Medium Earth Orbit

An Affordable Alternative To HEO?

AMSAT 2009

David Bowman G0MRF

Orbiting Satellite Carrying Amateur Radio 2009

Satellite Altitude

- ISS ARISS and External Payloads — 350km
- VO-52 — 605km
- AO-51 — 780km
- FO-29 — 1100km
- AO-7 — 1500km

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Orbiting Satellite Carrying Amateur Radio 2009

All Low Earth Orbit. *Range across footprint = 2R { arccos R/ (R+h) }*

Satellite	Altitude	Communications range km
ISS	350km	4130
VO-52	605km	5430
AO-51	780km	6006
FO-29	1100km	7002
AO-7	1500km	7997

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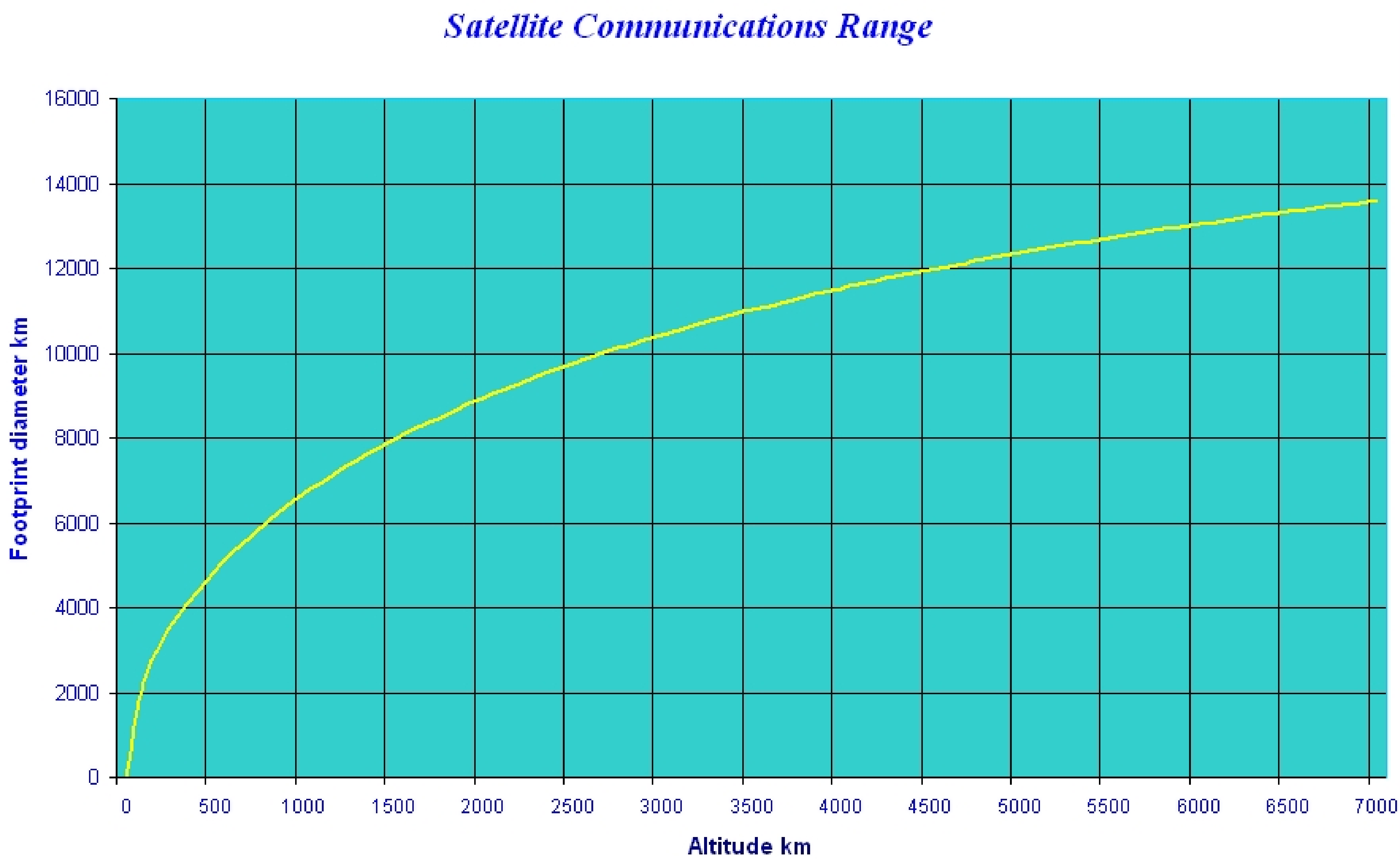
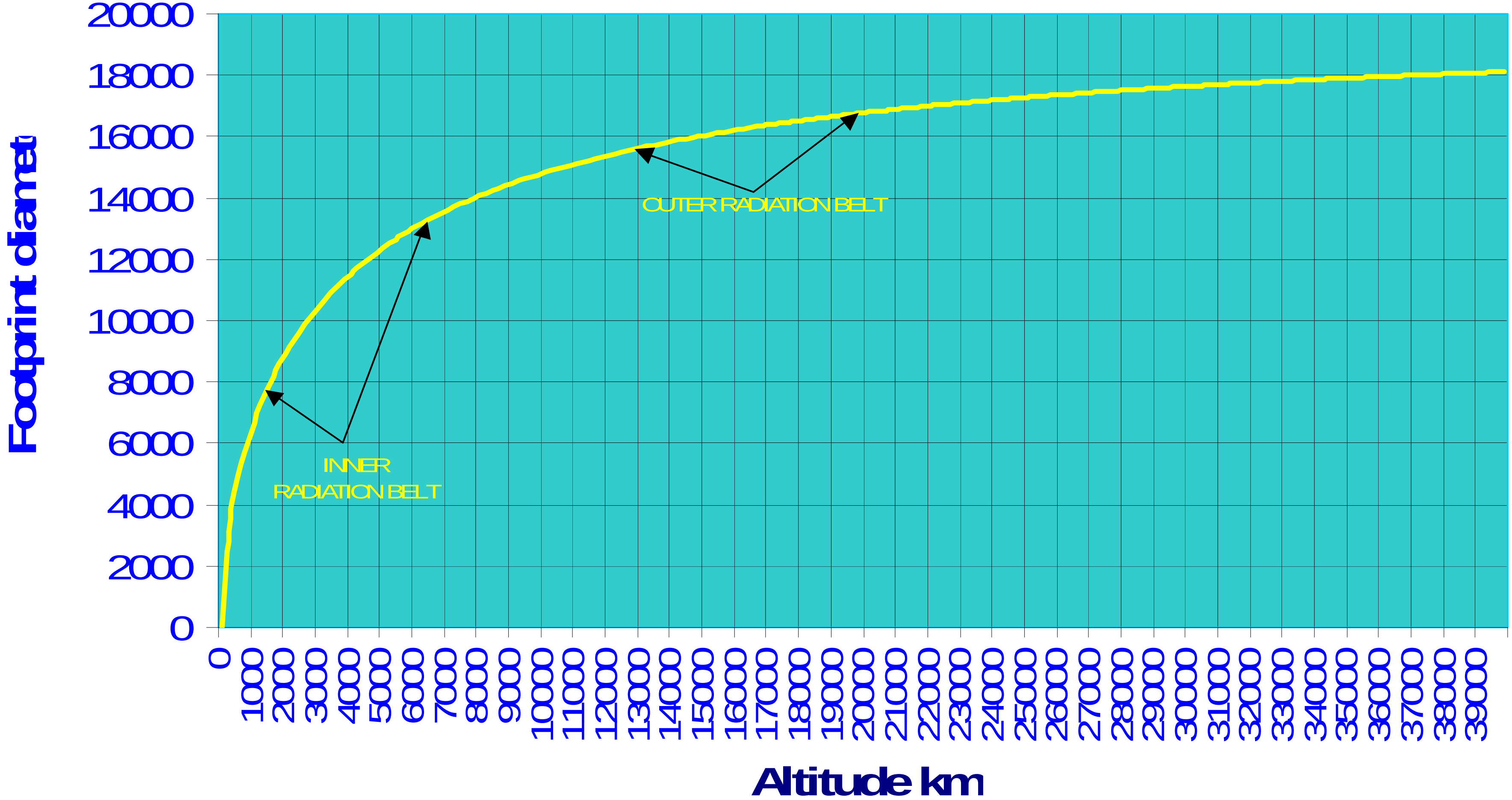

Satellite Communications Range
Footprint diameter km
0
2000
4000
6000
8000
10000
12000
14000
16000
Altitude km
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000

Satellite Communications Range



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Range Comparison for LEO MEO + HEO

LEO 200 – 2000km
MEO 2000 – 25000km
GEO 35786km
HEO (P3) elliptical Apogee 40,000km+

	Altitude	Communications range km
• AO51	780	6006
• MEO	7000	13687
• MEO	13000	15745
• P3	36000	18091

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Footprint of a Medium Earth Orbiting Satellite at an Altitude of 7200km

Advantages and Disadvantages of MEO

Advantages:

- Higher altitude = greater communications range
- A progression / higher skills level from LEO satellites
- Longer pass time. At 7000km altitude, a pass is 90 minutes
- Orbital transfer possible from low cost LEO launch

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Disadvantages:

- Direct flight to MEO unlikely. - Propulsion required.
- Mass of fuel represents loss of payload.
- Van Allen Radiation belts. – Risk to hardware.

Van Allen Radiation Belts

Lower radiation belt of protons appx. 1500km to 6000km

Upper radiation belt of electrons 13,000 to 20,000km

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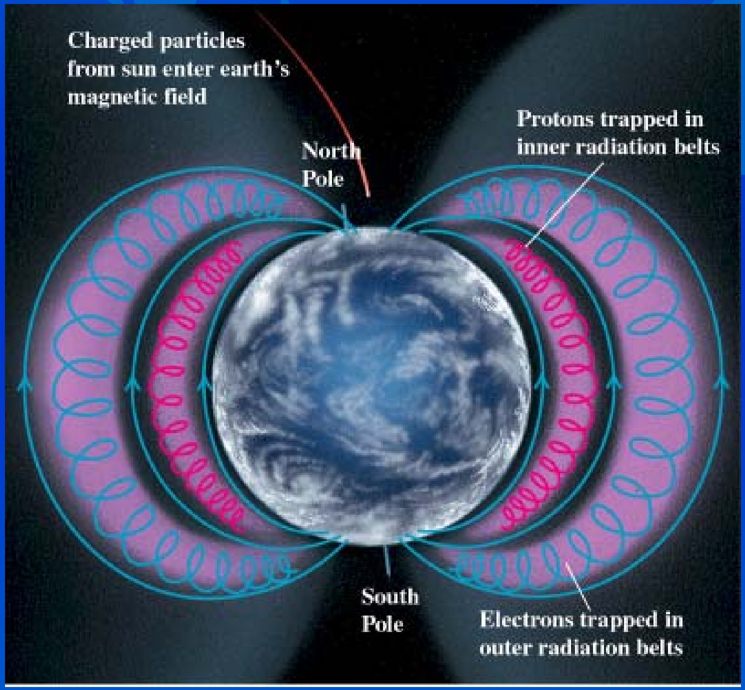

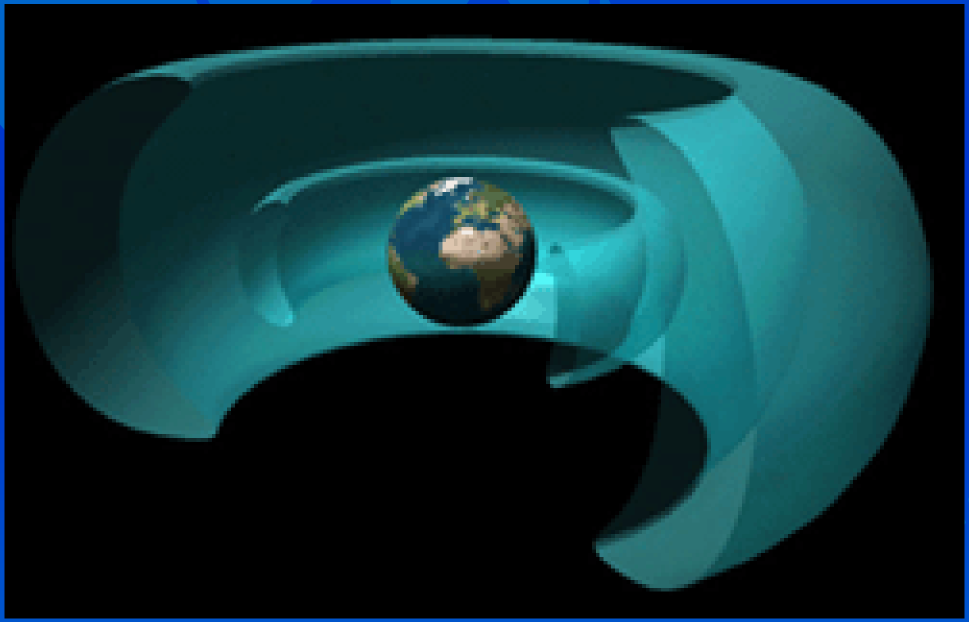

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Van Allen Radiation Belts

Amsat experience in the radiation belts.

• AO-10 operated for 3.5years in high radiation environment before suffering memory failure. Transponder continued for 10+yrs.

• AO-7 transponder has remained functional at 1500km for 34 years. Large total dose, but 1970's simple components appear tolerant.

Conclusion:

• Any MEOSat would benefit from rad hardened components, as evidence suggests COTS VLSI components vulnerable. Perhaps architecture using ACTEL FPGA as hardware controller would be suitable. Radiation hardened to 300k Rads + latch up immune. $5k

• As orbital lifetime at 7000km is very high, battery failure should not equal end of mission.

MEO Communications Link Budget

Satellite	Altitude km	Range km	70cm path loss	2m path loss
AO-51	750	2000	151.4	142dB
AO-40	35000	50000	179	169.7dB
MEO	7200	15000	165	155.4dB

For mode U/V   2m has 13.4dB greater path loss than AO-51

70cm has 14dB less path loss than AO-40

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Refer to paper for additional details or check with Jan King's Link budget calculator
However 320W ERP on U band uplink will reach the satellite. (30W + 9 element Yagi)
At the satellite, 4 Watts output on 2m will be sufficient for the return journey. GS 8dBic antenna

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Orbital transfer from LEO to MEO

- Due to the geometry of the radiation belts, a high inclination LEO is desirable

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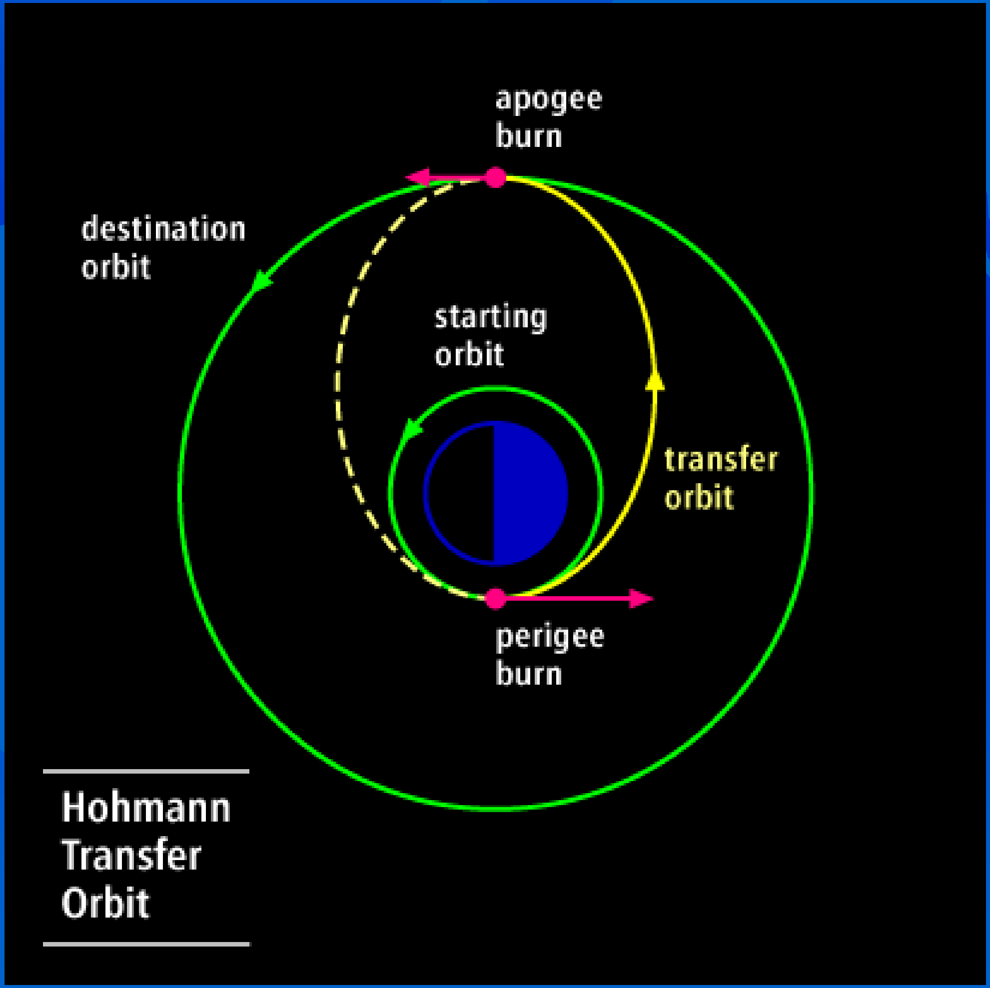
Orbital transfer from LEO to MEO

- Due to the geometry of the radiation belts, a high inclination LEO is desirable
- Raising orbit from 800km can be achieved in 2 stages. – Hohmann transfer



Orbital transfer from LEO to MEO

Propulsion technology	ISP
Cold gas	60
Mono propellant	220
Resistojet	120 - 220
Hybrid – Gas Oxidizer solid fuel	250
Bi Propellant	280
Arcjet	500
Hall effect Ion thruster	3000

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• To calculate required delta V and estimate fuel mass requirements use Excel spreadsheet by Achim Vollhardt DH2VA

Orbital transfer from LEO to MEO

Microsoft Excel - Copyofmeosat_propulsion

File Edit View Insert Format Tools Data Window Help Adobe PDF

E28 =

	A	B	C	D	E	F	G
1	**author: Achim Vollhardt, DH2VA**				mu=GM	3.98755E+14	
2					r_earth	6378000	m
3	circular orbit 1						
4	height	680	km	enter start orbit height in KM here			
5	r1	7058000	m				
6	v1=	7516	m/sec				
7							
8							
9	circular target orbit						
10	height	1500	km				
11	r2	7878000	m				
12	v2=	7115	m/sec				
13							
14	Hohmann Transfer Orbit						
15	semi-major-axis		a	7468000	m		
16							
17	V_perigee		7720	m/sec			
18	V_apogee		6916	m/sec			
19							
20							
21	delta_v(1)		204	m/sec			
22	delta_v(2)		198	m/sec			
23	delta_v(tot)		402	m/sec		THIS IS REQUIRED!	
24							
25	Isp		200	sec			
26	Launch mass		25	kg			
27	Empty mass		22	kg			
28	delta_v		251	m/sec		THIS IS POSSIBLE!	
29							

Meosat_propulsion spreadsheet.
Achim Vollhardt DH2VA

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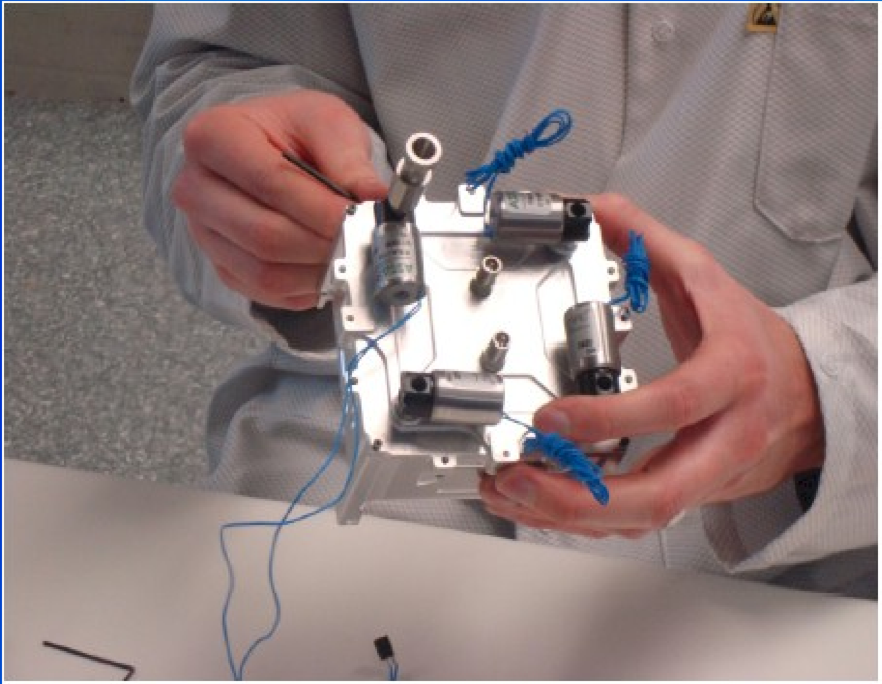
Propulsion Systems

An example of mono-propellant cubesat propulsion.



Picture by Chris Biddy / Dr. Thomas Svitek of Stella Exploration.

How does AMSAT get to LEO / MEO?

- Should AMSAT fully fund such a project?

- Launches: Historically AMSAT has used test flights –Ariane 4 / 5 but now Ariane and Soyuz are full cost commercial options.

- But there are other launchers currently being developed.

How does AMSAT get to LEO / MEO?

- Space-X Falcon 1
- Falcon 9 to GTO

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How does AMSAT get to LEO / MEO?

VEGA

- Maiden flight late 2009 from Kourou
- Max payload 1500kg
- ESA Education dept funded 9 cubesats on maiden flight
- 5 'VERTA' verification flight test program at 6 monthly intervals from maiden flight.
- Ability to deploy multiple payloads into different orbits.

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Medium Earth Orbit.
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Conclusions:

•Inclusion of simple propulsion can substantially increase coverage from high LEO / MEO

• We have 34 years of experience on the edge of the radiation belts

• Footprint from safe zone is 85% of coverage from HEO

• Arcjet propulsion can provide circular or elliptical MEO from LEO

• Propulsion technology is ‘shrinking’ in size and DC power requirement

• MEO in the safe zone offers opportunity for real science and partnership with commercial or research organization

• Science package with AMSAT functionality may be supported within ESA Vega verification flights

Thank you

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