Characterizing Infrared (IR) Sensor for Hypervelocity Asteroid Intercept Vehicle (HAIV)

Dec14-12

Client - Dr. Bong Wie
Advisor - Dr. Meng Lu

Leader - Sean Nichols
Webmaster - Yishu Mei
Communication Master - Chi Hoe How

Purpose

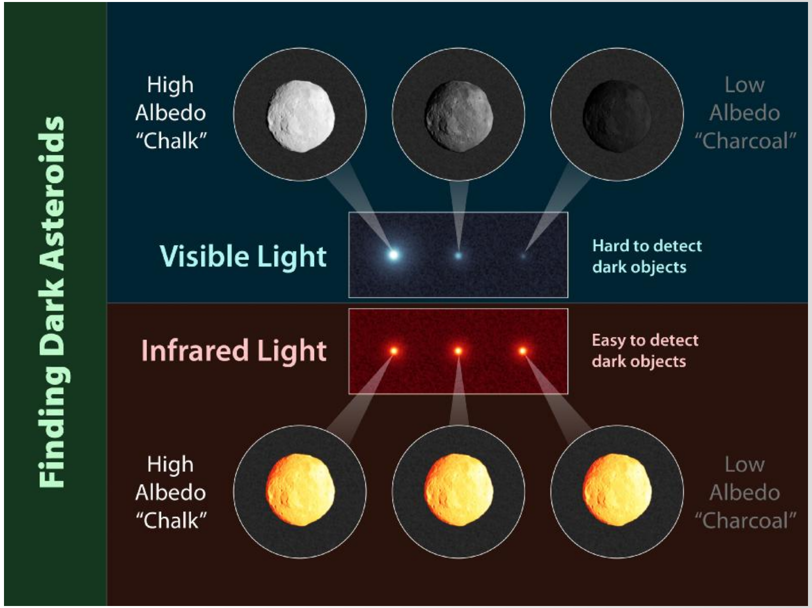
Background : Client's team has developed asteroid simulations

Problem : The feasibility of such a system was unknown

- IR technologies
- IR optics
- Distance of detection

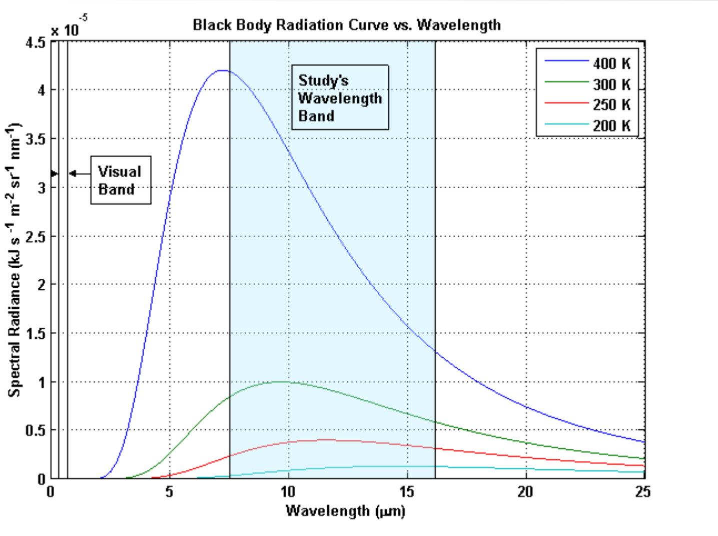
Solution : We are employed to:

- Research technologies
- Design such a system
- Perform cost analysis



Source: nasa.gov

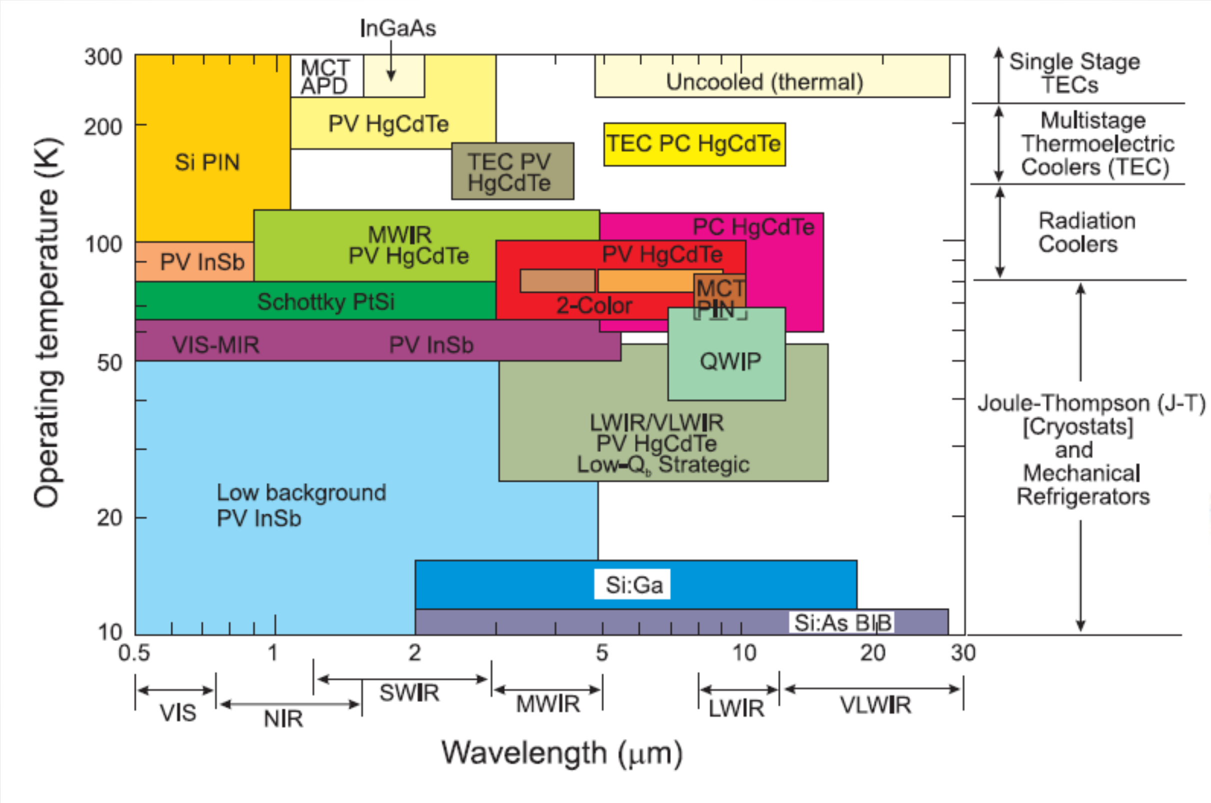
Initial Meetings



Early meetings with client

- Asteroid Parameters
  - Size (~ 50 m)
  - IR emission (~ 8 to 14 um)
- HAIV Parameters
  - Speed of approach (~10 km/s)
  - Time of detection (1 hour)
- Sensor types
  - Photon detector (cooling, high resolution, high speed, expensive)
  - Thermal detector (uncooled, lower resolution, slow speed, lower price)

Sensor Types



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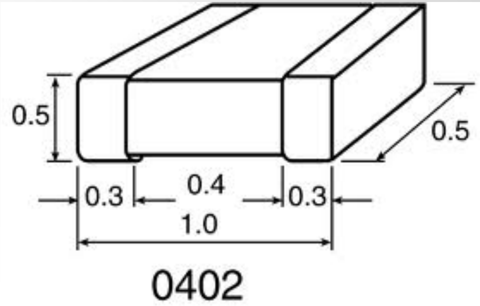
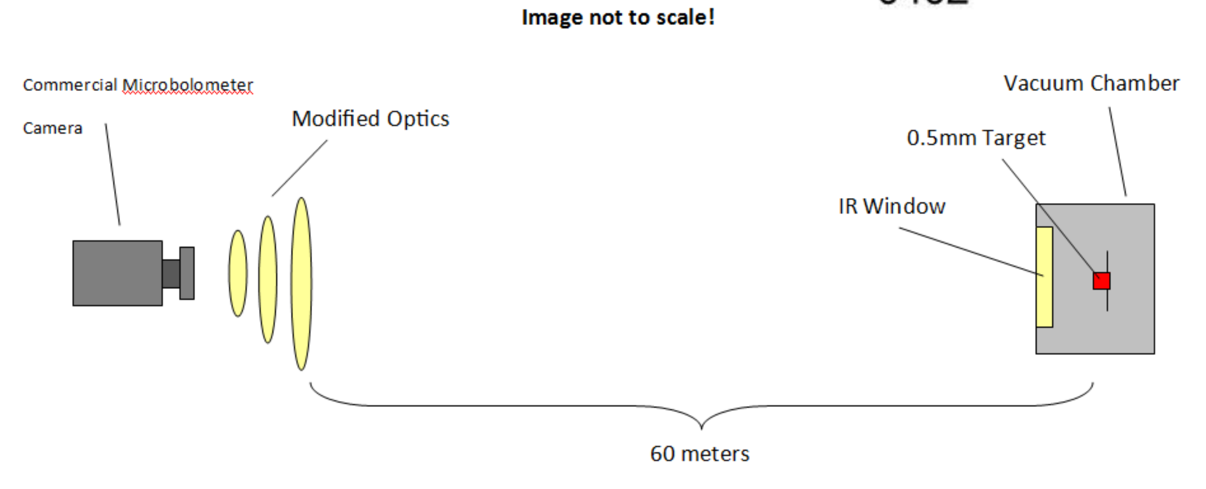
Initial Plan

Our initial idea

- Experiment Proposal
- Not within budget
- Hard to do

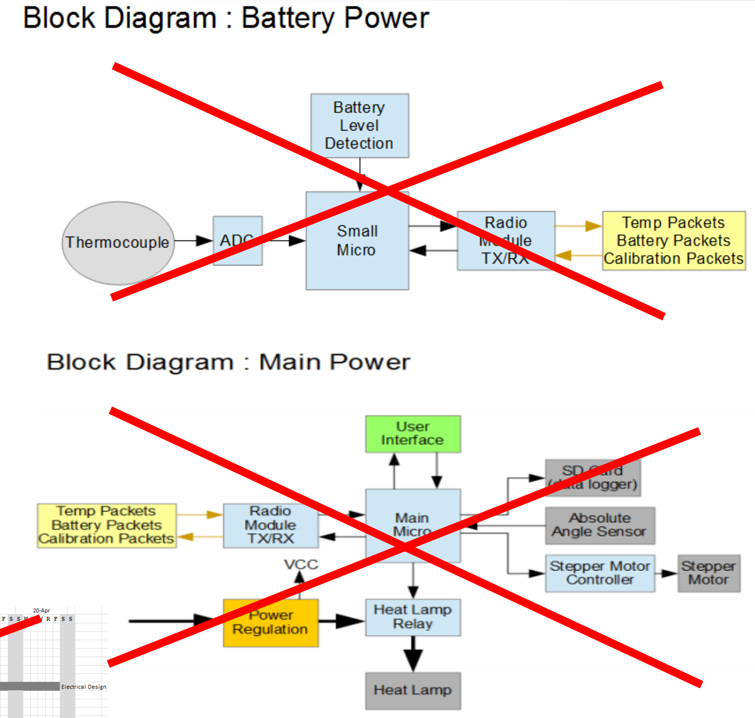


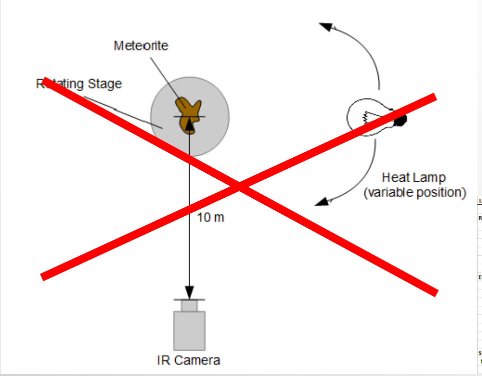


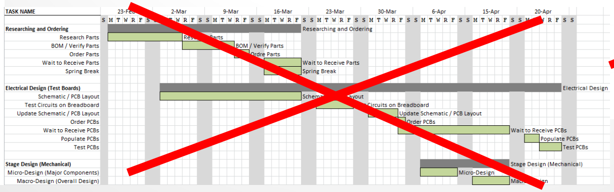
Next Plan

Our next plan - the turn table

- Heat object to specific temp
- Thermal distributions
- Differing light angles
- Disagreement







New Plan

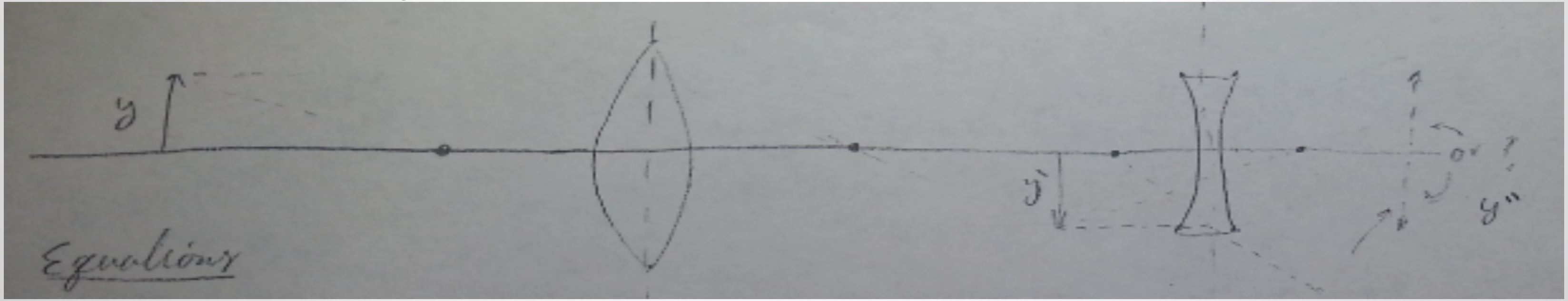
Design an optics system

- IR telescope design
- Simulations
- Differing parameters
    - Thermal Camera
    - Photon Camera
- Cost analysis
    - IR lenses / mirrors
    - Camera
    - Cooling

New Plan - System Design

Galilean Telescope Design

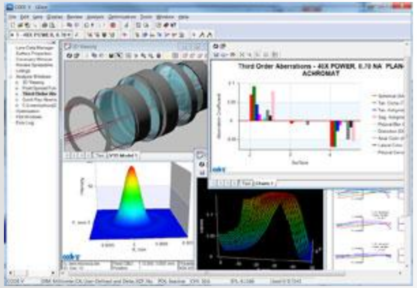
- Initial Exploration
- Non inverted image
- Large magnification
    - Low field of view
    - Lower brightness

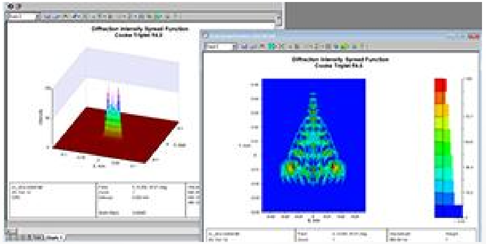


Testing Design

CodeV Design Software

- Plan to obtain student license
- Can model, analyze, optimize designs
- Scalability using radiance and irradiance





Images from http://optics.synopsys.com/codev/

Scalability

Radiance

$$L = \int_{\lambda_1}^{\lambda_2} \in \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{k_B T \lambda}} - 1} d\lambda$$

Irradiance

$$E = L\Omega$$

Solid Angle

$$\Omega = \pi \frac{r^2}{d^2}$$

$E = L\Omega$ => $E = L\pi \frac{r^2}{d^2}$

Set equal

$$E_{Lab} = E_{Real}$$

$$L\pi \frac{{r_{Lab}}^2}{{d_{Lab}}^2} = L\pi \frac{{r_{Real}}^2}{{d_{Real}}^2}$$

$$\frac{r_{Lab}}{d_{Lab}} = \frac{r_{Real}}{d_{Real}}$$

Example

$$d_{Real} = r_{Real} \frac{d_{Lab}}{r_{Lab}} = 50m \frac{72in}{2in} = 1800\ m$$

Camera Characterization

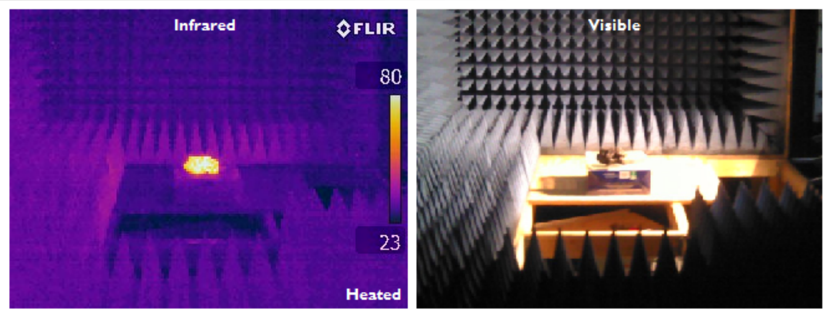
FLIR E30 (Forward Looking Infrared)
- Bolometer Resolution : 120x160
- Output Format : Radiometric JPEG
- Visible and IR cameras

Meteorite
- Weight : approx 5 lbs.
- Composition : Mostly iron
- Diameter : approx 5 inches

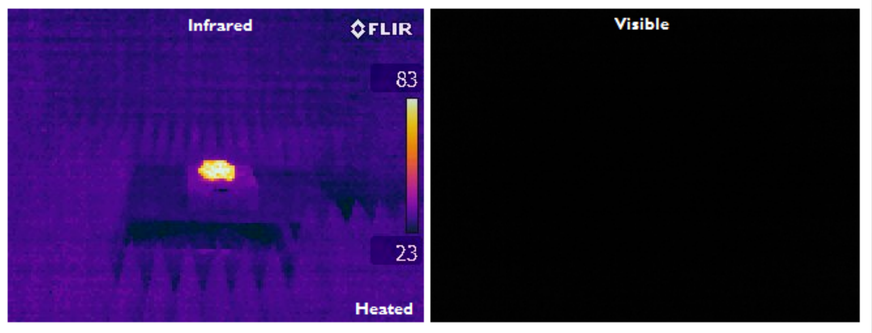
Camera Characterization

Preliminary Thermal Measurements

- Heated sample and took images
  - proof of concept.



- Heated with light source



- Heated with no light source

Obtaining Thermal Info

Thermal distribution

Software Used : MATLAB, FLIR Tools

- MATLAB
  - Edge detection
    - localized
    - finds all values within edge
  - Distribution calculations
  - Interpolated temperature from pixel values (no longer needed)
- FLIR Tools
  - Bolometer output (.csv)

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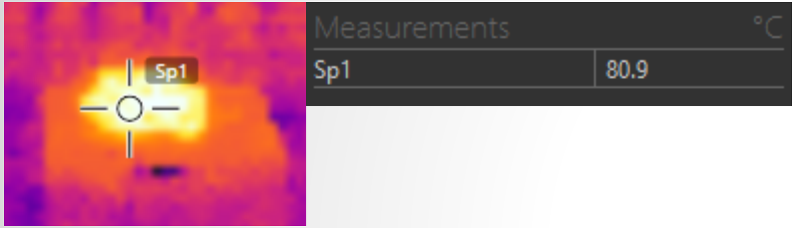
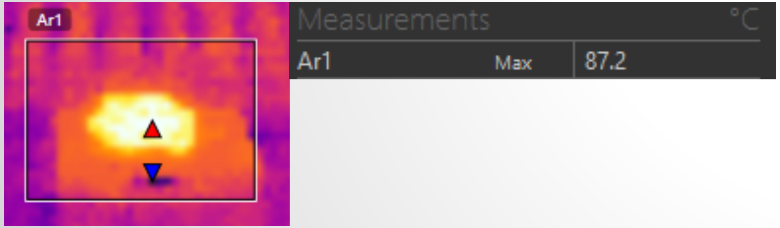
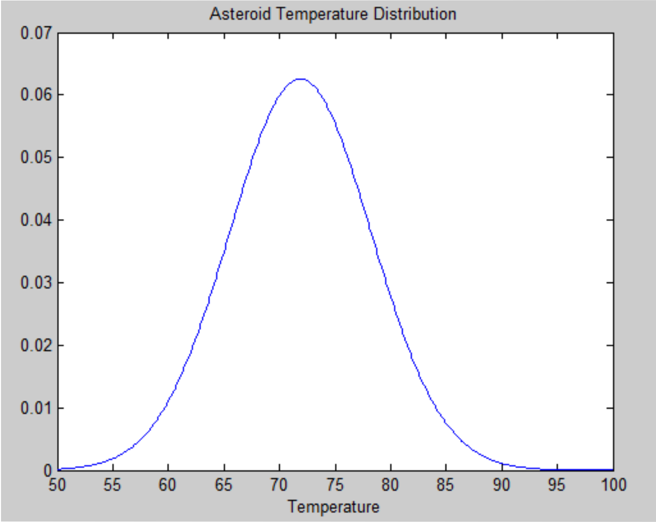
Obtaining Thermal Info

Flir Tools





MATLAB



Max Temp : 80 C

Future Work

- Continue galilean telescope
- Explore other telescope designs
- Bolometer noise considerations
    - Phonon Noise
    - Photon Noise
    - Johnson Noise

Questions