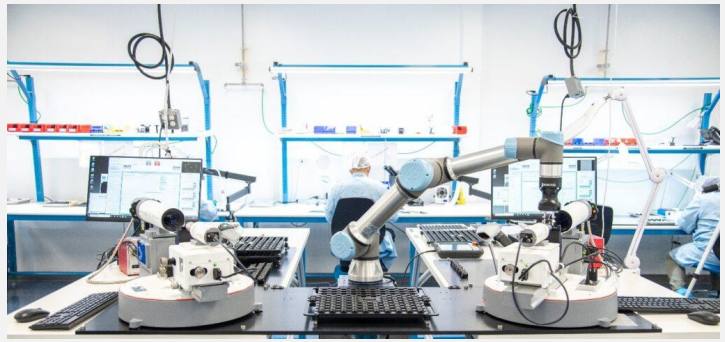
In-Process Inspection

- Check sub assembly performance
- Middle ground for inspecting early before getting to finished assembly



Final Functional Testing

- Ensure quality of final finished product
- Avoid escapes
- Watch for trends!

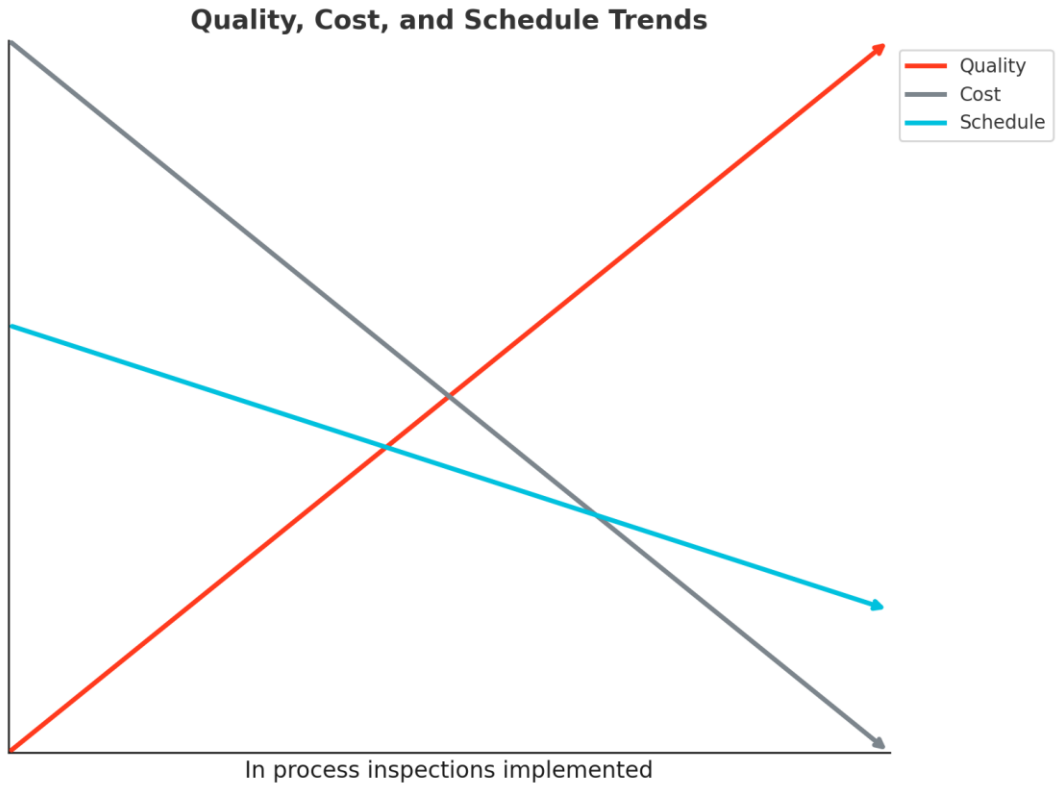


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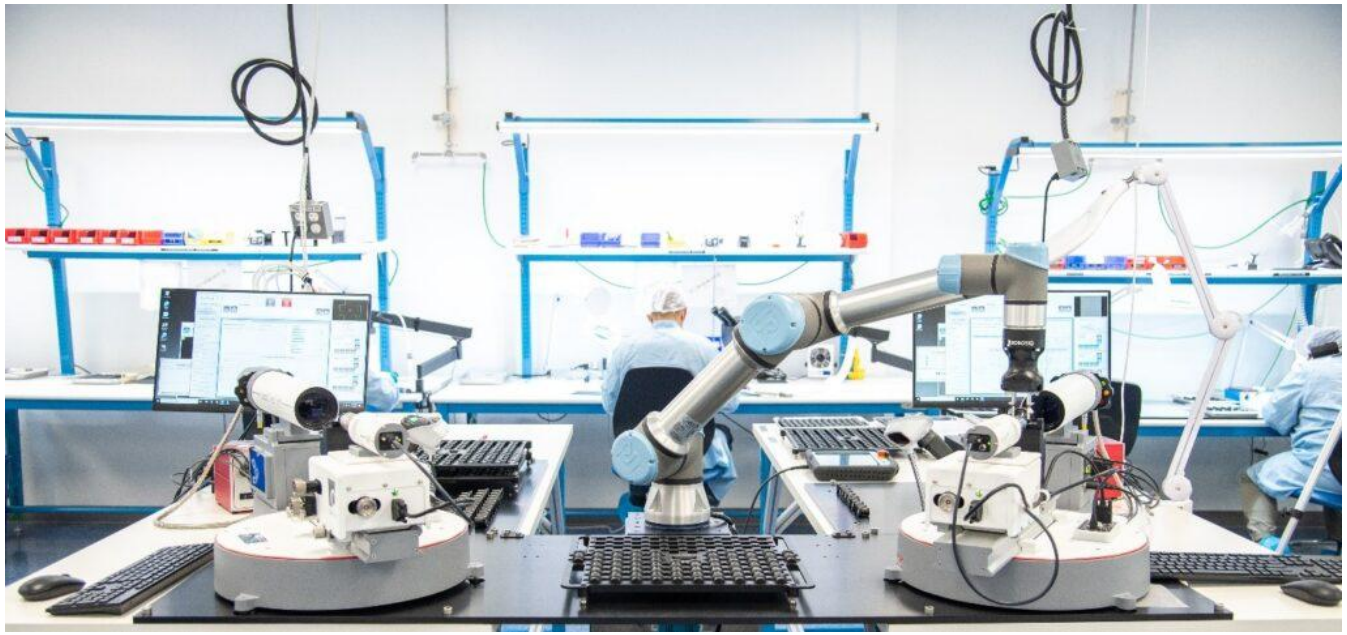
How Metrology enables Assembly Success

- Schedule
  - Open bottle necks
  - Find defects early
- Cost
  - Minimize scrap material
  - Minimize touch time
- Quality
  - Feedback required in build process
  - Final assemblies perform to specification
  - No escapes!



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Final Functional Test





- Eliminate escapes
- Monitor performance trends
  - Immediate feedback
    - Build issues
    - Equipment issues
  - Metrics for team
- A record of the performance going out the door

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Do I have enough metrology? - Summary

- Implementing Optical Metrology Inspections can be done at any point in the build process: incoming inspection, in-process inspection, and final function testing
- More inspection does not necessarily result in a better outcome!
- Implementing inspection steps should be done to optimize for the following
  - Quality
  - Schedule
  - Cost
- There are many different optical metrology devices – select the appropriate one for your needs
- Data from inspection steps is critical for continuous improvement

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Summary

- Identifying what you want to measure helps determine metrology tools and foundation for a consistently performing system.
- Determining what you want to measure isn't usually as straightforward as you expect.
- Design and modeling work bridges the gap between different component metrology targets.
- Specifications and requirements will guide how you are going to measure
- Sub-assembly and full system testing often requires some form of customization
- Implementing Optical Metrology Inspections can be done at any point in the build process: incoming inspection, in-process inspection, and final function testing
- More inspection in production does not necessarily result in a better outcome!
- Implementing inspection steps should be done to optimize for quality, cost, and schedule.
- There are many different optical metrology devices – select the appropriate one for your needs
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Bottom line: a metrology mindset saves projects

- You reduce (enormous amounts of) confusion during the build process
- You get more consistent prototype and production outcomes
- Less downtime
- Saving **$$$+++** doesn't sound that bad, right?