Low-Cost Single Mirror Telescope
Product Requirements Document
Team Z-Telescope

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Customer: Jim Zavislan, Professor of Optics at the University of Rochester

Document Number 00001

Revisions Level	Date
G	12/11/2015

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Rev	Description	Date	Authorization
A	Initial PRD	10/30/2015	YC
B	Specifications and Schedule created.	11/18/2015	YC
	Rewrote Vision.		
	Telescope Specifications		
C	Formatting	11/24/2015	JH
	Team Name change		
D	Block Diagram	12/8/2015	AB
	Table of Contents		
E	Formatting	12/8/2015	YC
	Customer Information		
	Project scope		
	Team member responsibilities		
	Regulatory issues		
	Intellectual resources		
	Budget		
F	Updates from class feedback	12/9/2015	JH
G	Updates from customer feedback	12/11/2015	AB,JH&YC

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The low-cost single mirror telescope is an internally driven product. As such its design inputs were derived from Jim Zavislan.

Vision:

A low cost single telescope with a single mirror for planetary observation with a camera instead of an eye. The main objective is to get young students interested in astronomy/optics. The telescope should be able to be operated by children 12 years and older. The telescope should use a manual tracking to keep planets in field of view so multiple images can be taken as the object transits the field of view. Software will stack multiple images to create a final image of higher quality. A mechanical pointing system should be able to place naked eye planets in the field of view. The construction of the telescope should be simple enough that most supplies (not optics) can be purchased at a home improvement store.

Project Scope:

Optical Engineering Senior Design Team (OPT 311) is responsible for the following deliverables:

- Telescope optical design
  - Dimensions and surface figure of the optics
  - Spacing between optics (vertex - vertex)
  - Tolerances on all optical elements (Decenters, Tilts, etc.)
  - Location and diameter of aperture stop
  - Preferred method of optic mounting, as a starting point
- Telescope mounts will be designed for fabrication in a machine shop.
- A fully operational prototype with a user guide.
- A budget and bill of electronics and software.
- An assembly procedure for future builds.
- Designating a camera to be used.
- Identifying a stacking software for use with the telescope.

We are not responsible for:

- Design of electronics and software
- Building a sensor (we are buying a commercially available webcam see Appendix C)
- Writing image stacking software.

Team Responsibilities:

Yeyue Chen: Project Coordinator, Document Handler, Telescope optical design
Josh Hess: Customer Liason, FEM and CAD-Mechanical
Akil Bhagat: Scribe, Testing & Modeling

Environment:

As an outdoor observation tool, it needs to operate in the following environment:

Temperature

-20—105 F – operation range

Relative Humidity

>0% - meets specifications

Resist contact with rain.

Resist degradation by condensation.

Run under battery power.

During normal operation, no maintenance will be required. Maintenance such as cleaning the glass surface may be required, depending on use, once a month.

Regulatory Issues:

Due to the primary focus of utilizing commercially-available technology, the resulting product will adhere to the laws and regulations of the components. The telescope should not be used to direct to the Sun by naked eyes.

The telescope will be designed to minimize the possibility that the telescope can direct an image of the sun at any person.

Fitness for use:

The system will:

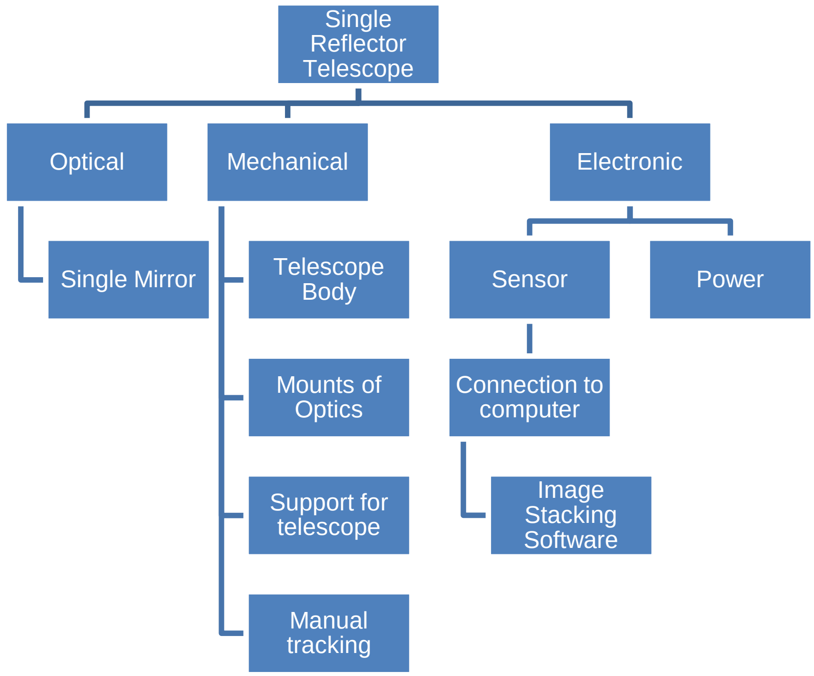
- Be robust (resist a 1 meter fall without any visible deterioration of image quality)
- Have a single surface with optical power
- Not have automated tracking, instead use sidereal motion to translate the planet across the FOV of an “inexpensive” web camera
- Capture multiple digital images as the planet transits the FOV
- Use image processing software to aggregate the images and enhance resolution (aka “Stacking” the images)
- Be able to preview images on the telescope

- Image stacking to be done on a separate machine
- Process image to resolve the red spot of Jupiter, the ring structure of Saturn and track the position of the Jovian Moons
- Telescope can be easily operated by people 12 years of age and older
- Visual pointing of the telescope would place "naked eye" planets in the FOV

It is desirable that:

- The system is low-cost enough for a school budget
- Able to resolve Uranus with image processing
- Can be built by 12 year old
- Image processing could be done on a Chromebook, laptop or other portable computer
- The system have no obscuration

Block Diagram:



Intellectual Resources:

Jim Zavislan (UR, Optical Engineering) for system help, agreed to help
Qiang Lin (UR, Mechanical Engineering) for FEM and CAD help, agreed to help
Prof. Ginberg, No contact, Suggestion by Zavislan

Appendix A: Code V Full Telescope Specifications

Specification	Value	Unit	Comments
Sensor			
Sensor Size	= 6.35	mm	¼ inches = 6.35 mm
Sensor Pixel Pitch	= 0.0056	mm	5.6 µm = 0.0056 mm
Sensor Full VGA Resolution	= 640 X 480		H X V
Sensor F/#	= 5.6		From Sensor Spec Table
Sensor Diameter	= 4.48	mm	De = $\sqrt{640^2 + 480^2}$ x $0.0056\ mm = 4.48\ mm$
Eyepiece Focal Length	= 25.088	mm	fe = De X F/#
Eyepiece Full Field of View	= 10.2	Degrees	De/2 = fe * tan (θ/2)
Objective			
Angular diameter of Saturn	> 14.50	Arc-second	
Angular diameter of Jupiter	> 29.80	Arc-second	
Angular Resolution	> 0.7	Arc-second	"Dawes Limit" (Cassini's Division)
Diameter of Objective	< 170	mm	Do = 120/P_R
Magnification	= 76	X	M = Do/De
Objective Focal Length	= 1906.688	mm	fo = M X fe
Objective Full Field of View	= 483.156	Arc-second	FOVo = FOVe/M
System			
F/#	= 11.2		F_R = fo/Do
Wavelength	656.2725	nm	Visible Spectrum
	587.5618	nm	
	486.1327	nm	

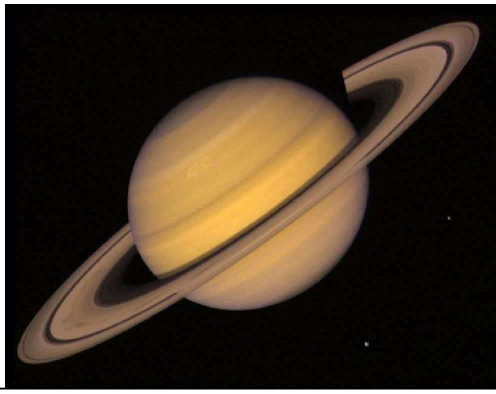
Appendix B: Detector Specifications

Detector	**ICX098BQ**
Sensor Size(pixels)	640x480
Pixels size(um)	5.6
Camera	Logitech QuickCam Pro 3000
Price	~25$

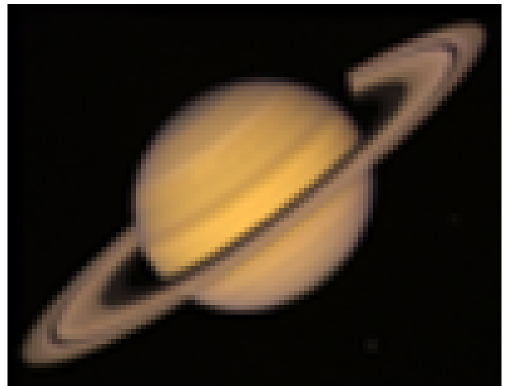
Appendix C: Budget:

Part	**Spec**	**Price**
Sensor	Logitech QuickCam Pro 3000	$25
Software	Keith's Image Stacker	$15
Mirror	Off-axis parabolic mirror - TBD	< $50
Lens	TBD X 3	< $50
Manufacturing	TBD	< $100
Total		< $500

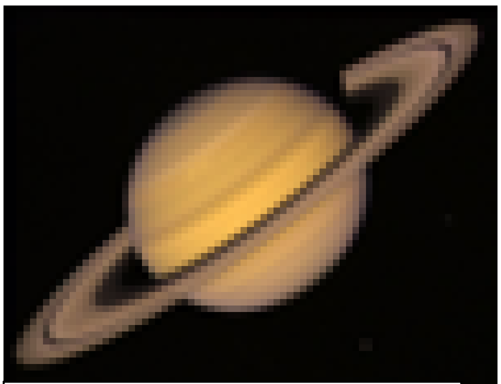
Appendix D: ImageJ Decimation study



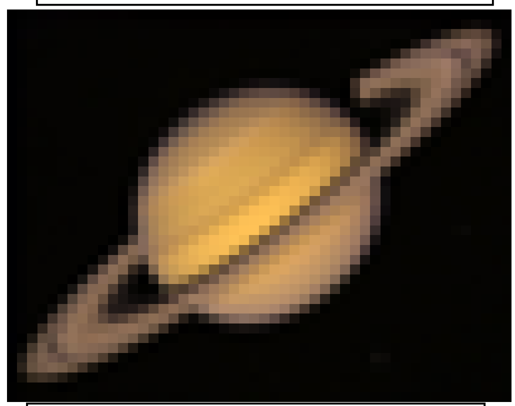
Original Photo by Voyager 2: 617x480



100x79 Focal Length ~5.5m



75x59 Focal Length ~4 m



50x40 Focal Length 2m

25x19 Focal Length ~1

Process.

1. Take original image (ex 617x480) into ImageJ.
2. Reduce size of image (ex 100x79)
3. Scale new image to be the same displayed size.
4. Using $h=f*\tan(\Theta_{1/2})$. Where h is half the larger length of the new image(ex 100/2 =50=h).
5. The resulting image approximates the image quality of the calculated focal length.

Appendix E: Schedule

Date 2015	Objective
11/20	In-class PRD Review 2 -rewrite PRD in our words -preliminary detector research -preliminary optics specifications
11/30	-choose a detector/webcam -settle on specifications for optics -rough optical design
12/2	Meet with Zavislan -finalize specifications with customer -discuss rough optical design
12/9	Final PRD Review

Date 2016	Astronomical Event	Goal
January		Preliminary mirror design And CAD modeling
February		Order optics and begin mechanical fabrication
2/7	Mercury at Greatest Western Elongation	Order sensor and connect to software selected
2/22	Full Moon	Test resolution of sensor
March		Assembly
3/8	Jupiter at Opposition	First build complete
March		Analyze data. Optimize system
3/23	Full Moon	Second round testing
April		Rebuild system
4/18	Mercury at Greatest Eastern Elongation	Second build complete
4/22	Full Moon (Pink Moon)	Last round testing