Mech-Aero 2013

Searching for near-earth asteroids from space

Neha Satak
Klaus Smit, Roy Tucker, Shen Ge and Hyerim Kim
ExperimentalCenter for Applied Physical Systems (ECAPS), LLC

December 25, 2015

Presentation Outline

1. **Discovery of Asteroids**
2. **MOTESS Instrument**
3. **Space versus Earth based Observation**
4. **SMOTESS Design**
5. **Conclusion**

Asteroids

The Devils[1]

The Heroes[2]

[1] http://top-10-list.org/2011/09/19/top-10-armageddon-predictions/2/

[2] http://gizmodo.com/5904727/how-the-space-miners-will-bring-trillions-of-dollars-to-earth-live-coverage

Asteroid Population

D(m)	$>$ 1000	1000 - 140	140-40	40-1	Total
H(mag)	$<$ 17.75	17.75-22.0	22.0-24.75	$>$ 24.75	
N (Estimated)	966 $\pm$ 45	14,000	285,000	Unknown	
N (Observed)	900(159)	4,709(1239)	2,396	1,793	9,798(1398)
Obs/Est (%)	93 4	34	1		

NEA detection summary with potentially hazardous asteroids (PHAs) in parenthesis.

Discovering Asteroids

Observatories

There are more than 1700 observatories listed on the Minor Planet Center.

Space Based Telescopes

- B612 Sentinel
- NEOSSat microsatellite (CSA)
- ESA Gaia
- NEOCam
- NEOWISE

Space Versus Earth Based Observation

Earth Based

Earth Telescope

- No Launch Cost
- Atmospheric Interference & Zodiacal light
- Fixed orbit and rotation speed of Earth

Space Based

Space Telescope

- High Launch Cost
- Orbit and rotation period can be optimized for observation
- No Atmospheric Interference but Zodiacal Light

The MOTESS Instrument

Inventor: Roy Tucker

CCD

- Simple design
- Capable of operating in scan-mode
- Supports thinned, back-illuminated CCDs
- 16-bit digitization
- Four-stage thermoelectric cooling
- Vacuum enclosure

Three Telescope Configuration

Optical Design

- 14 inch aperture f/5 Newtonians
- 48 arcminute field of view (24.5 millimeter CCD)
- 2.83 arcseconds per pixel (24 micron pixels)
- Acceptable coma and field distortion

Roy Tucker is the co-discoverer of Apophis 99942!

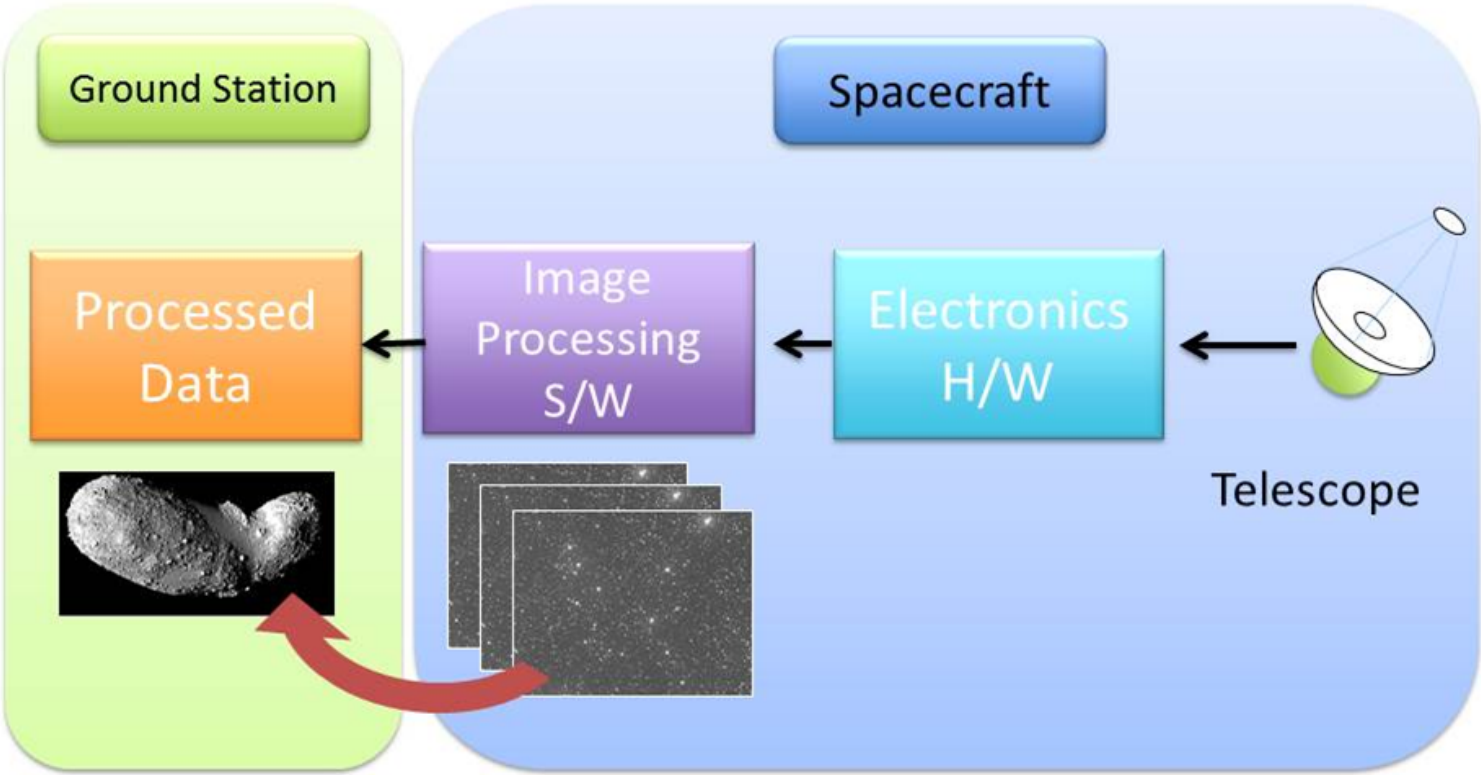
MOTESS

Scan Mode Imaging	Stare Mode Imaging
Continuous imaging process allows no wasted photons and high instrument productivity but with limits on integration time	Total freedom to image any part of the sky with whatever integration time is desired
Simultaneous integration, read out, and movement to next field	Collection of photons must be interrupted when moving to the next field
Precision pointing and tracking not required but limited to a band around the sky near the rotational plane	Requires precision pointing and tracking
Reduction of CCD cosmetics due to averaging effect of imaging process Simplified and improved image calibration	

Detections by MOTESS

- 1188 Discoveries
- 766 numbered objects
- 32 of the numbered objects have been named
- 990 of the discoveries are identified with numbered minor planets
- 133 of the discoveries are involved in multiple-apparition orbits
- 110 of the discoveries are principal designations

SMOTESS System



SMOTESS

1. The spacecraft operates in a Venus-like orbit
2. The design has 4 to 8 telescopes
3. It detects asteroids of size greater than 40m
4. Its operation lifetime is 10 years
5. Asteroids will be detected onboard the spacecraft

Space Telescopes

Telescopes	Cost	Launch Date	Position	Type	Detect
Sentinel B612 Foundation	$450M	2018	Venus-like orbit	Infrared	Asteroids
NEOSSat CSA	$10M	Feb, 2013	Low Earth Orbit	Visible	Asteroids
GAIA ESA	$700M	Oct, 2013	Sun-Earth L2	Visible	Stars
NeoCam Caltech	$425M	-	Sun-Earth L1 Halo	Infrared	Asteroids and Comets
NEOWISE UCLA & NASA JPL	$320M	2009	Earth Polar	Infrared	Asteroids
SMOTESS ECAPS	$78M - 178M	-	Venus-like	Visible	Asteroids

Software

Automatic Detection Onboard

The PinPoint astrometric engine is by far the most sophisticated and powerful programmable software available to automatically detect asteroids in images from automated telescopes and cameras.

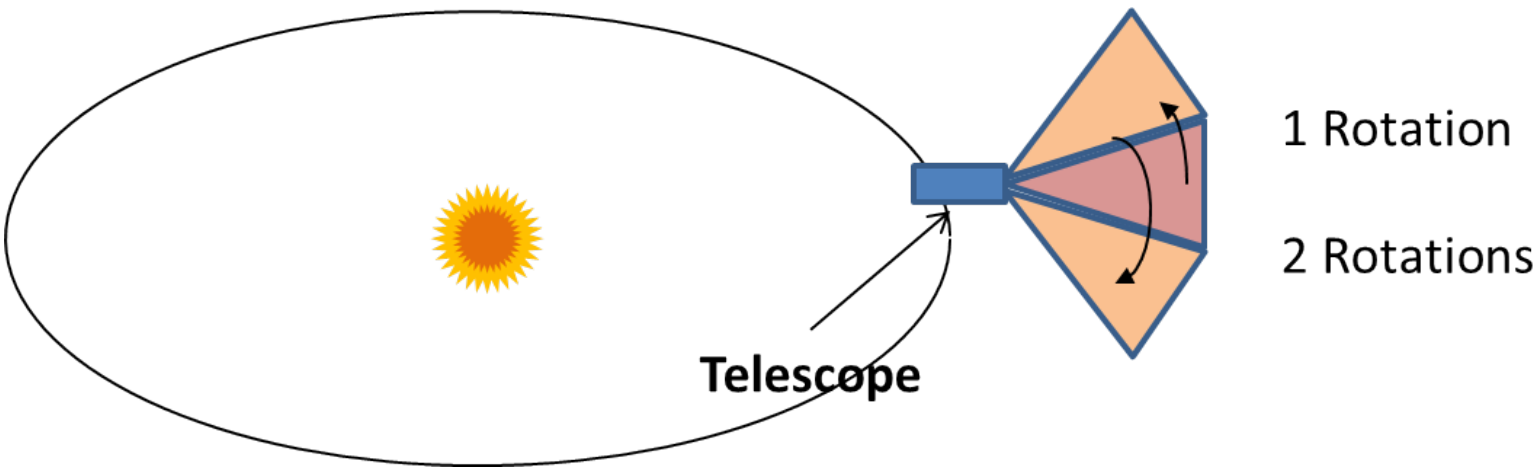
Tasks

- Parallelize for faster processing
- Design a user independent calibration routine to operate onboard
- Design hardware for efficiently storing, processing and transmitting data

Design Parameters

1. Years of operation
2. Number of telescopes
3. Camera orientation changes
4. Optical parameters

Rotation



Detection in Space

Zodiacal Light

The zodiacal light is the reflection of sunlight from dust particles and it varies with solar elongation angle and the ecliptic angle.

Limiting Magnitude

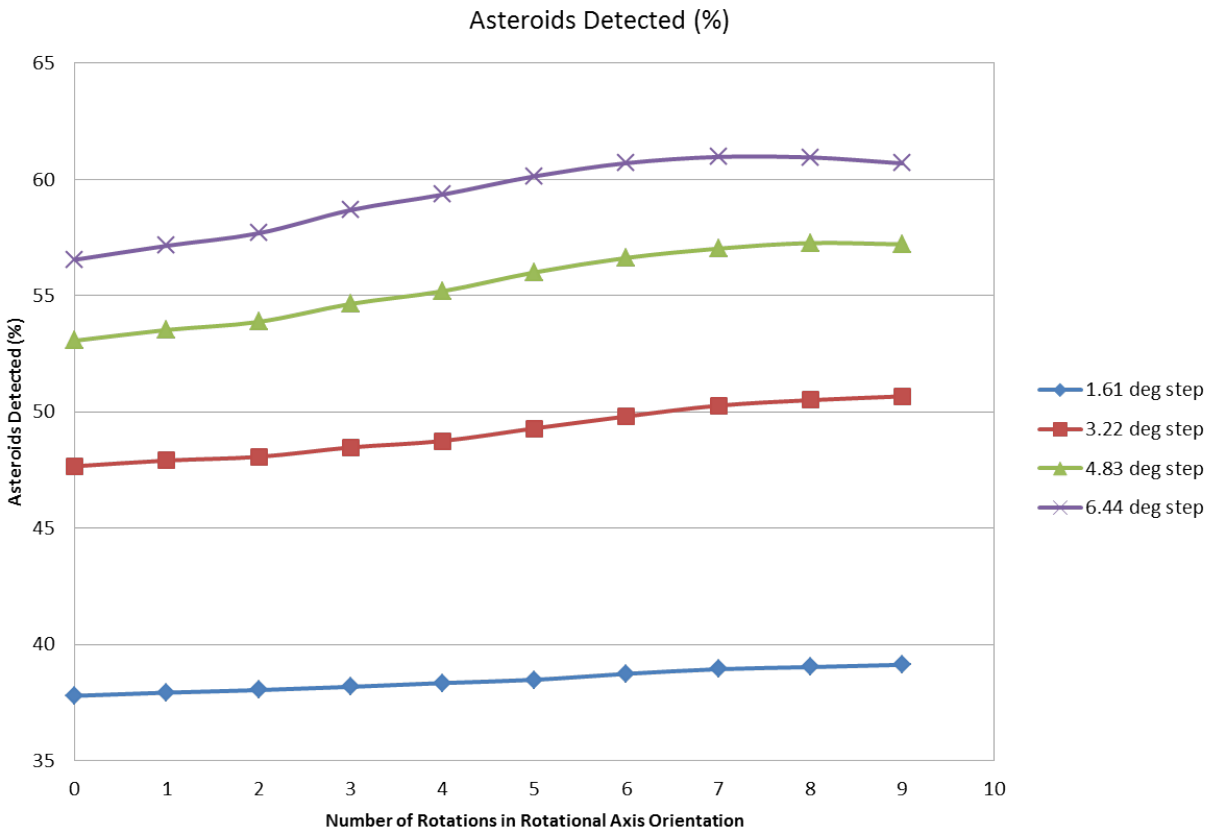
The limiting magnitude is mainly limited by the zodiacal light.

Various limiting magnitudes of SMOTESS with respect to solar elongation at a Venus-like orbit.

Solar Elongation (deg)	30	40	60	90	140	180
Detection Threshold (mag)	23.0	23.4	23.9	24.2	24.4	24.4

Optimizing Number of Telescope & Rotations

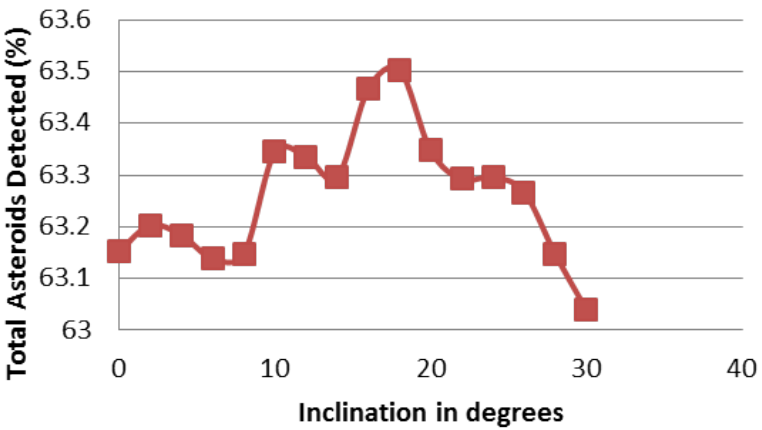
Venus-like Orbit a = 0.7 e = 0.06 i=0

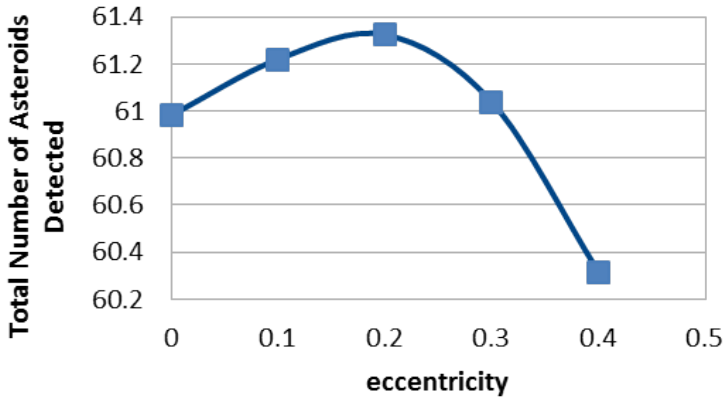


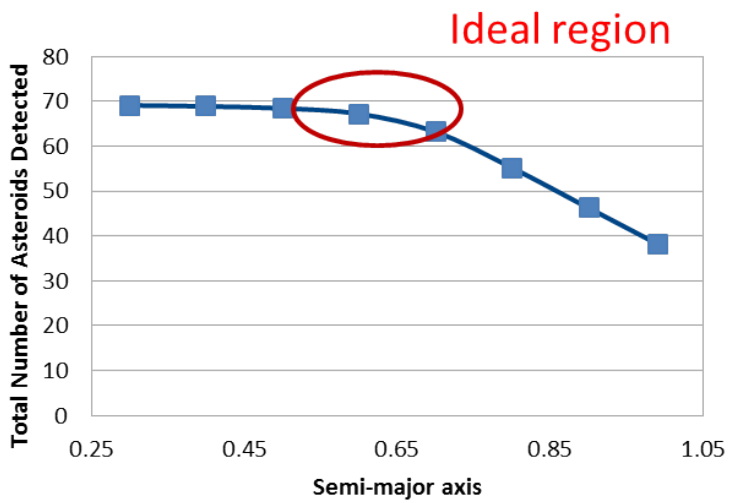
Parameters Chosen

- No. of Telescope = 6 No. of Changes = 8

Orbit Optimization

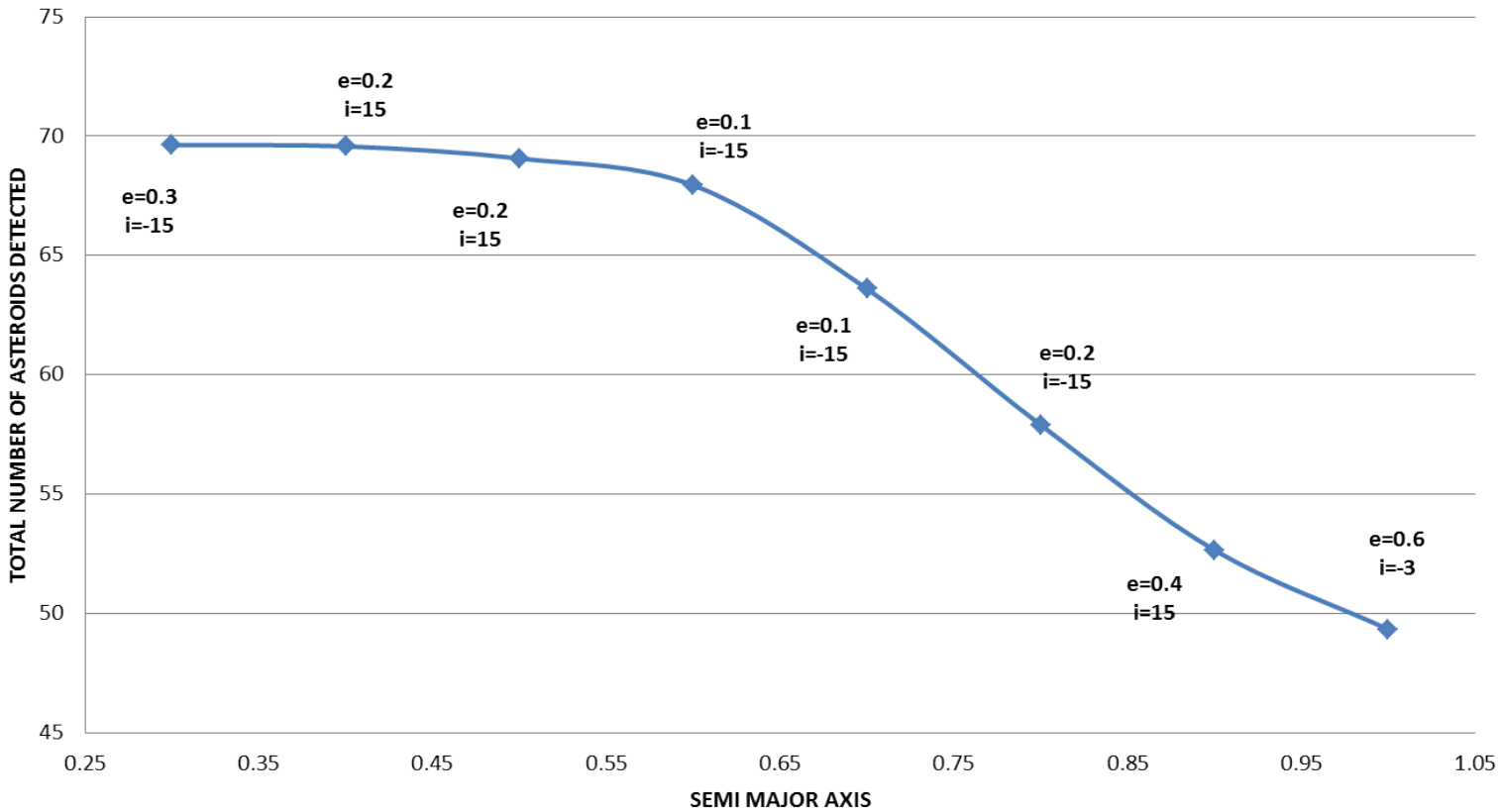






- Semi-major axis is the most influential parameter
- Making the eccentricity slightly higher than zero optimizes the performance
- The inclination should also be increase to 10 to 20 degrees for optimal performance

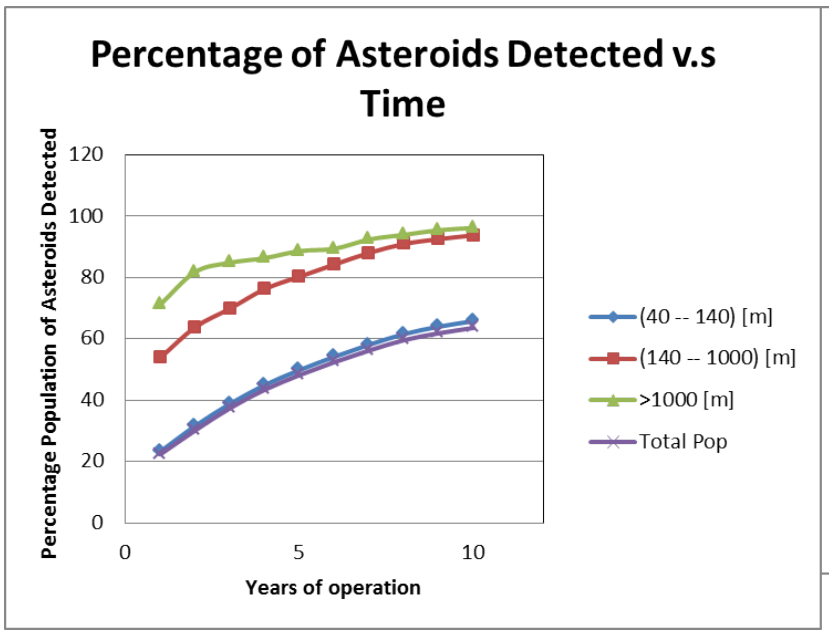
Orbit Optimization

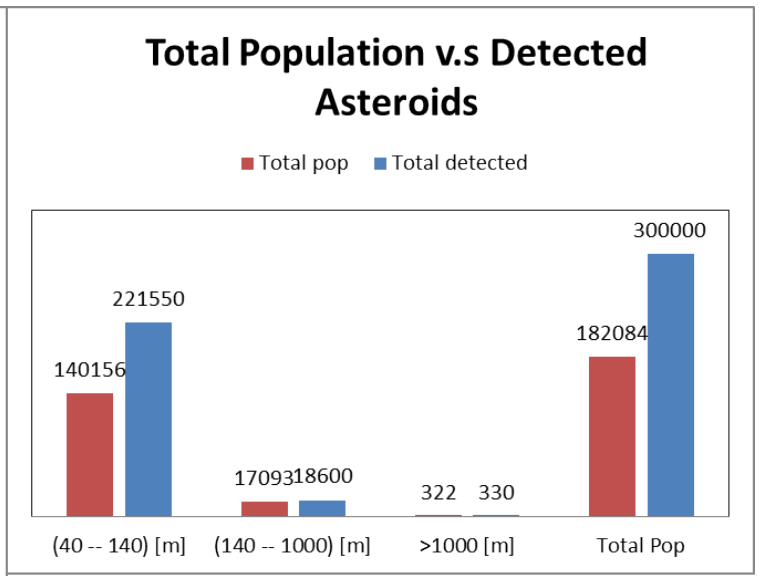


Orbit Optimization

Orbital Parameters

- a = 0.7 e=0.1 i=15 degrees





Advantages of SMOTESS Design

- **Longer life time** as it does not require energy to precisely point the spacecraft unlike telescopes based on stare-mode imaging
- More **cost effective** as there are no continuously moving parts.
- **Simple Design**
- The SMOTESS is derived from the MOTESS design which is already **tried and tested**.

Conclusions

The SMOTESS is a space-based optical telescope designed to detect asteroids larger than 40 metres diameter. It uses the scan-mode imaging technique which is cost effective and does not require precise pointing of the spacecraft.

Thank You