# System Level Technical Analysis for EO Sensors

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# Audience Warmup

This Q&A happens at the title slide, and is NOT projected

- Raise your hands if you have a smart phone with a camera with you
- How many of you have seen images from the Hubble Space Telescope or Google Earth?
- How many of you are already EO systems engineers?

- The camera module is the primary thickness constraint for smartphones
- ~80% of smartphone pictures include one or more faces

- On to “System Level Technical Analysis for EO Sensors”

# Outline

## System Level Technical Analysis for EO Sensors

- Generic electro optic systems
- Technology improvements electro optic systems
- Subsystems relationships
- Takeaways

# Generic Electro Optic Systems

# Top Level Facts

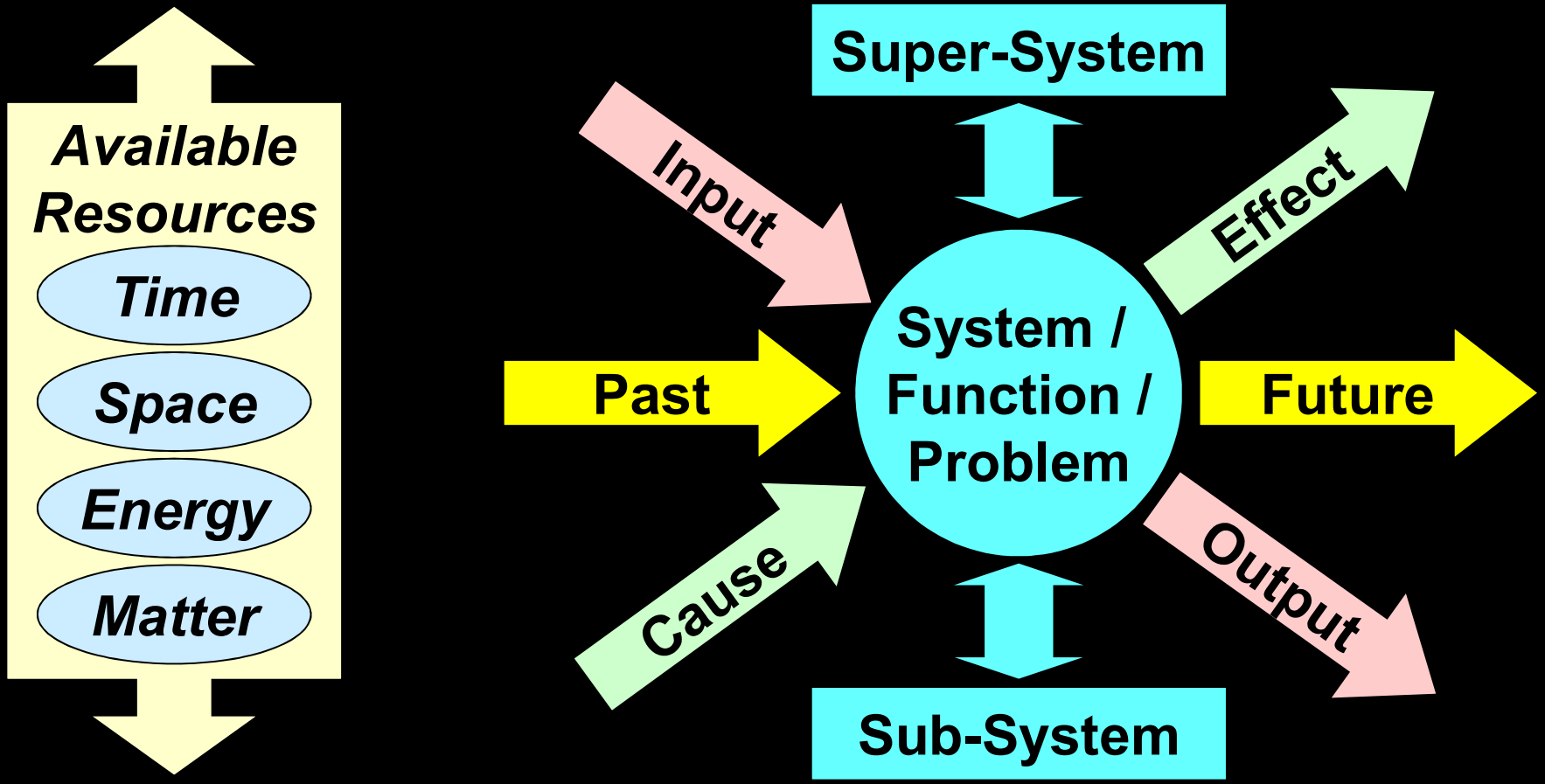
## Ingredients of EO systems have not changed

- Complexity always requires many iterations
- Everyone has systems engineering responsibilities
- Advanced technology improves cost, size, weight & power
- System is part of a super-system & contain subsystems

My Subsystem May Be Your System

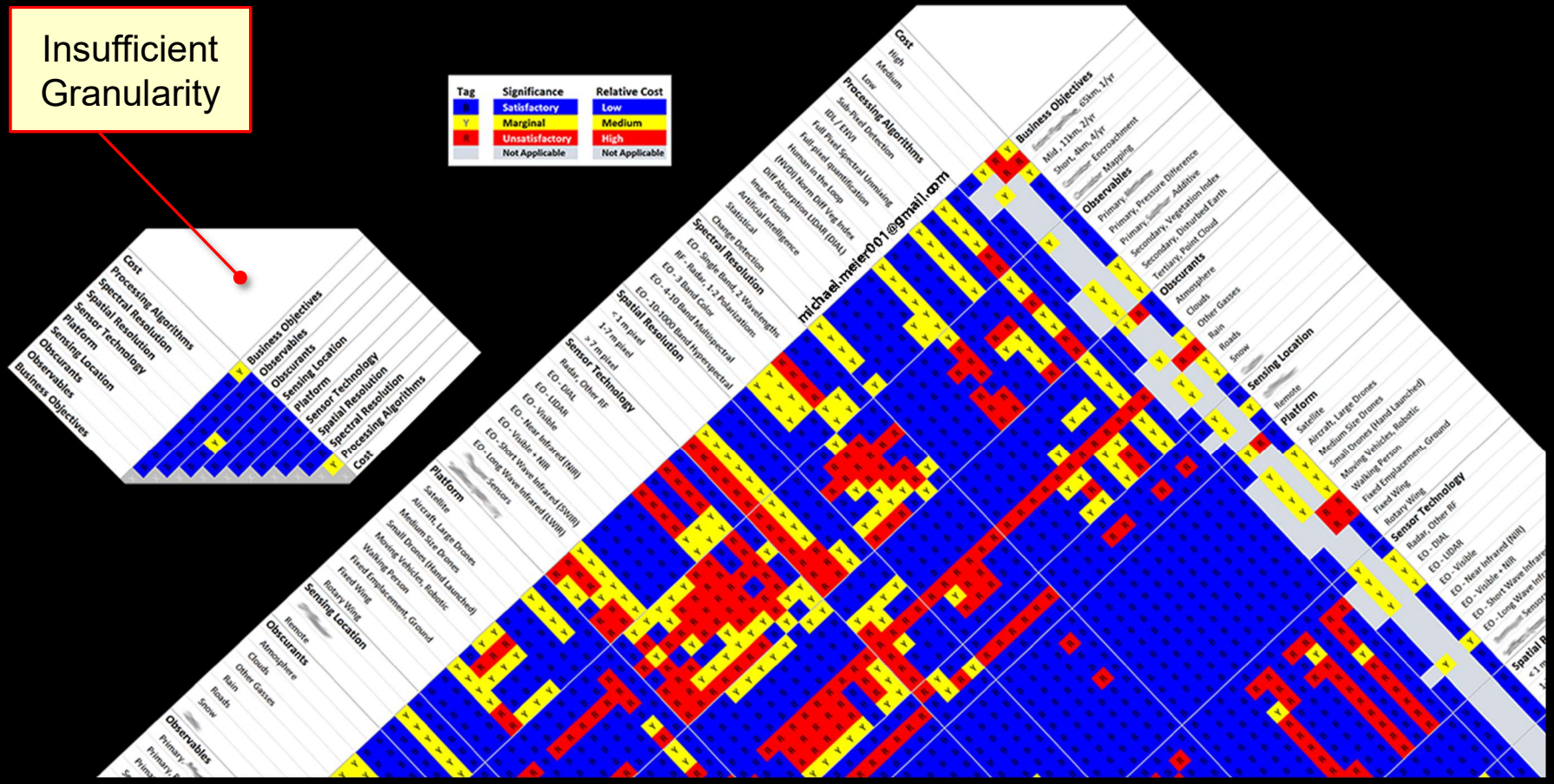
# System Relationships

System is part of a super-system & contain subsystems



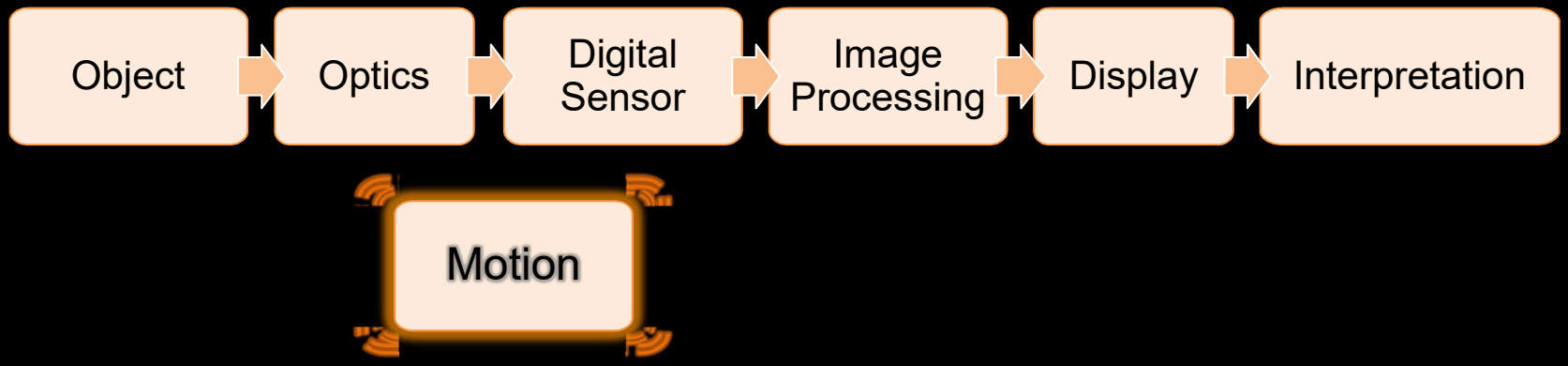
# System Relationships Example

## Technical, Business, & Regulatory Decision Matrix




Spectral EO on Airborne Platform Selected

# EO Sensing System - Simplified

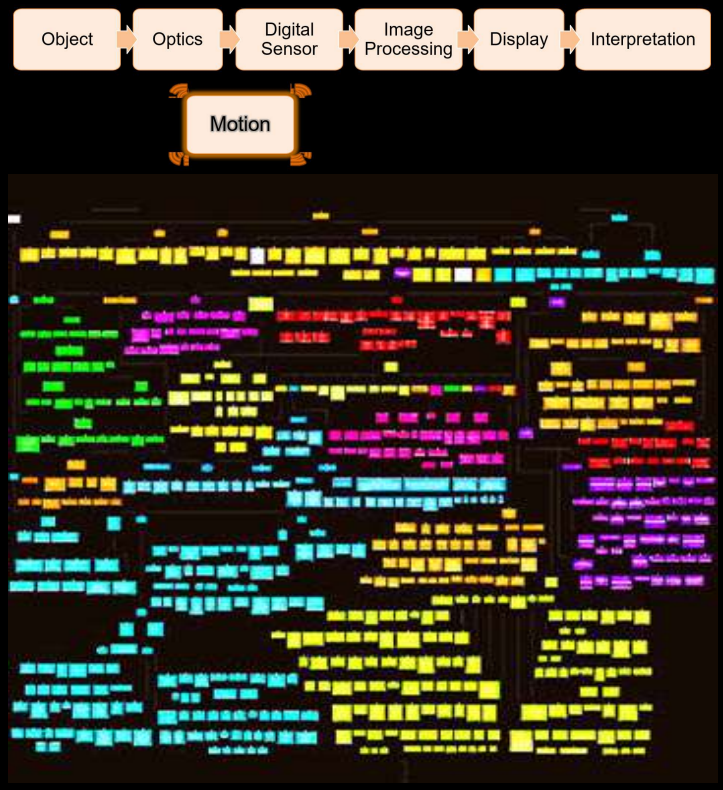



- Digital image - array of numbers to be interpreted
- Array can represent any part of electromagnetic spectrum

## Always Model the Entire Image Chain

# EO Sensing System - The Reality

- Start Simple, Functions First
- Over 600 Parameters May Affect Image Quality
- Other Factors
  - Personnel Availability
  - Shrinking Schedules
  - Constrained Cost




## System Engineering Requires A Team

# Stages of Technology Evolution

## The System Evolution "S-Curve"

**Stage 0 -** the system does not yet exist but important conditions for its emergence are developing

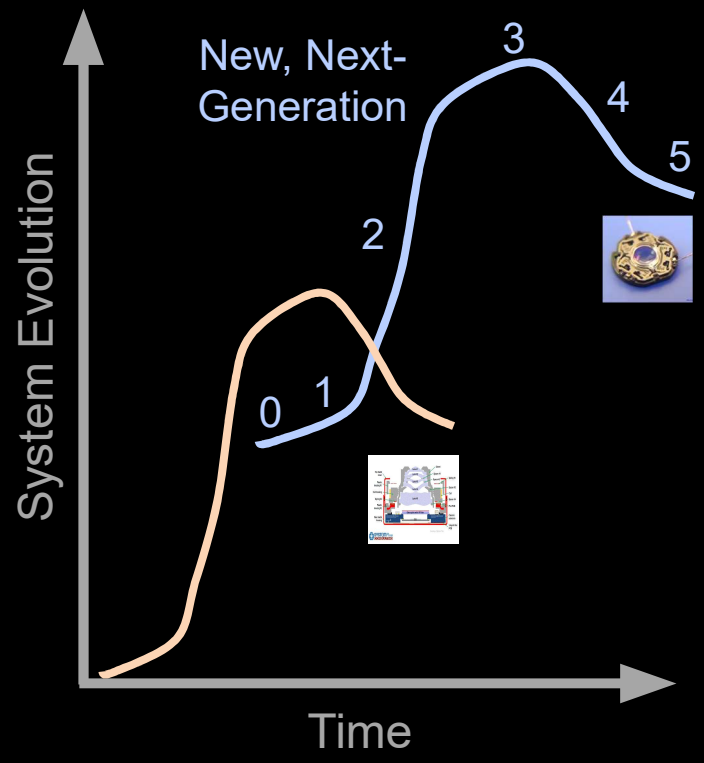
**Stage 1 -** a new system appears due to a high-level invention and begins developing slowly

**Stage 2 -** society recognizes the value of the new system

**Stage 3 -** the resources of the system's original concept are nearing exhaustion

**Stage 4 -** a new system or next-generation system emerges to replace the existing one

**Stage 5 -** the existing system has a limited area of application and thus is not completely replaced by the new system




Products, Software … Even Personal Maturity Have S-Curves

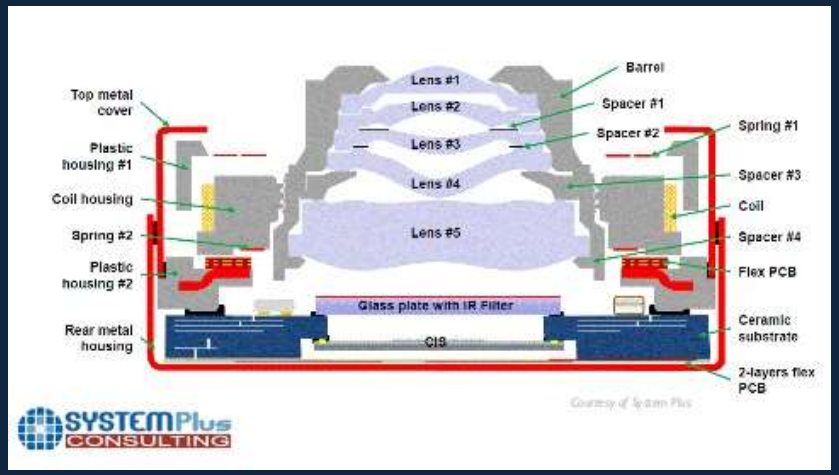
# Technology Improvements Electro Optic Systems

# Technology Evolution

## Implementing the Smartphone Focus Function

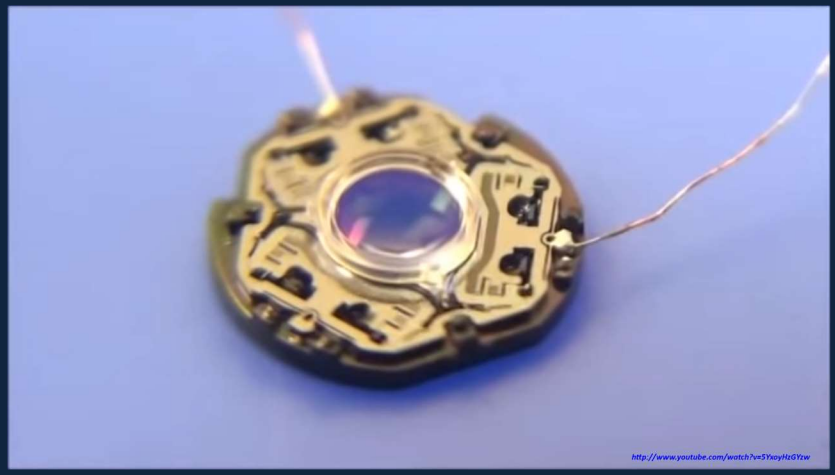
### Voice Coil Motor

- VCM Patented by Bell in 1874
- Hysteresis of Stroke about 8%
- Higher Power 100mW peak
- Worse optics Decenter & Tilt




### MEMS Focus + Pitch, Roll, Yaw

- Faster Operation – Less Mass
- Lower Power
- Lower operating temperature
- Improved Noise & Corner MTF



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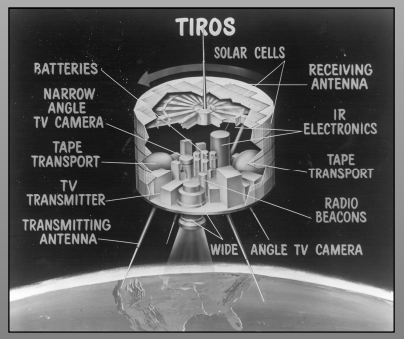
# Electro Optical Sensor Systems

## A Few Historical Technical Accomplishments

### TIROS 1

**1960**

- First weather satellite
- Television Infrared Observation Satellite
- NASA experiment
- Used Two Slow Scan Vidicons




### Sharp J-SH04

**2000**

- First Cellphone Camera
- 0.11 Mpix
- "Camera great for spying, could be held against a keyhole"

### WorldView-3

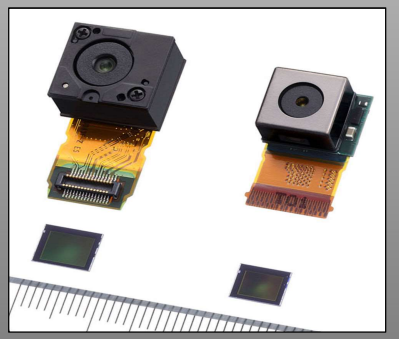
**2014**

- Commercial Remote Sensing Satellite
- Multimode Collection
- 36 Bands + Pan

### Exmor RS™ Module

**2016**

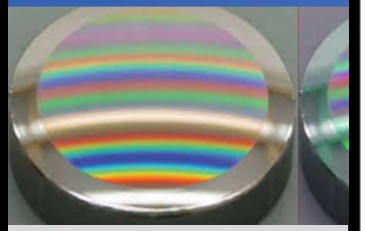
- 22 Mpix, 1µm /pix
- 1st Stacked CMOS
- 3-Axis electronic image stabilization
- Both Phase & Contrast Autofocus
- 30 FPS, 4K Video (3840 x 2160) QFHD



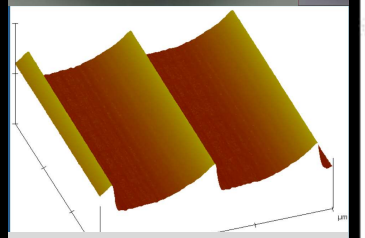
# Airborne Instrument System - Example

## Hyperspectral Thermal Emission Spectrometer (HyTES)

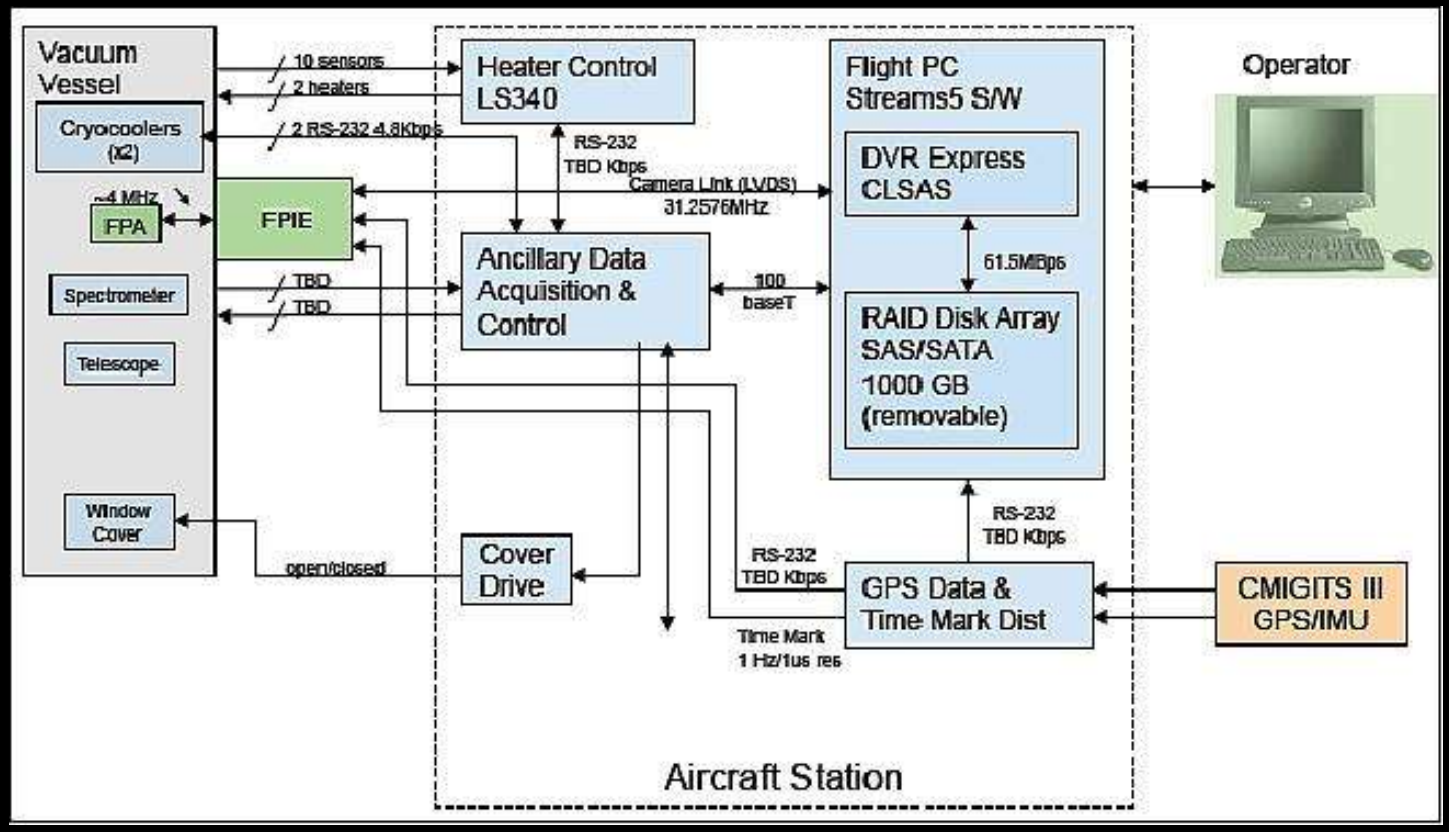
Solid Optic



Concave Grating



E-beam Profile



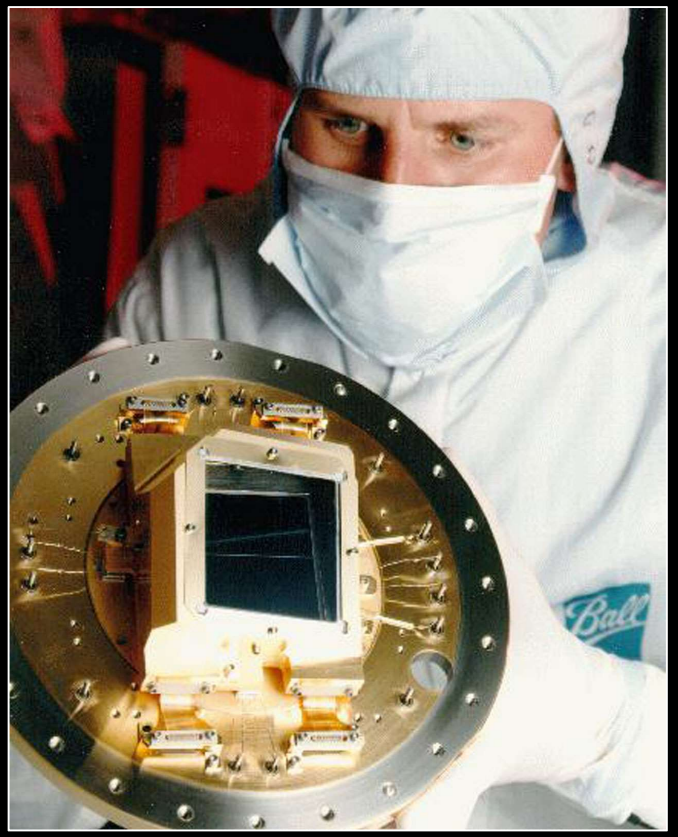

Laboratory ➡ Airborne ➡ Spaceborne

# Silicon Focal Planes

## Endoscopy vs. Hubble Advanced Camera for Surveys

**NanEye Medical Imaging**


**CCD in ACS Wide Field Channel**

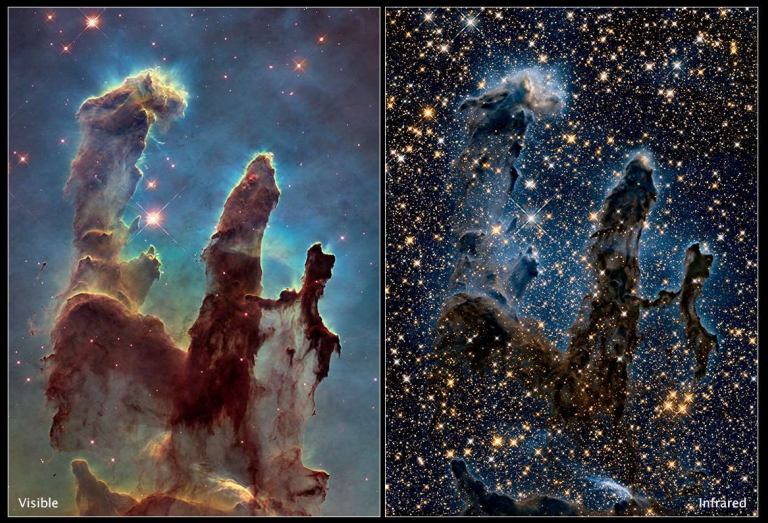


# End User Experiences

## System Solutions Uniquely Satisfy Each Customer

**World's Largest Selfie**

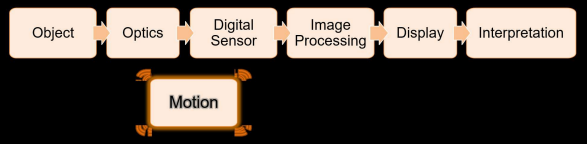

**Pillars of Creation by HST**



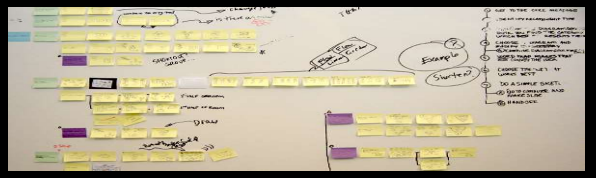
# Takeaways

## System Level Technical Analysis for EO Sensors

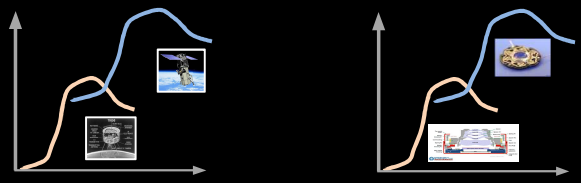
- Model the Entire Image Chain




- System Engineering is a contact sport



- Technologies Evolve



**System Engineering Requires A Team**