SUMMARY:

- Optical engineering:
  - Need for relatively high awareness and participation in the overall effort by optical engineers. Shortage of optical engineers in industry. Limited understanding of basic optics in an industrial setting. Unique manufacturing processes with trade secrets and fragmented vendor base.
- Overview of standard procedure for a consumer product – product development is driven by value proposition followed by marketing requirements, product requirements and engineering requirement
  - Give example of Google glass with differing value propositions
- 6 sigma manufacturing concept description
- Optical design must take into account supply chain based implementation issues
- Defining QC processes and tools – part of optical design for high volume products
- Involve the personnel associated with these tasks as consultants and reviewers for optical design
- Implementing at high volumes –some steps include: important to have at least one alternate design available, build prototypes, simplify design to maximum extent by using electronic and software compensation, design experiments to test the system with simpler hardware, define metrology tools from component to module to system, conduct design reviews with product teams and manufacturing teams, determine and negotiate on new sets of specs, visit suppliers, discuss specs, discover gaps and tools to bridge gaps,…this is a never ending process
- To summarize: (1) successful optical design is hinged upon active participation of optical engineers in overall product design effort (2) higher focus on discovering over meeting any arbitrary specifications

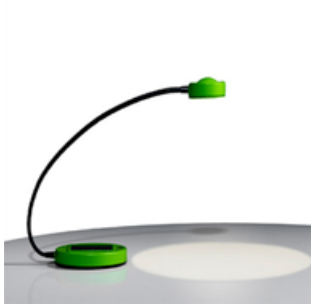
Google

Optical Design for Consumer Optics

Anurag Gupta

08/19/2014
SPIE Annual Meeting 2014
San Diego, CA

Consumer Products using Optics



Integrated Consumer Products with Optics

Complex integration of optics, ID, electronics and software

Optical Engineering

Optical Engineering as a discipline :

- Considerable shortage of optical engineers in the industry. This also include the unrecognized need for optical engineers on a program.
- Limited understanding of basic Optics in an industrial setting by those without formal training in Optics.
- Unique manufacturing processes with trade secrets and a fragmented vendor base => Long lead times for prototyping and manufacturing.

Need for relatively high awareness and participation in the overall effort by optical engineer(s).

The Social Side of Optical Design

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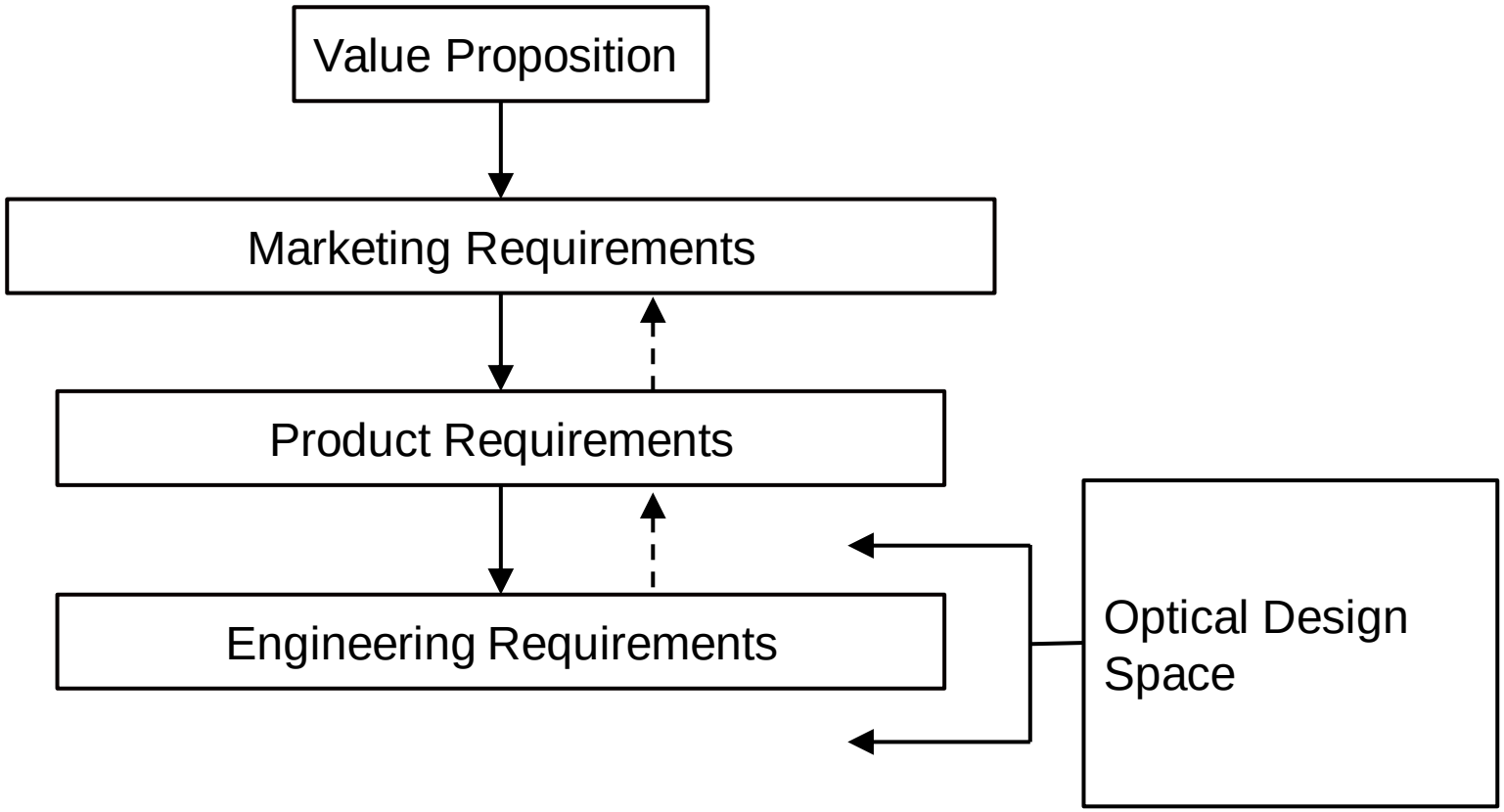
Educating or actively sharing information with coworkers

Building trust with other teams including suppliers

Developing effective negotiation skills to foster discussions on engineering trade offs.

Standard Procedure for a Consumer Product Design



Questions to be answered:
What is the role of optics?
What are the **minimum** enabling requirements for optics?

HMDs - Differentiated Value Proposition creating a large product space

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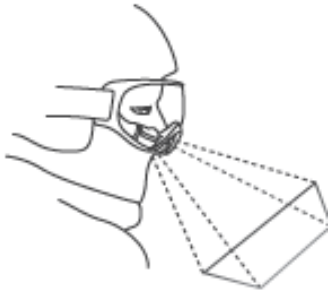
Smart Glass

Defense

Entertainment

Future Differentiators - Medical, Education, Sports, Training



HMD: Value based Product Requirements

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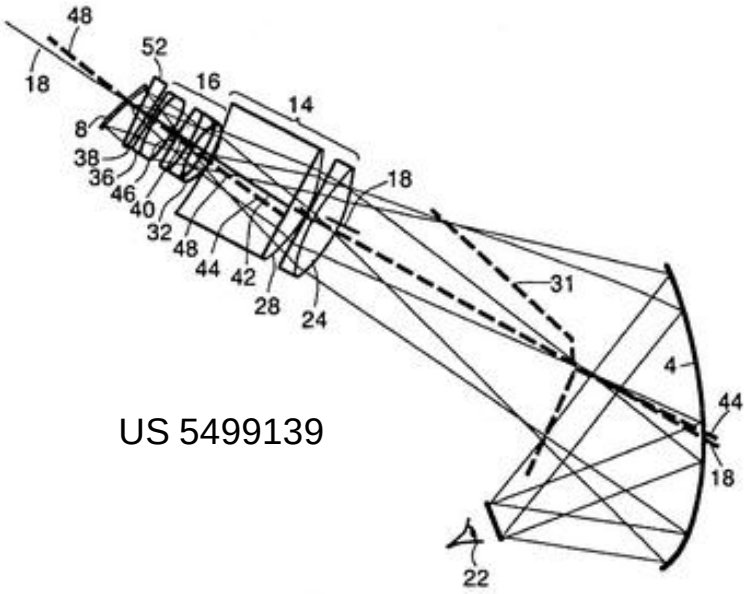
Importance	Military	Entertainment	Smart Glasses
1	**Comfort:** Nose Weight / head fit / ergonomics	**Comfort:** Nose Weight / head fit / ergonomics	**Style** leading up to technology disappearance eventually
2	**Optical Performance** - Eyebox and Eye Relief (1), FOV (2), Resolution (3)	**Functionality:** Sensors suite, Content, Apps	**Comfort:** Nose Weight / head fit / ergonomics
3	**Functionality:** Sensors suite, Content, Apps	**Price**	**Price**
4	**Price**	**Optical Performance** - Eyebox (1), FOV (2), Resolution (3)	**Functionality:** Sensors suite, Content, Apps
4	X	X	**Optical Performance** – wide variety of choices

Application Specific Optical Design (ASOD)



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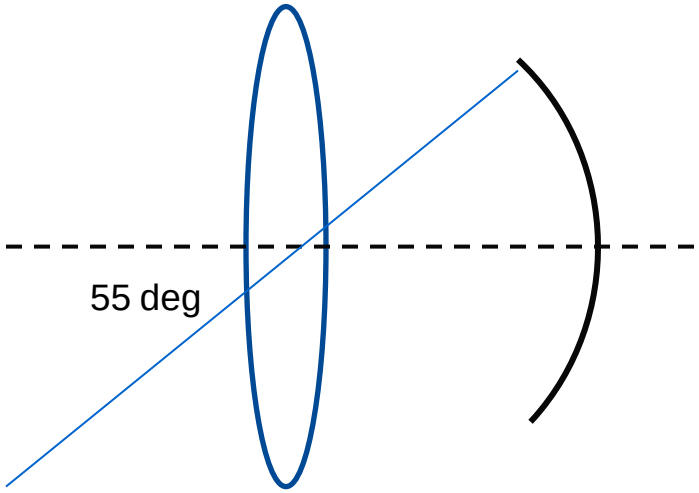


Complex optical train but enables high resolution wide angle display

Feasible implementation with proper planning

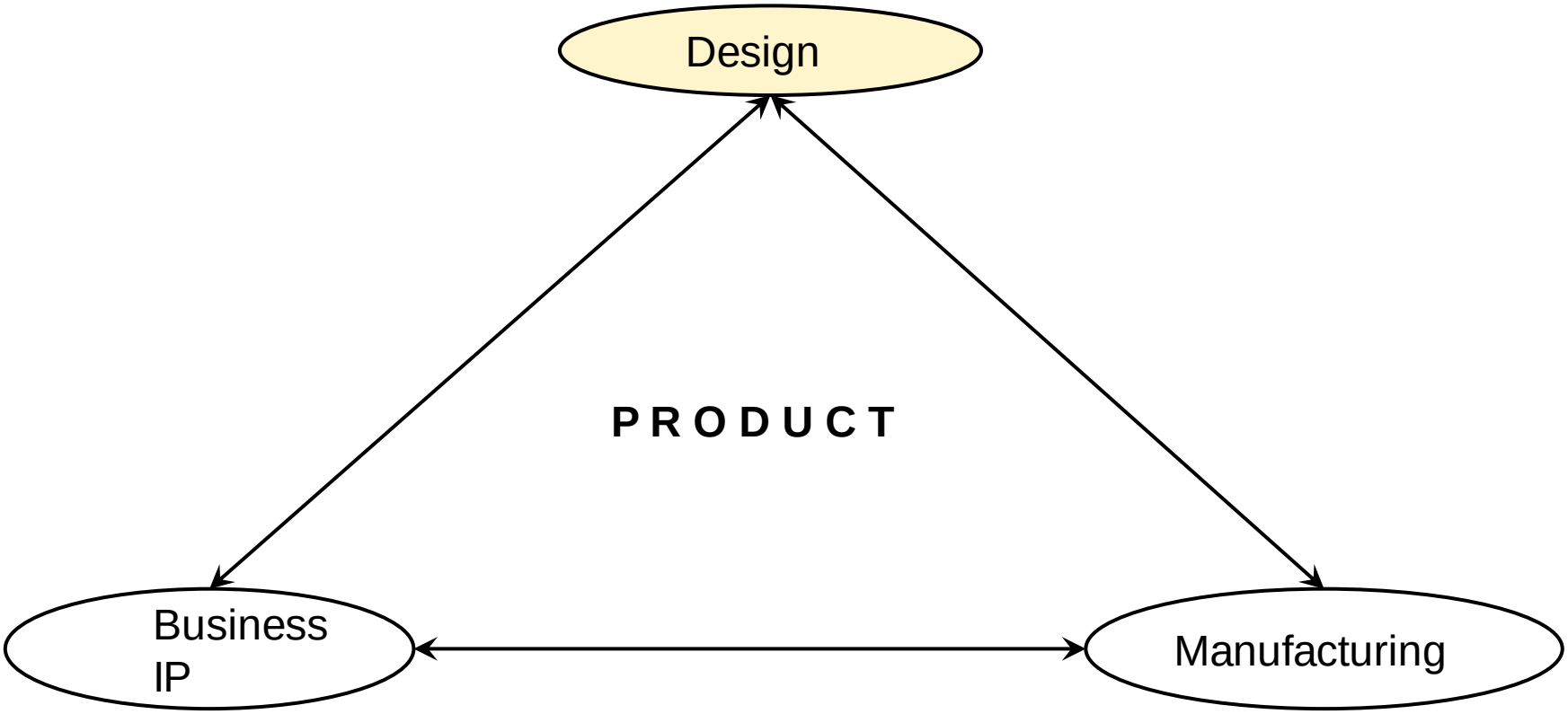
Software compensation of color and distortion.

Eye adaptability addresses the field curvature

High resolution only at the center of the FOV

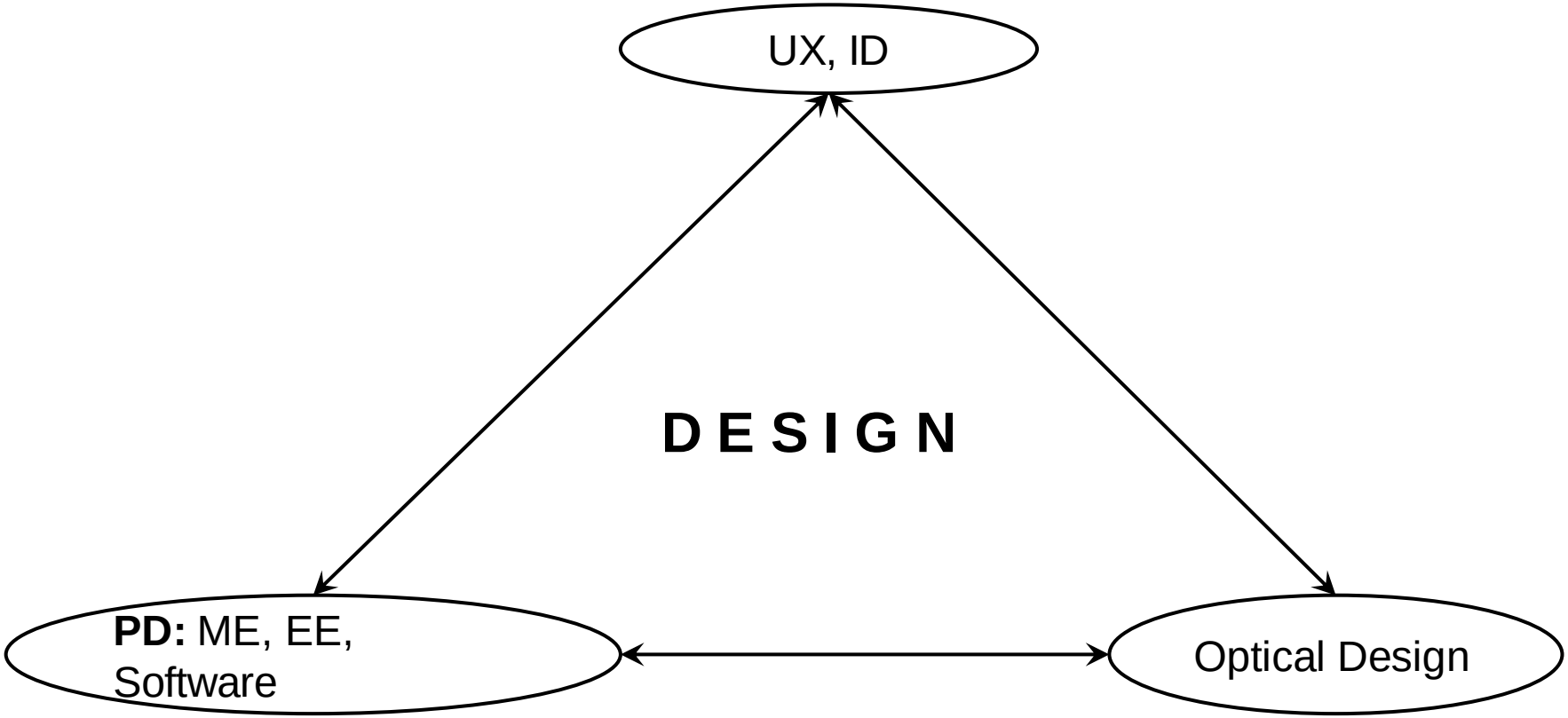
Result: Immersive Experience with easy implementation – Oculus VR

Product Centric Systems Engineering Approach



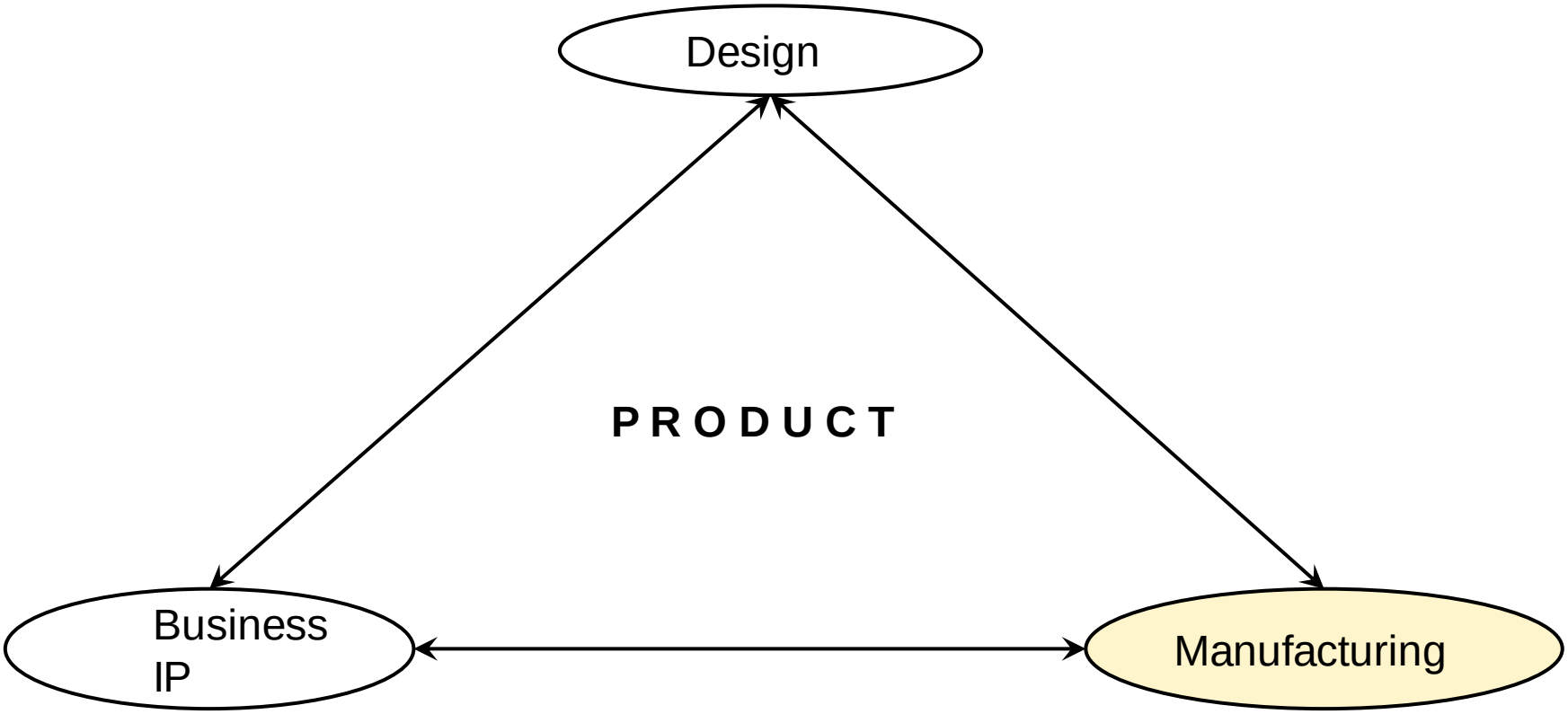
Plan for multiple options - backups and parallel paths if affordable

Optical design in overall design perspective

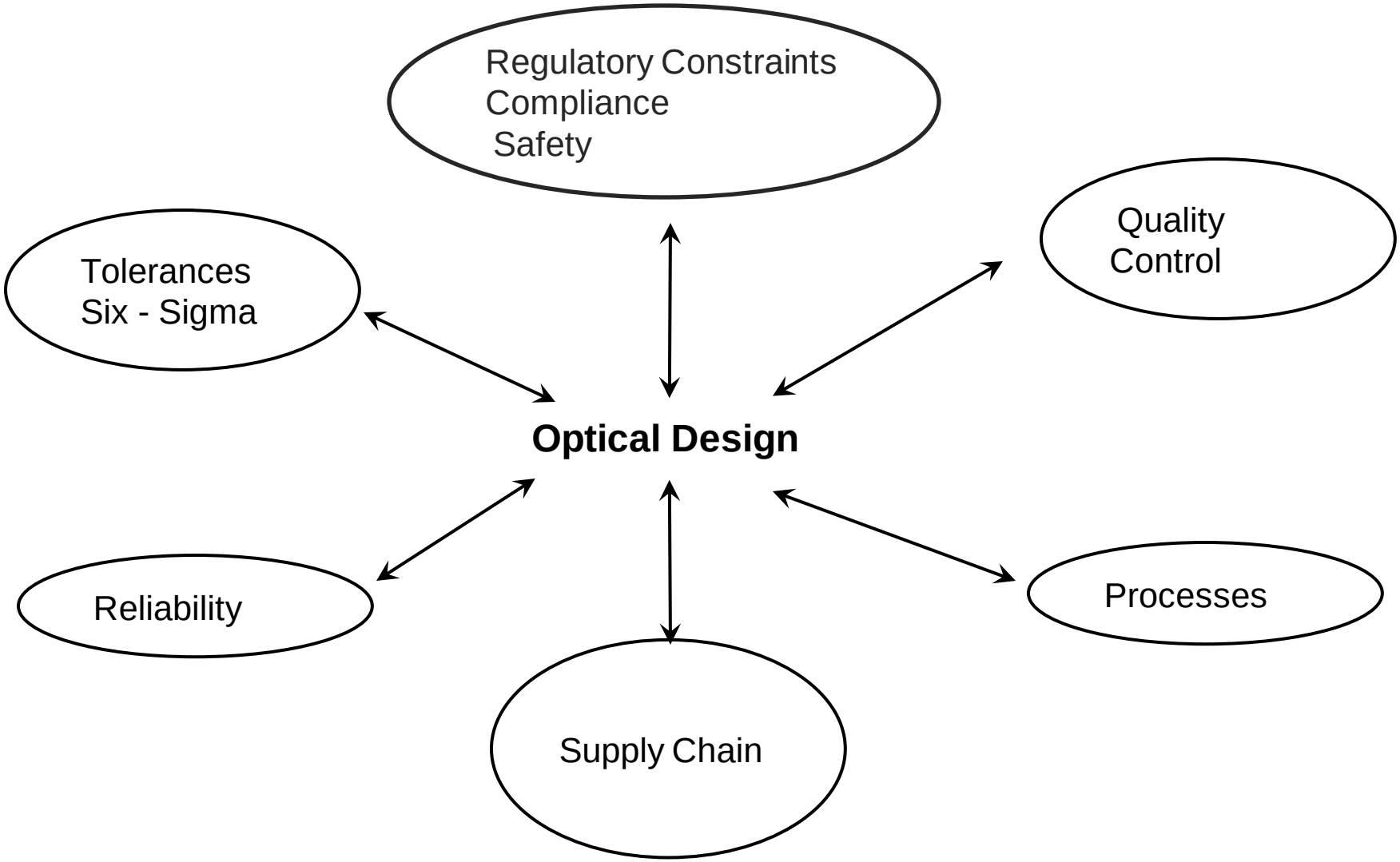


Discover the correct problem to solve

Product Centric Systems Engineering Approach



The Web of Manufacturing



Design for manufacturability

Tolerances

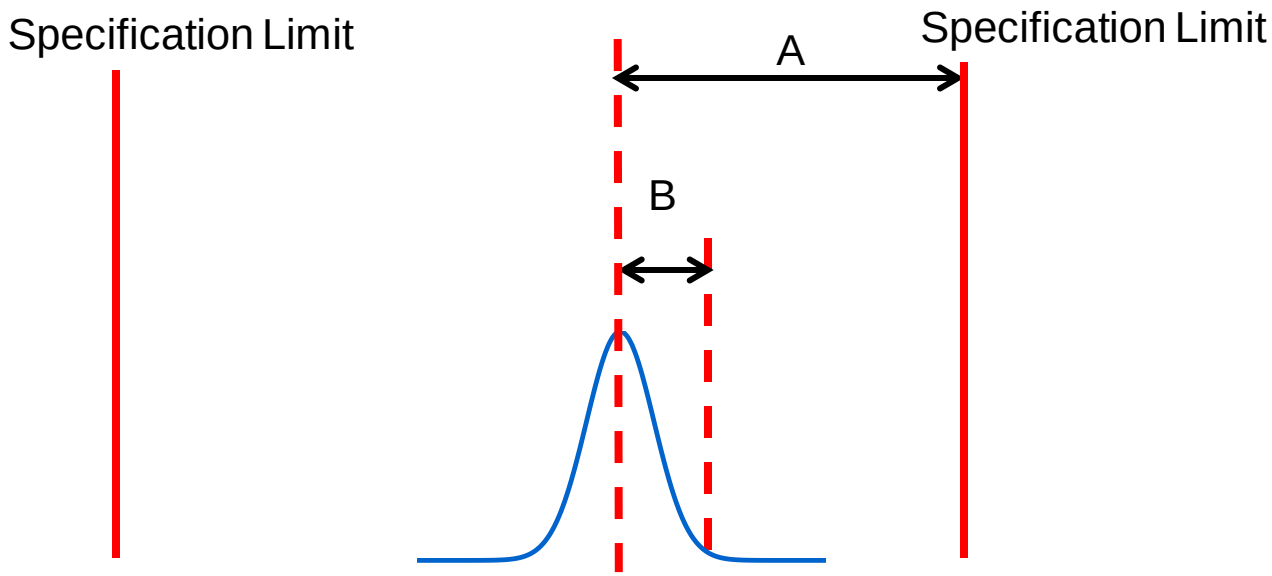
Unique for each supplier.

Engineers must spend considerable time with the suppliers studying their capability.

Tolerance have to be negotiated with the suppliers in terms of 6-Sigma manufacturing terms such as Cpk (process capability) instead of just the specification limits on variables.

6σ manufacturing concept

Assumes normal distribution in statistical variation



A = minimum deviation from specification mean
B = 3σ deviation from the specification mean

Process Capability, Cpk = A/B

Cpk ≤1 (Poor)
Cpk ≥ 1.33 (Acceptable)
Cpk ≥ 1.5 (Good, standard)
Cpk ≥ 2 (Excellent or 6σ => Less than 3.4 defects per million opportunities)

6σ Manufacturing and Optics

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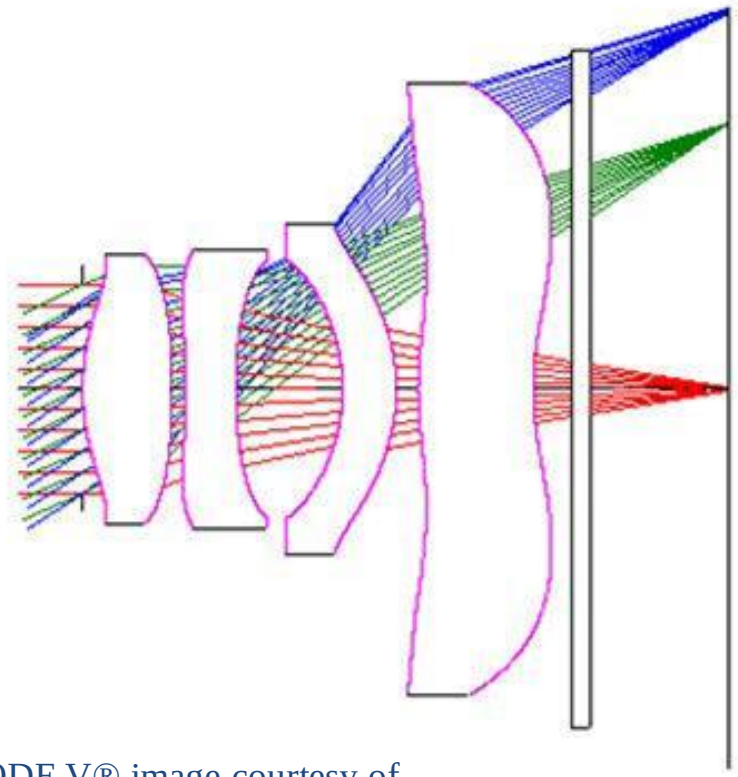
For Optics to be amenable to six sigma manufacturing principles.

a) Process control via clear definition of goals, metrology and manufacturing tools / processes.

a) Increased tolerance => Robust Design. Differentiate early between must-have and nice-to-have.

Mobile Camera Lenses: Tight tolerances and low yield



CODE V® image courtesy of Synopsys, Inc.

Specs today : < F/2.0, FOV > 70 deg,
Pixel size: 1.5 um - 2 um

Decenter Tolerance: 1 - 2 um

Lens Yield: 70 - 97%

Camera module yield: 40-80%

Final optical test to enforce 6σ module level certification

Supply Chain Constraints

Google

Complexity caused by multiple geographic locations involved in processing the same part sequentially - liability, insurance, yield

Cultural and language barriers

Shipping - time, customs, packaging

Capacity constraints

Single source risk

Optical Design must take into account supply chain based implementation issues.

Quality Control

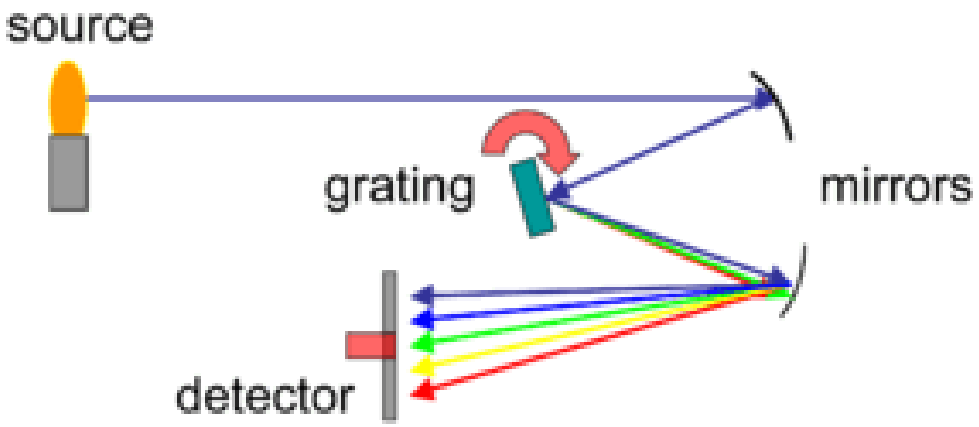
(I)ncoming QC, (O)utgoingQC, (I)n (P)rocess QC

Metrology Tools

(S)tatistical (P)rocess (C)ontrol – identify dominant causes of variation, eliminate assignable cause, monitor for shifts over time.

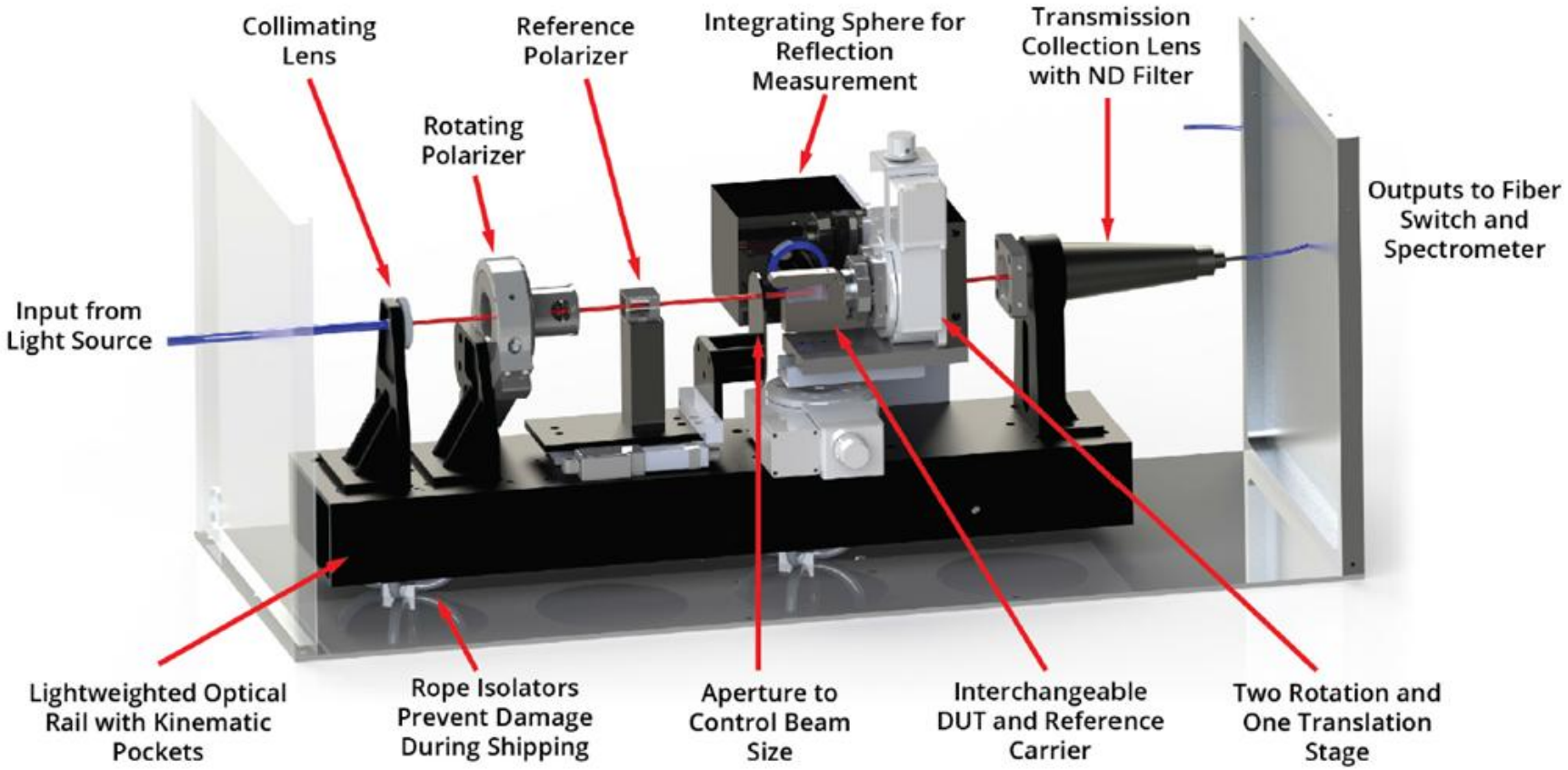
Defining QC processes and tools - part of optical design for high volume products

Compact spectrometers for modular metrology



Less performance than large traditional spectrometer instruments but more flexible.

Custom Automated Multi-axis Spectrometer System



Courtesy: Evan Richards

Reliability, Safety and Regulatory Considerations

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RoHS compliance of materials

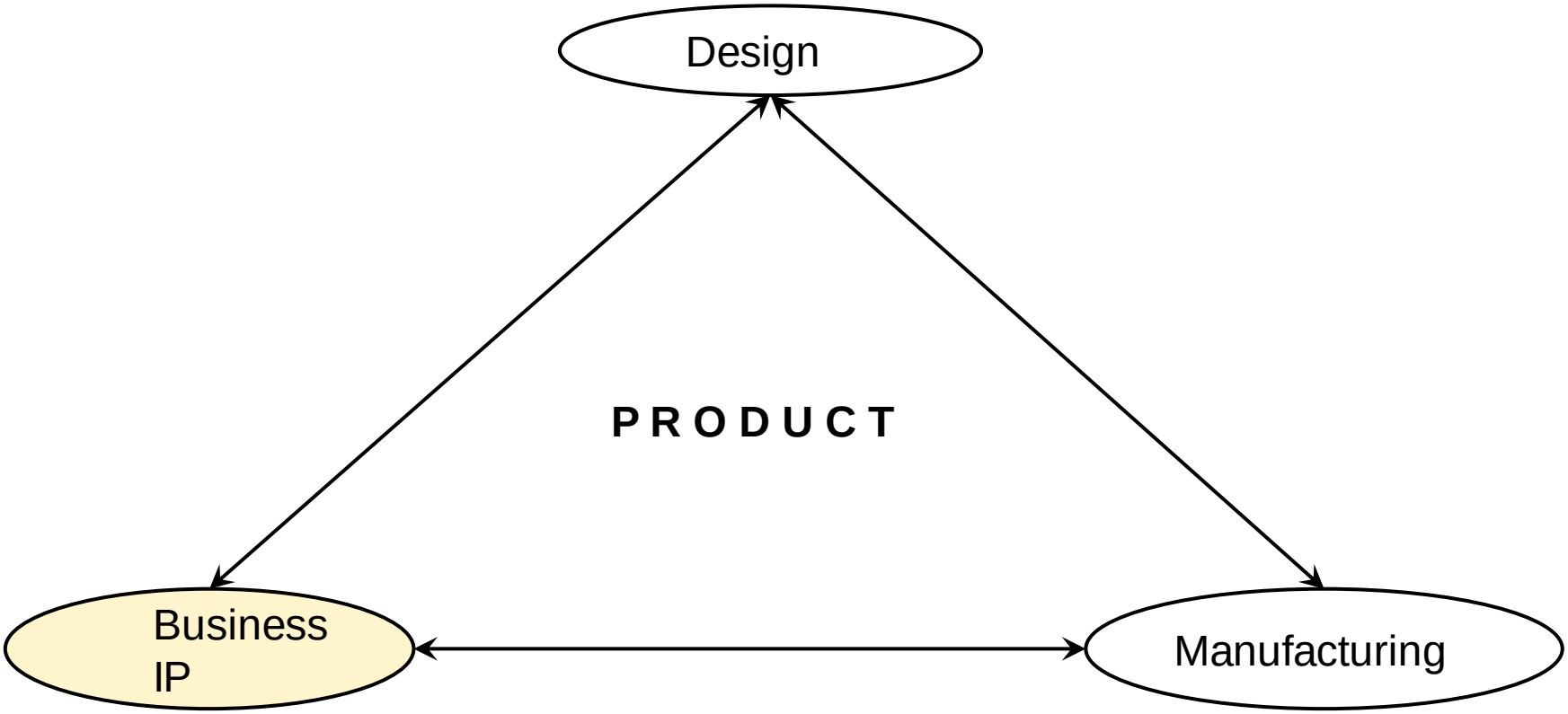
FCC compliance of communication systems

Radiation safety standards for LEDs and Lasers

(F)ailure (M)ode and (E)ffects (A)nalysis exercise for reliable design. Identify the failure mechanisms, their probability, severity of effect and methods for reproducing them.

Involve the personnel associated with these tasks as consultants and reviewers for optical design.

Product Centric Systems Engineering Approach



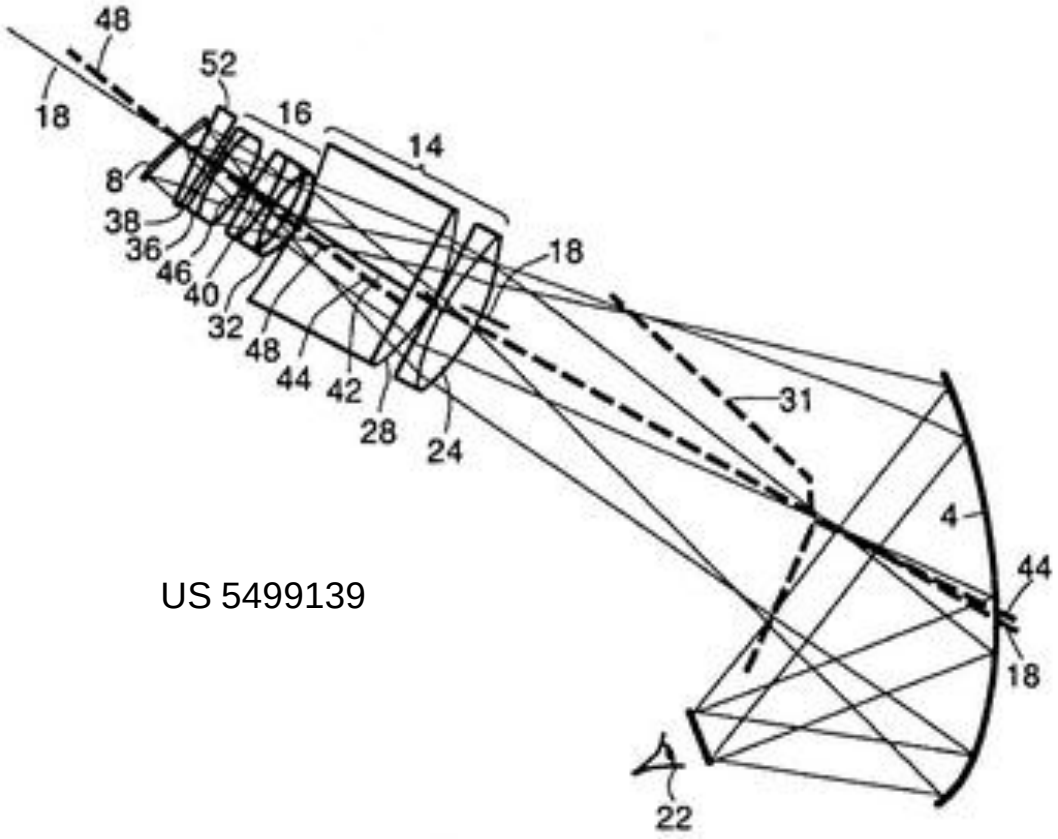
Licenses and Business Development

IP

Contract

Relationships

How to implement at high volume something like this?



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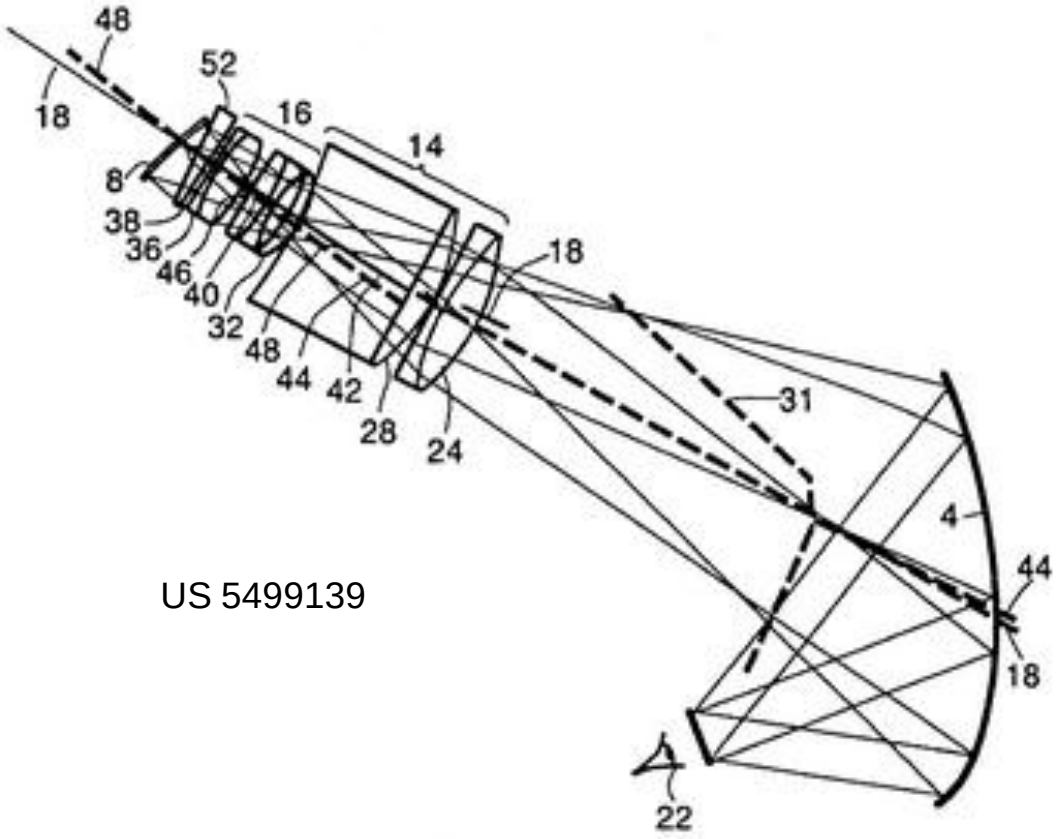
How to implement at high volume something like this?

Have at least one alternate design available that achieves similar goals under similar constraints.



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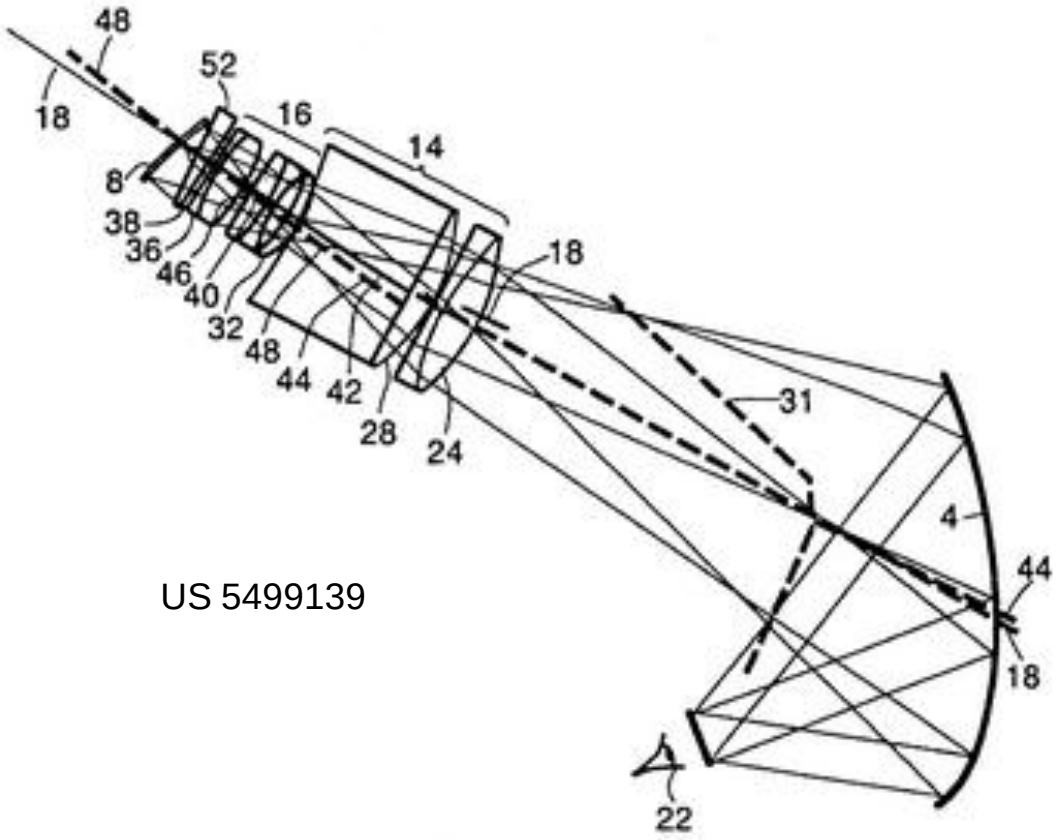
How to implement at high volume something like this?

Alert IP and Business Teams.



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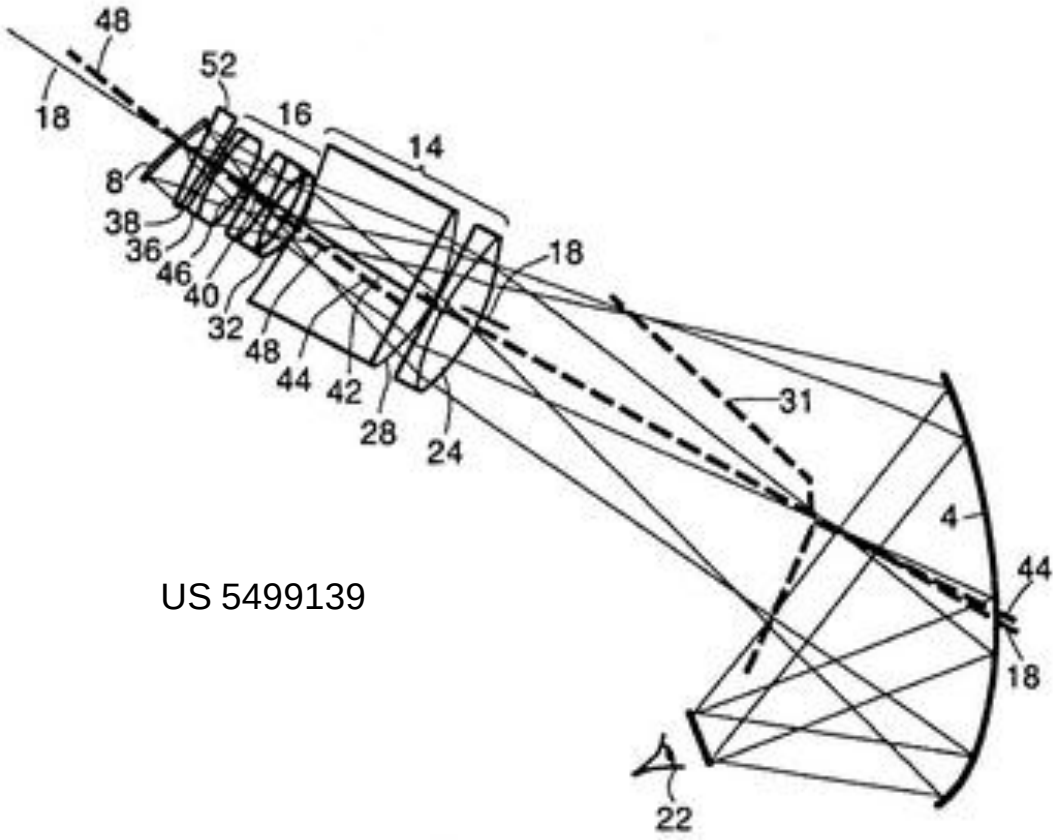

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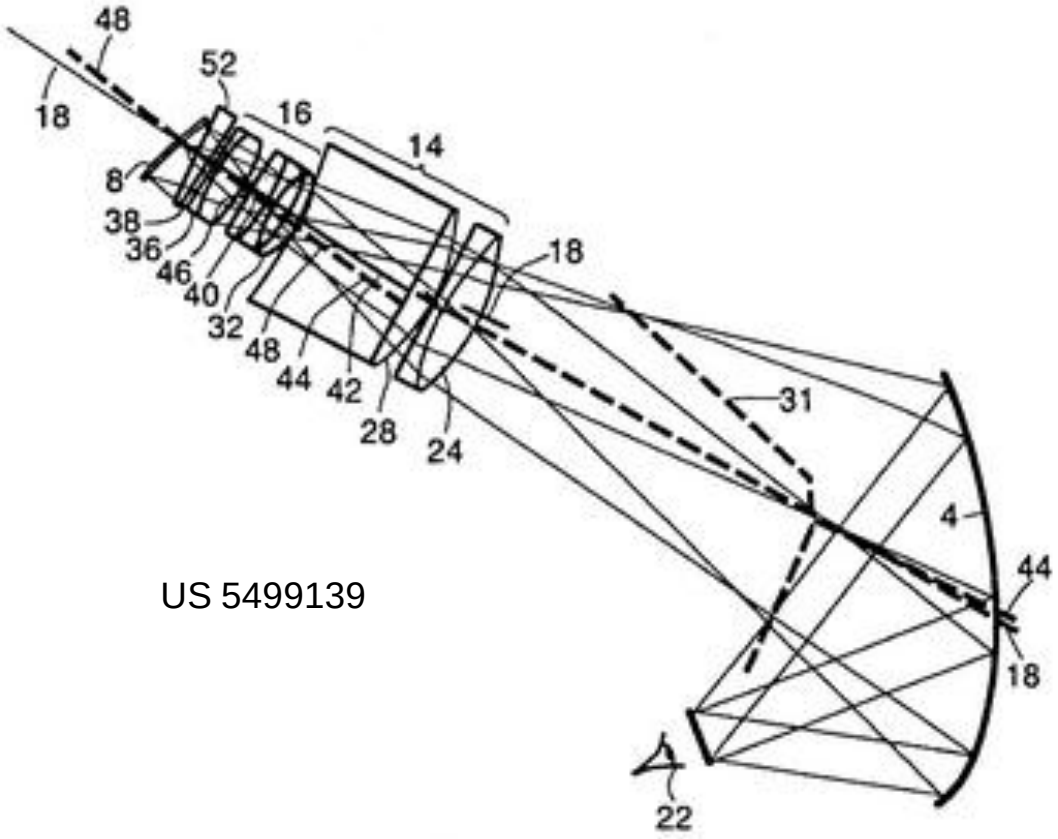
A design is likely to change dramatically when subjected to well defined goals of product requirement with constraints on size, weight and appearance from Industrial design and User experience.

Get ready for large scale changes.

How to implement at high volume something like this?



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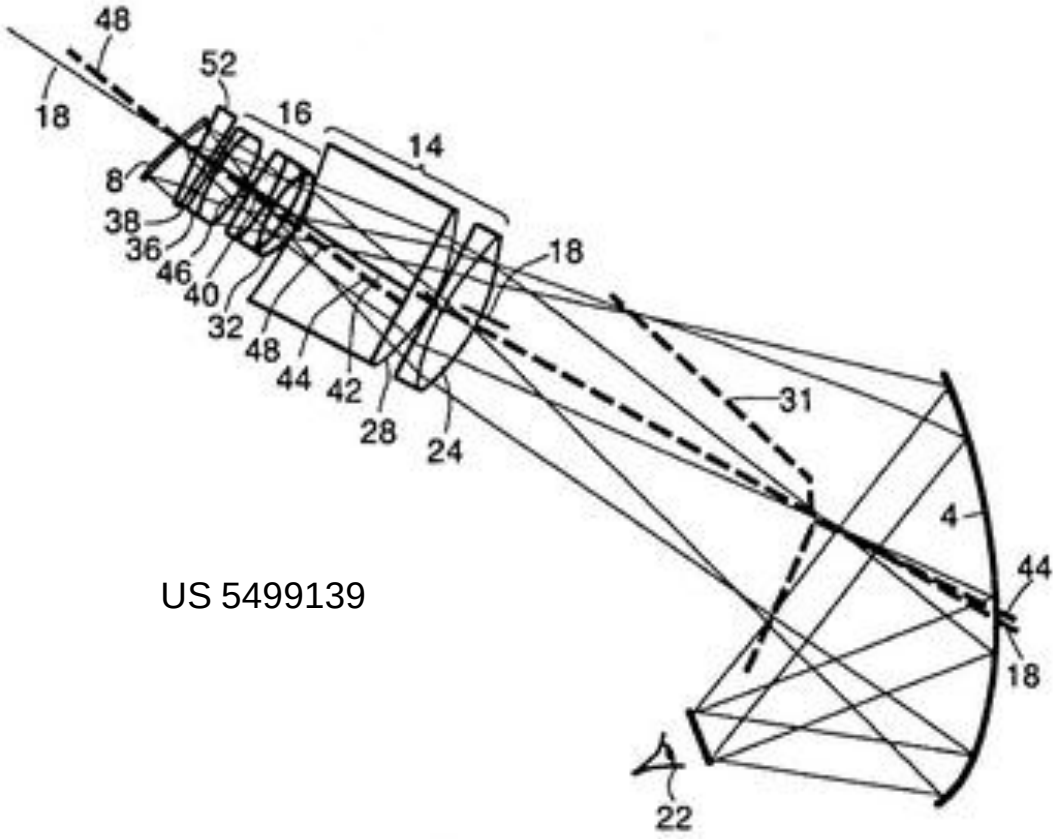
Build prototypes – not necessarily this design - to check the validity of goals that address the value proposition.

Build 10s or 100s of test devices and distribute among the team with suggested use cases.

What are the minimum enabling requirements?

Change the design and the specs as per the discovery process.

How to implement at high volume something like this?



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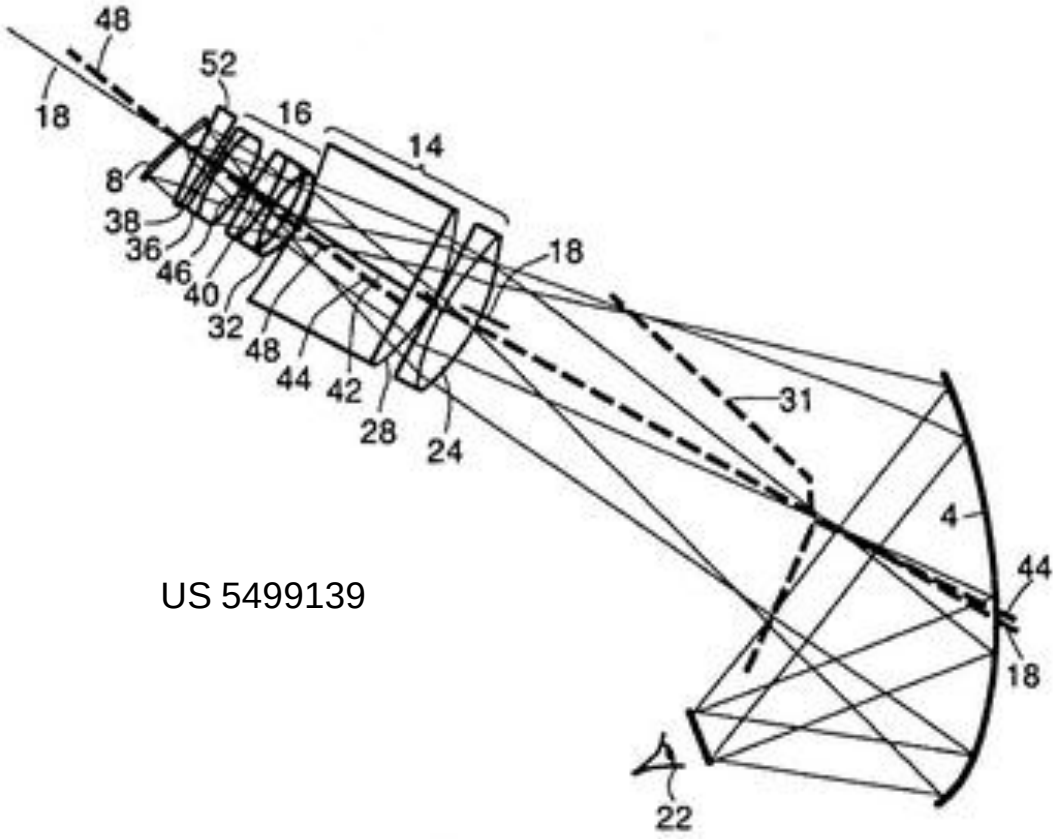
Simplify design to the maximum extent by using electronic and software compensation.

Design experiments to test the system with simpler hardware.

Build and handout large number of prototypes.

How to implement at high volume something like this?



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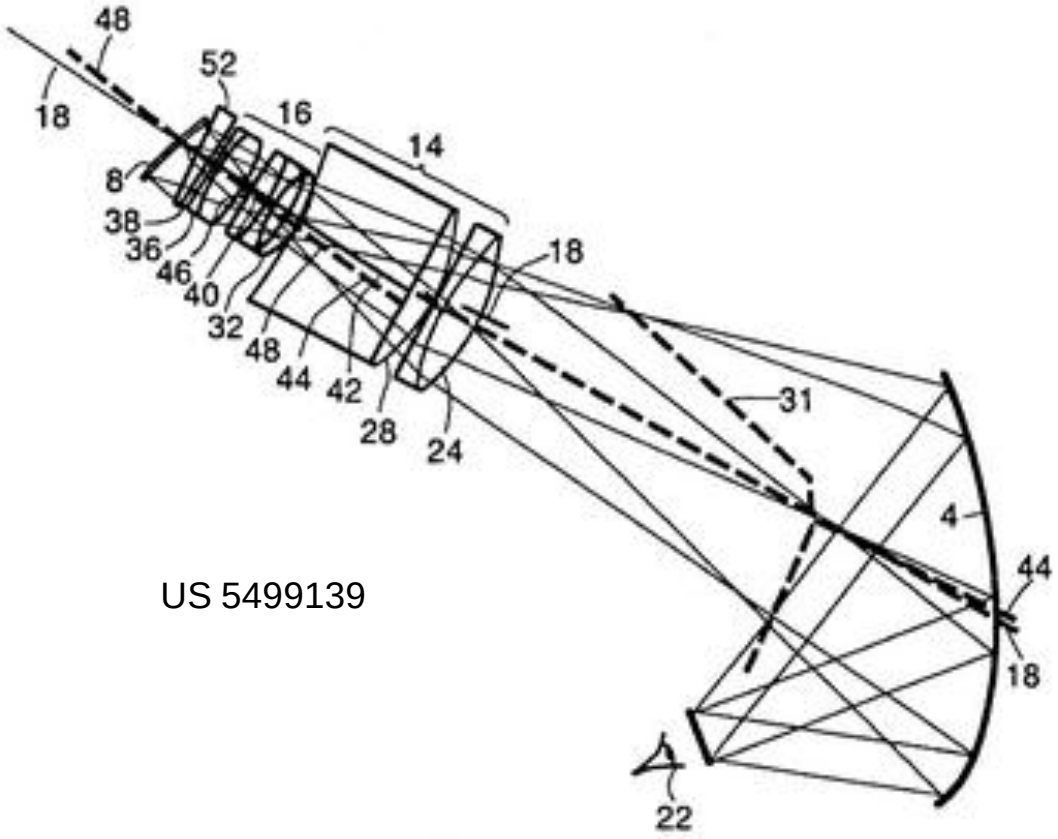
Define metrology tools from component to module to system.

Can the specs and tolerances defined be tested? If not, procure or design and build the tools.

How to implement at high volume something like this?



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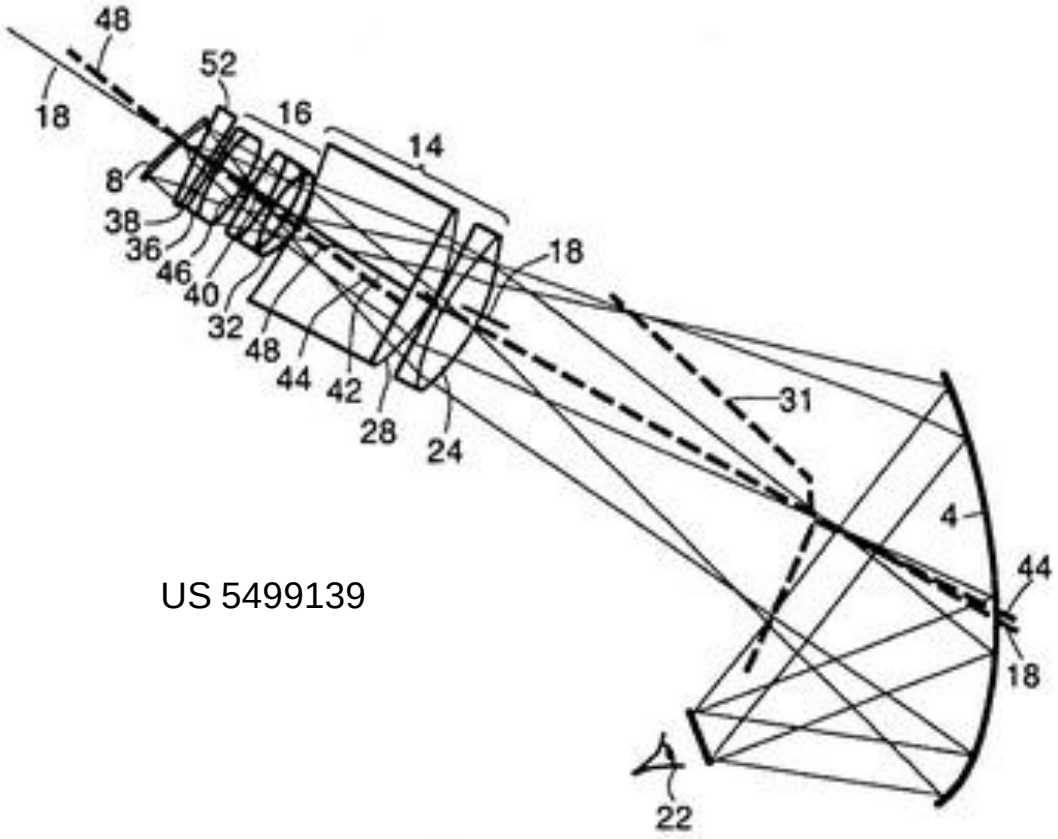
Design optics for mechanics that does not require active alignment, allows for modular integration of optics where each module can be subjected to SPC.

Involve QC team to work through this process.

Define and procure relevant metrology tools.

How to implement at high volume something like this?



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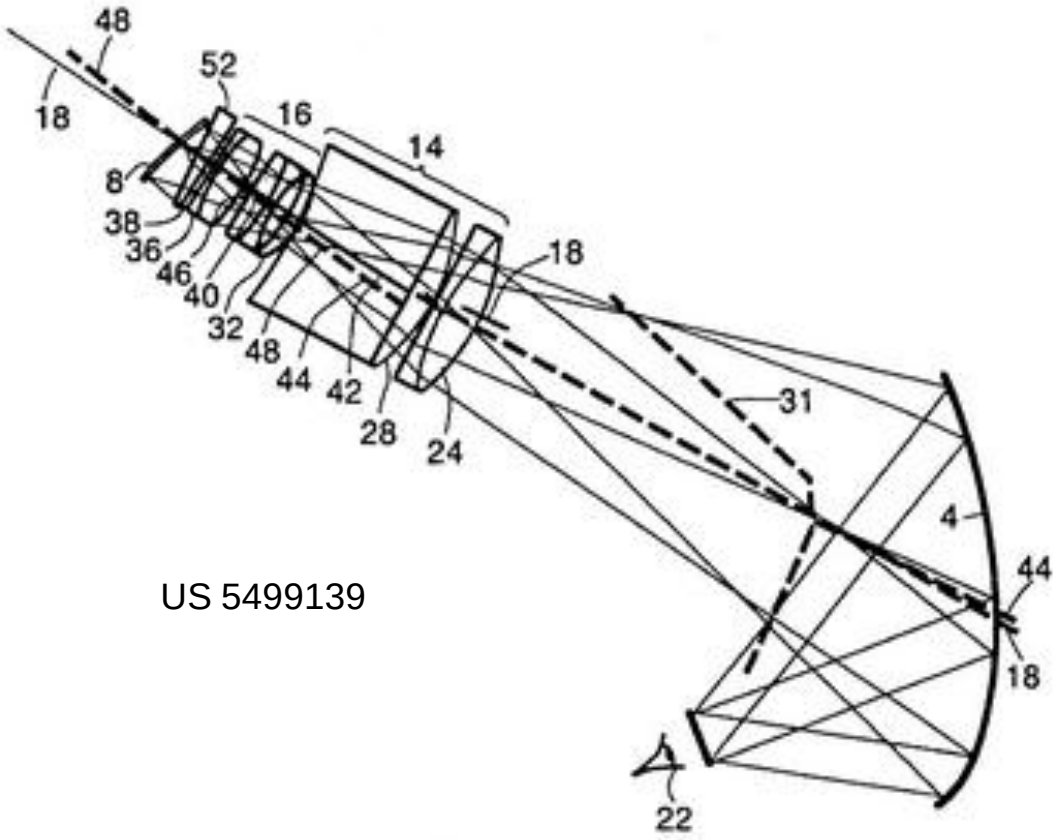
Conduct design reviews with product teams and manufacturing teams with information relevant to their goals and constraints.

Determine and negotiate on the new set of specs and implement design changes.

How to implement at high volume something like this?



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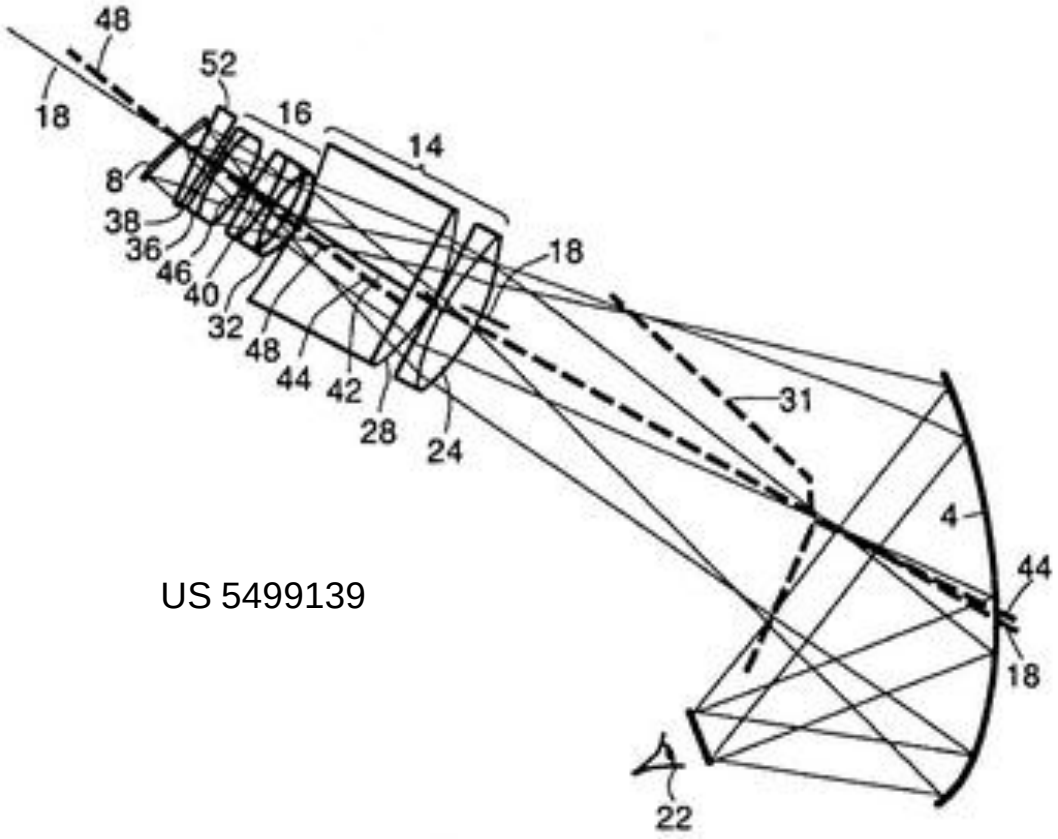
Visit suppliers, study the processes and run experiments to validate the assumptions.

Discuss the specs, tolerances, metrology, throughput, yield, work flow, supply chain complexity and cost.

Discover gaps and tools to bridge those gaps.

How to implement at high volume something like this?

Involve the reliability team and run the FMEA exercise to discover potential pitfalls.



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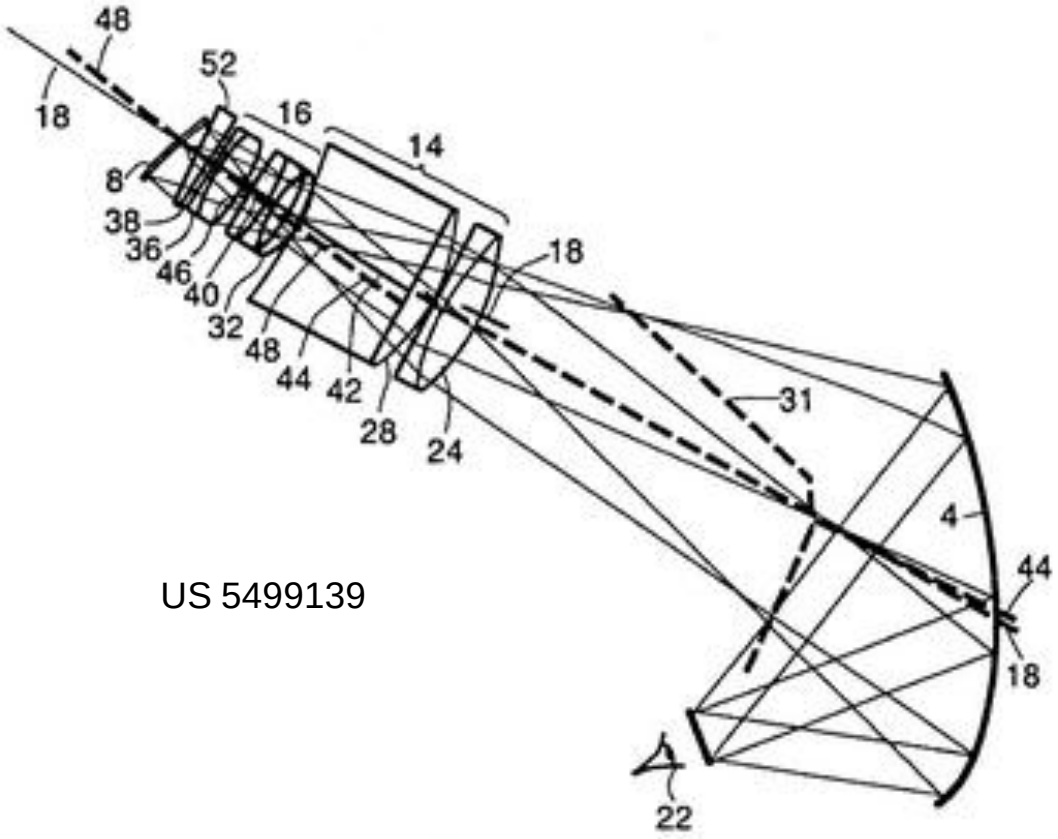

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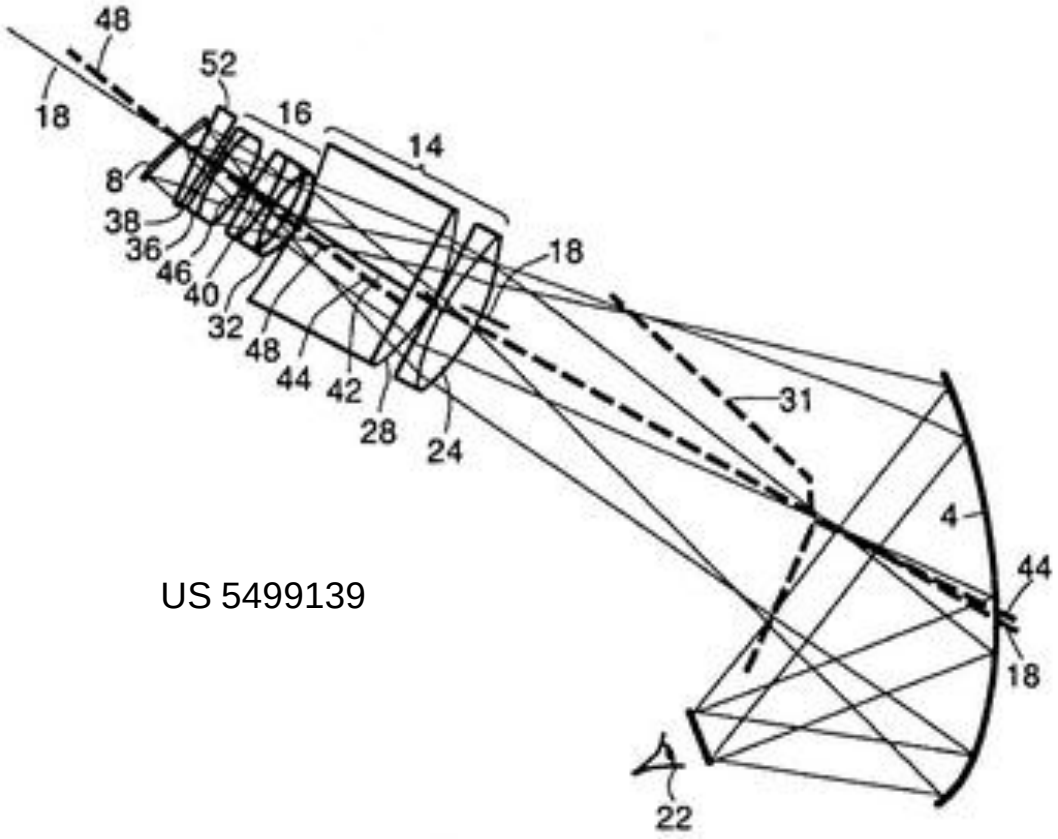
Revisit the designs and rerun the entire exercise from the beginning.

This IS a never ending process.

How to implement at high volume something like this?

Somewhere in the process, you will find there is a factory running and your product shipping.



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Summary

- Successful optical design is hinged upon active participation of optical engineer(s) in the overall product design effort.

- Higher focus on discovering over meeting any arbitrary specifications.