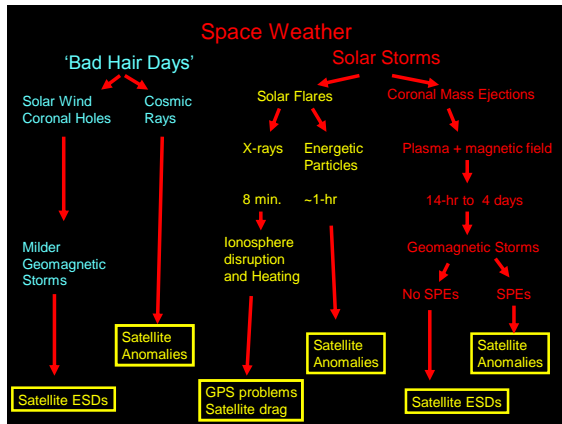


Severe Space Weather and Satellite Vulnerability

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Director of Planetary Sciences
NASA

American Meteorological Society: The Risks of Space Weather : April 12, 2016



Satellite Real Estate ca 2005

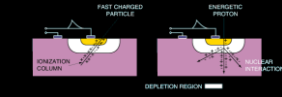
Location	Commercial	Military	Research	Total
LEO	273	94	70	437
MEO	19	101	12	132
GEO	308	51	8	367
Totals:	600	245	91	936

- Total Satellite Fleet (ca Dec, 2004)..... ~ 936
- Total invested hardware + launch costs..... ~ \$ 230 billion
- GEO Transponder Capacity..... ~ 6,800
- GEO industry annual revenue..... \$ 87 billion
- LEO + MEO satellite annual revenue..... \$ 10 billion
- Satellite Industry annual revenue..... \$ 225 billion

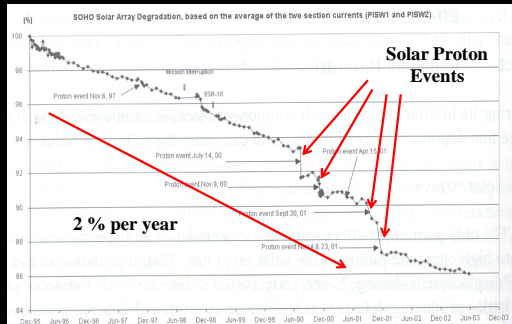
Operational GEO satellites ca 2015 = 419
Replacements launched after 2005 = 276

Physical Effects of Space Environment

- Low energy electrons
 - High energy electrons
 - Solar flare protons
 - Ionizing dose
 - Non-ionizing dose
 - Heavy ions/cosmic rays
 - Ultraviolet Light
- Surface charging (ESD)
 - Internal charging (IESD)
 - Solar array degradation
 - Electronics, material aging
 - CCD's, optical couplers
 - Single event effects
 - Solar panel surface degradation



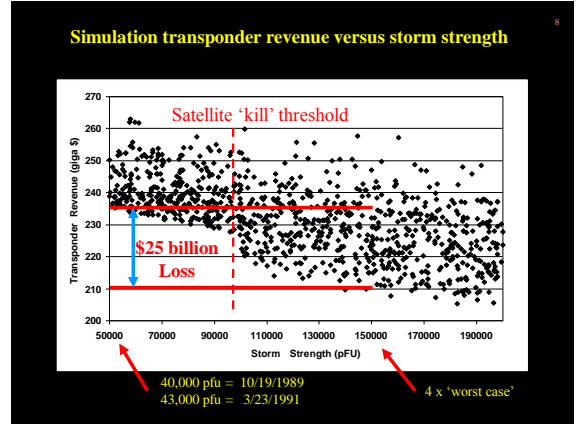
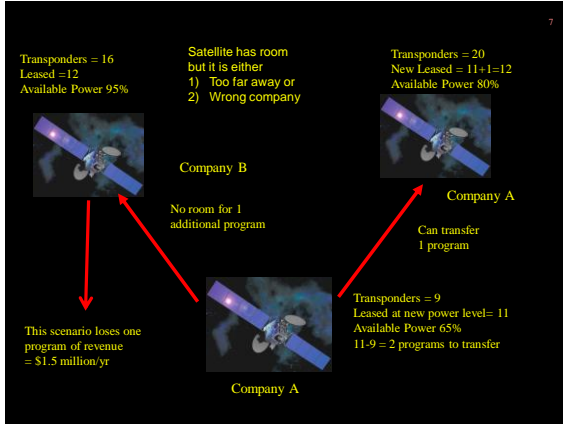
Satellites and solar power loss



Satellite Transponders as Revenue Generators

Name	Page	F	P	SR	PEC	Crypt	Satellite
Discovery Channel China Feeds	3764	Y	19950	3/4			Intelsat 8 (366.0°E)
Discovery	4140	H	19510	3/4	DigiQ...	AMC 11 (133.0°W)	
Discovery	4020	H	20270	3/4	DigiQ...	AMC 11 (133.0°W)	
Discovery Channel	4080	Y	28270	2/3	DVB-S2...	Intelsat 8 (366.0°E)	
Discovery Channel	2666	H	21060	3/4	DVB	Intelsat 3R, L1 (43.5...)	
Discovery Channel	3994	H	21090	3/4	DVB	Intelsat 3R, L1 (43.5...)	
Discovery Channel America Latina	3940	H	27690	7/8	PowerVu	Intelsat 9 (08.0°W)	
Discovery Channel America Latina	4160	Y	20270	3/4		SatMex 5 (116.0°W)	
Discovery Channel America Latina	3966	H	21090	3/4	PowerVu	Intelsat 3R, L1 (43.5...)	
Discovery Channel America Latina	3994	H	21090	3/4	PowerVu	Intelsat 3R, L1 (43.5...)	
Discovery Channel Argentina	3994	H	21090	3/4	PowerVu	Intelsat 3R, L1 (43.5...)	
Discovery Channel Australia	2764	Y	19950	3/4		PowerVu	Intelsat 8 (366.0°E)
Discovery Channel Belarus	12226	H	25540	7/8	PowerVu	Sesat 4 (4.0°E)	
Discovery Channel Belarus	12244	H	27320	3/4	DVB...	Arktis 1R (50.5...)	
Discovery Channel Brazil	3880	H	27690	3/4	PowerVu	Intelsat 9 (08.0°W)	
Discovery Channel Central Europe	12226	H	25540	7/8	PowerVu	Sesat 4 (4.0°E)	

C and K-band transponders are leased at \$1.5 million/yr



The good news is that GEO satellites are very robust!

- Plenty of reserve transponders
- Large solar panel power margins
- Satellite Anomalies are rare so MTP > 200 yrs vs 10-yr satellite life
- Lots of well-designed contracts to back up transponder failures
- Solar Cycle 24-25 predicted to be mild

Drop me a line.....
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Check out my space weather books on
 Amazon.com