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TINYSCOPE The Feasibility of a 3-Axis Stabilized Earth Imaging CubeSat from LEO

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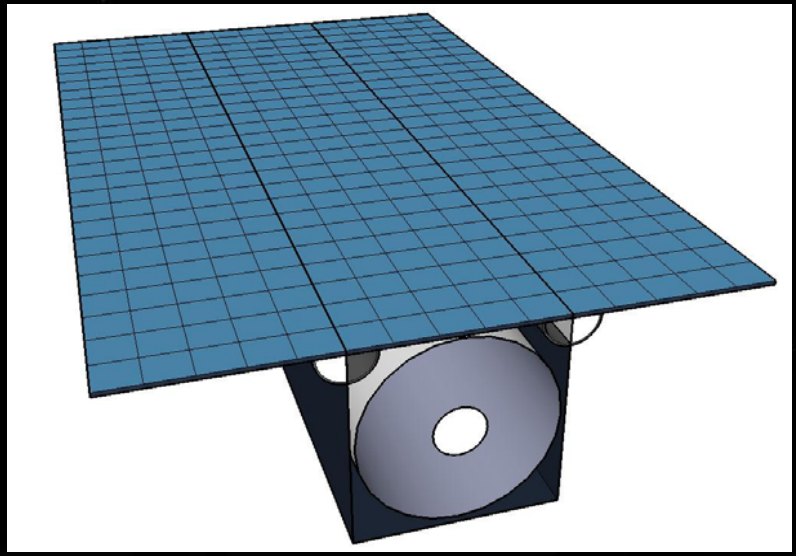
NAVAL POSTGRADUATE SCHOOL

TinyScope

Spacecraft Robotics LABORATORY

Allen Blocker
Chance Litton

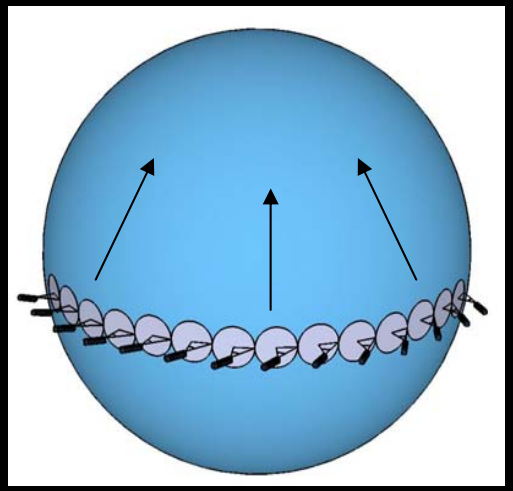


Paul Oppenheimer
Jason Hall

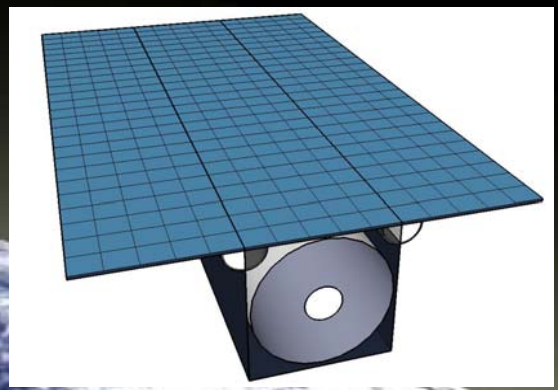
Marcello Romano

The Concept

Cost Effective Distributed Access Space Capability



Time Critical Imagery for The Tactical User



Orbit Considerations

Table 1 – Orbital Lifetime

Altitude (km)	200	300	400	500	600	700
Lifetime (solar min)	3 days	90 days	2 years	4 years	10+ years	10+ years
Lifetime (solar max)	2 days	60 days	180 days	3 years	10+ years	10+ years

$$BC = \frac{m}{C_D A} = 100 \frac{kg}{m^2}$$

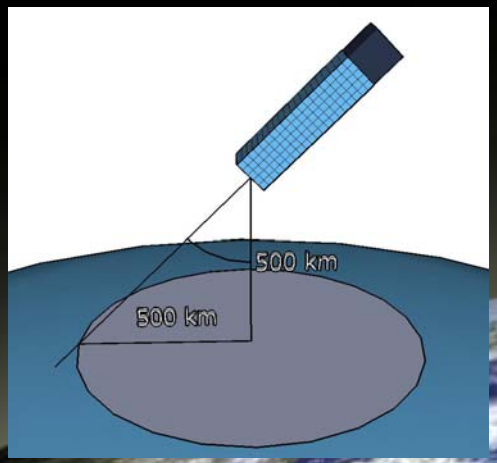
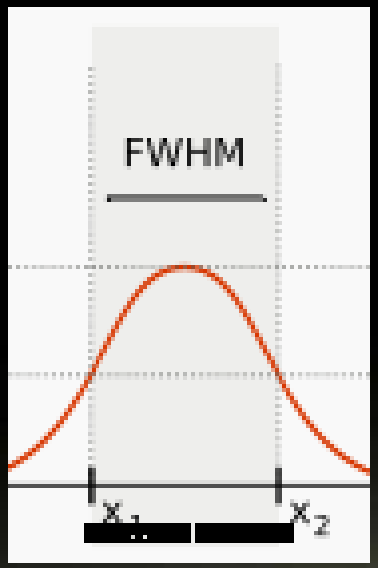


Table 2 – Ground Separation Distances

Wavelenth (m)	Ground Separation Distances: Angular res (rad) 3.7E-06 - 6.1E-06	
5.0E-07	h (km)	GSD (m)
Aperture (m)	200	0.9 - 1.5
0.1	300	1.3 - 2.2
Quality Factor	400	1.8 - 2.9
1.2	500	2.2 - 3.7
	600	2.6 - 4.4
	700	3.1 - 5.1

Payload Performance

$$GSD = \left(\frac{1.22\lambda}{D} \right) h \cdot Q$$



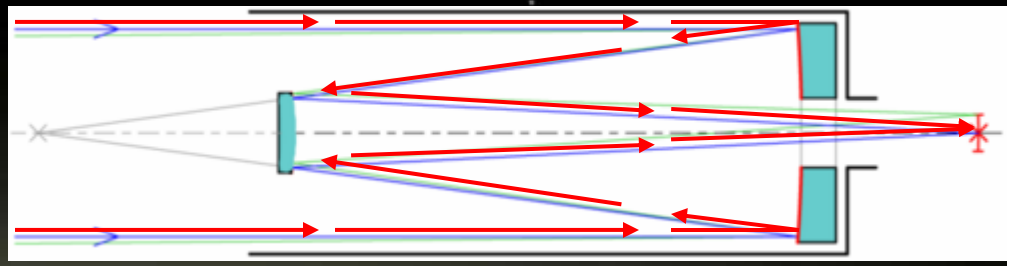
Aperture (cm)	9.8
Focal Length (cm)	150
FPA Size (pixels)	4288
FPA Pitch (um)	6
IFOV (urad)	4.0
FOV (deg)	0.98
GSD (m)	2.00
F#	15.31
FPA Format (mm)	25.7
FWHM (um)	7.3
Blur Over Sample	1.2
Swath (km)	8.6

Payload Design

COTS Option

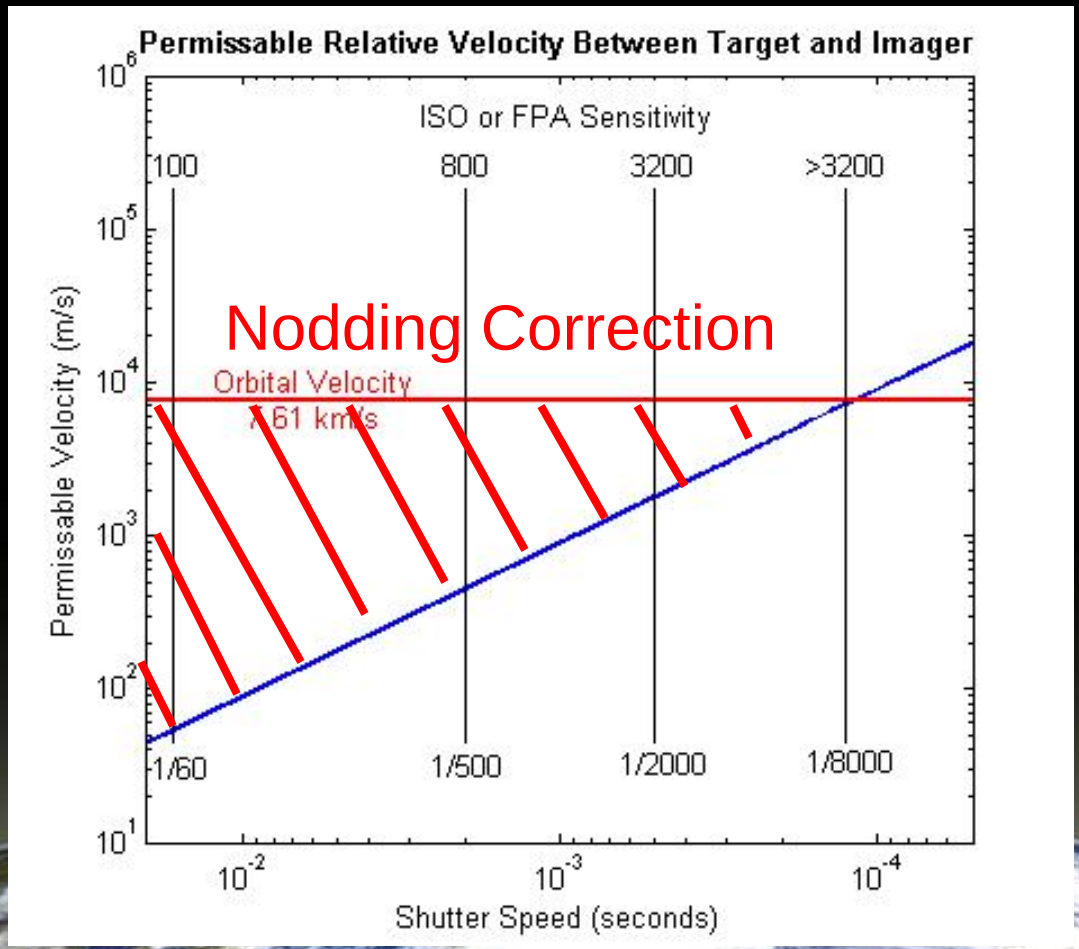
Meade CTX-90
90 cm Aperture / f=125 cm
Nikon D300
6 micron pitch/4288

Custom Design
Optimized Train
Space Ready



Motion Blur and Jitter

1/3 Pixel Blur at 2.7 m GSD
= 0.9 m of relative motion



ADCS Problem Statement

- Service Targets (4 / orbit)
  - Acquisition (large maneuvers)

$T=4*\theta*I/t^2$

TINYSCOPE Slew Angle, Time and Torque

Ixx, Iyy	**Angle**	**Time**	**Torque**
0.19 kg*m^2	deg	sec	mNm
Izz	150	50	0.8
0.02 kg*m^2	90	30	1.3
Ave Slew Rate	45	15	2.7
3 deg/sec	30	10	4.0
	10	3	12.1

ADCS Problem Statement

- Service Targets (4 / orbit)
  - Acquisition (large maneuvers)
  - Image capture (fine-pointing)

ADCS Rate-Precision Requirements

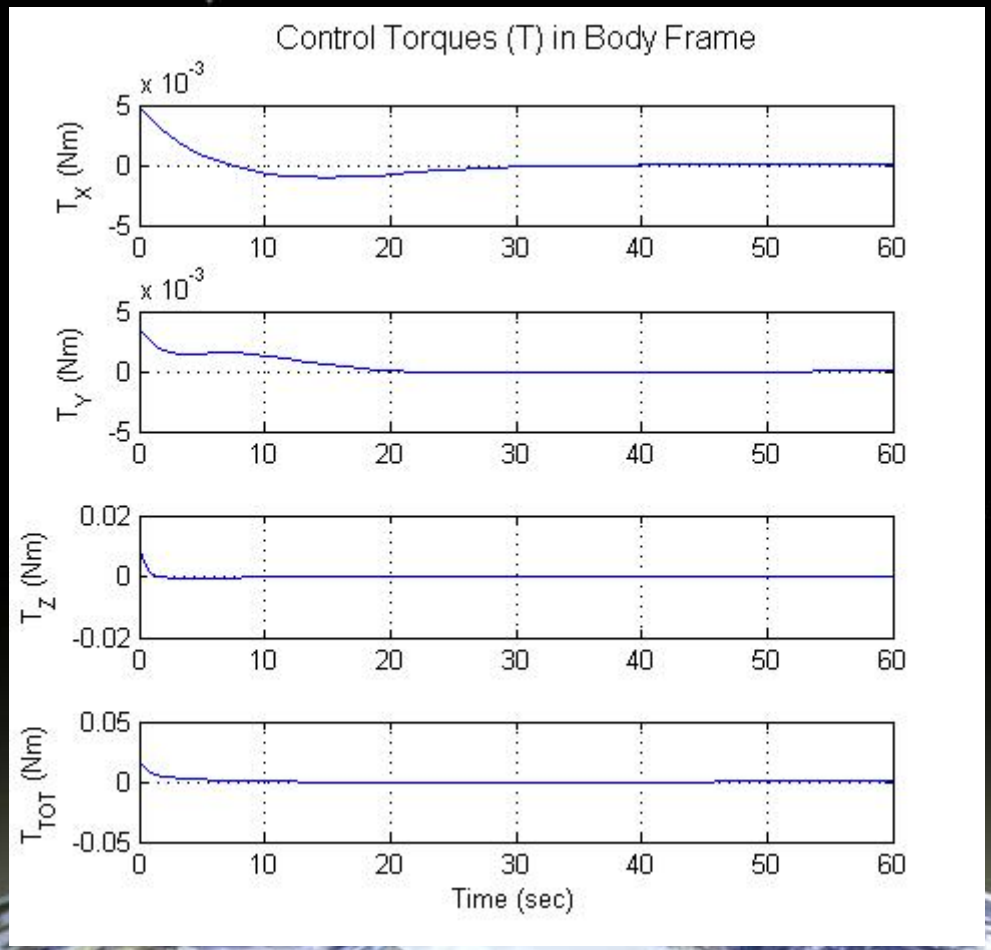
Shutter Speed	1/60	1/500	1/2000	1/8000	sec
Pointing Rate	0.0001	0.0009	0.0036	0.0144	mrad /sec
	0.0062	0.0516	0.2063	0.8251	mdeg /sec

*Calculations done for 0.9 m allowable blur at 500km slant range

ADCS Model

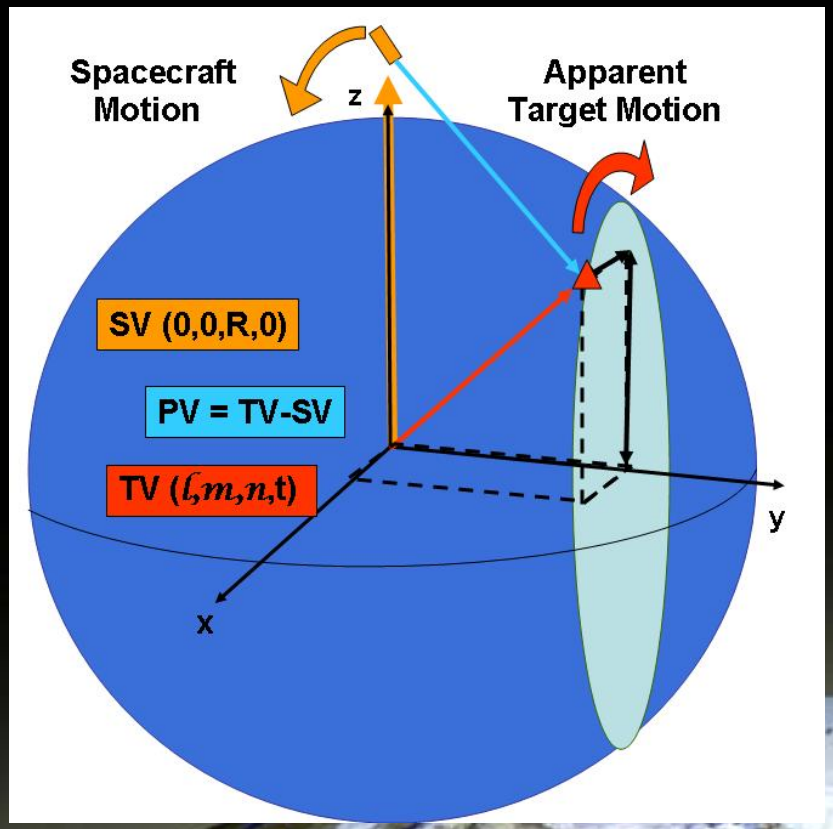
- Sun-Soak Target Acquisition Maneuver
  - Quaternion Feedback Controller
  - (disturbance torques present)

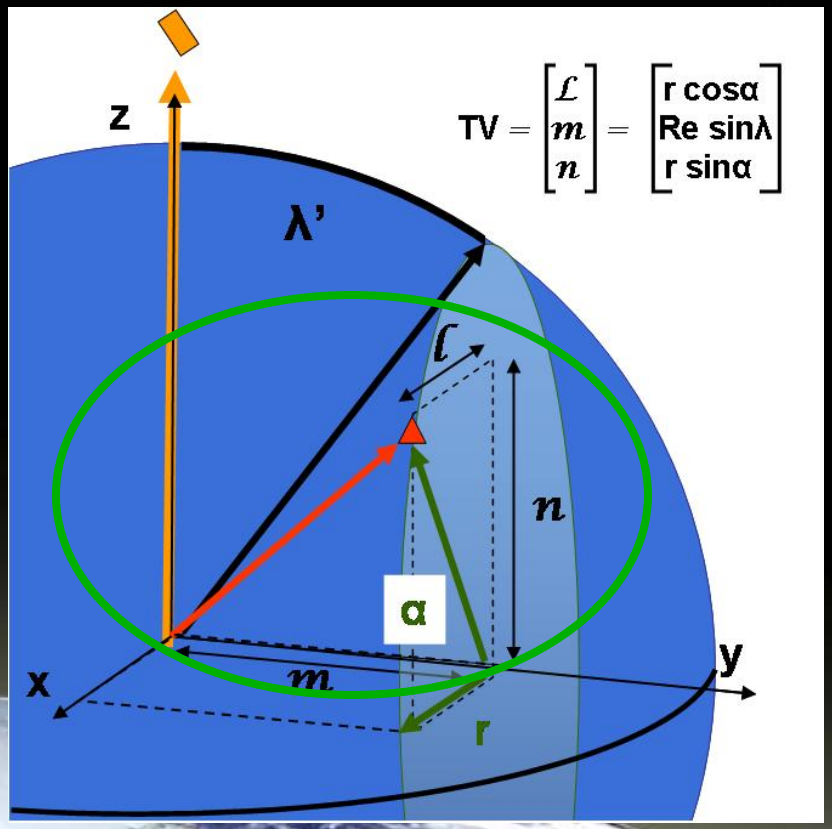
ADCS Model


Control Torques (T) in Body Frame
x 10^-3
T_X (Nm)
5
0
-5
x 10^-3
T_Y (Nm)
5
0
-5
T_Z (Nm)
0.02
0
-0.02
T_TOT (Nm)
0.05
0
-0.05
0
10
20
30
40
50
60
Time (sec)

ADCS Model

- Pointing Vector Reference Frame



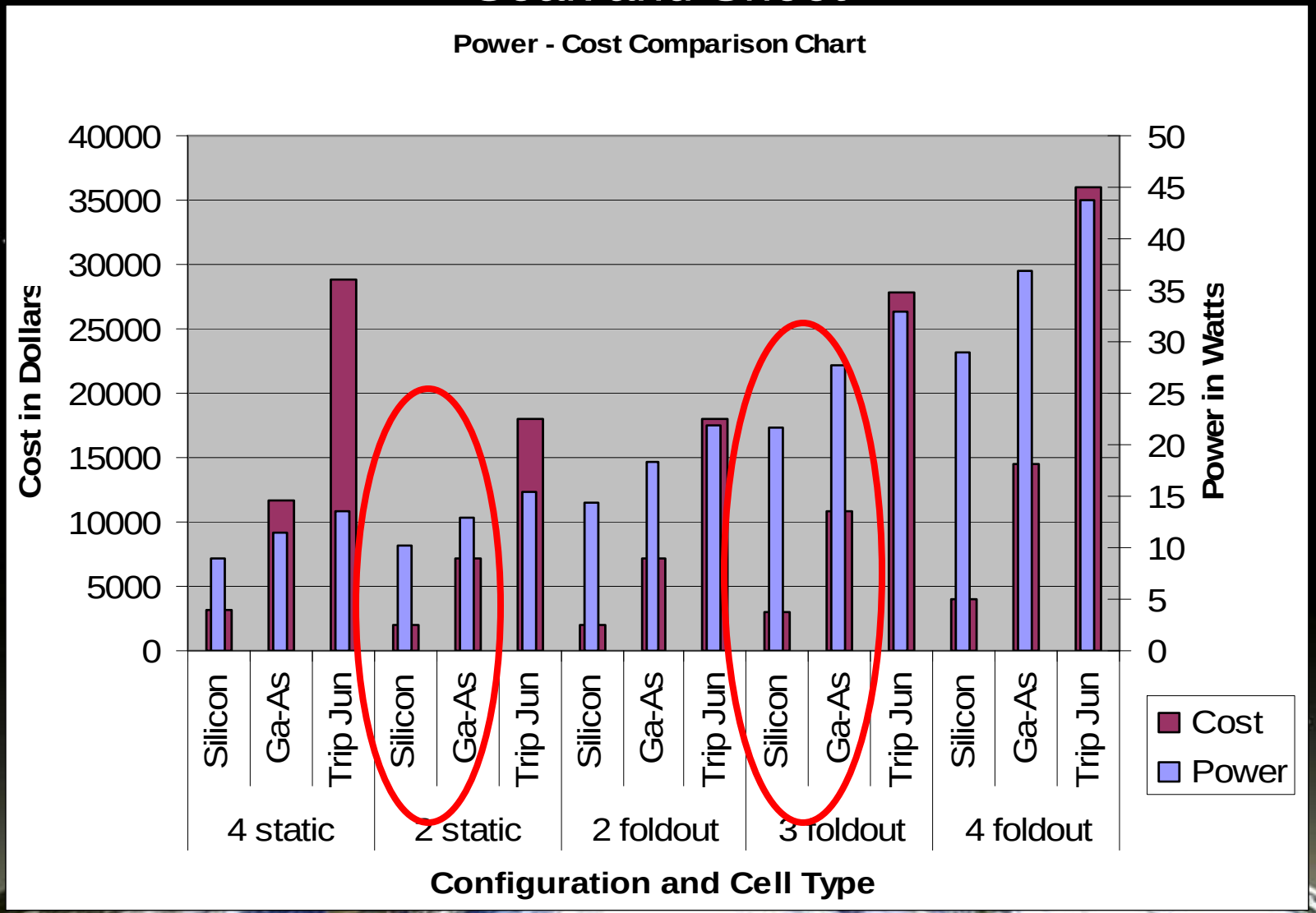


ADCS Model

- Nodding for Image Capture
  - Quaternion Feedback Controller
  - (disturbance torques present)

Electrical Power

Soak and Shoot



Comm Link

Table 7: Communications Downlink Summary

Communication Link Design	Downlink		
	TM	Store/Dump	Live Mode
Frequency Band	S-band	Ka	Ka
Frequency Range (GHz)	2.5-2.54	17.7-19.7	17.7-19.7
Bandwidth (GHz)	0.040	2.000	2.000
Transmitter Power (W) per beam	0.03	0.47	0.21
Transmit Antenna Diam (m)	0.05	0.05	0.05
Transmit Antenna Beamwidth (deg)	167	23	23
Slant Range (km)	1695	1695	1695
Data Rate (bps)	1.5E+03	1.8E+06	8.0E+05
Image set size (Mb)	-	768.0	96.0
Minutes to download full set	-	7	2
Link Margin (dB)	6.0	3.6	3.6
Req DC Power (W)	0.10	1.43	0.63
Total Req DC power (TM + DL~W)	-	**1.5**	**0.7**

Note: The Store/Dump method is a contingency; Live Mode is the primary operating mode.

TinyScope