

Evaluating the Present and Potential Future Impact of Small Satellites

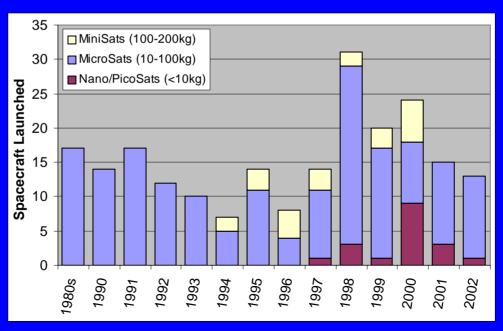
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Objective



- Answer the question—"Are small satellites a complimentary or a disruptive technology?"
 - Emphasis on the near to medium term
 - Largely qualitative analysis
- This is NOT an assessment of whether small satellites are useful
- Launch history:



Method: Market-Based Analysis



- Three market segments:
 - Military
 - Civil
 - Commercial
- Focus on U.S. market
- Growth can come from one of three means:
 - Displacement of larger satellites
 - Maintenance of existing market share in a growing market (arguably this is not disruptive but is just "riding the wave")
 - Creation of new markets

Military Space—Displacing Large Satellites



Major Military Space Programs as of 2001:

Program	Sponsor	Purpose	Mass (kg)
DSP	Air Force	Nuclear and missile warning	2400
DMSP	Air Force	Weather monitoring and prediction; to be replaced by NPOESS	1500
MilSatCom EHF	Air Force	Communications	~7000
MilSatCom Polar	Air Force	Communications	
T-SAT	Air Force	Communications	
GPS	Air Force	Precise position, velocity, and time transfer	1545
NPOESS	Air Force	Weather monitoring and prediction; co-sponsored by NOAA and NASA	~2000
SBIRS-High	Air Force	Nuclear and missile warning; replacement for DSP	
Space-Based Radar	Air Force	Moving target tracking; radar mapping	
Wideband Gapfiller	Air Force	Communications; successor to DSCS	6000
DSCS	Army	Communications	1235
MUOS	Navy	Communications	
Sat Comm Systems	Navy	Communications	

Displacing Large Satellites

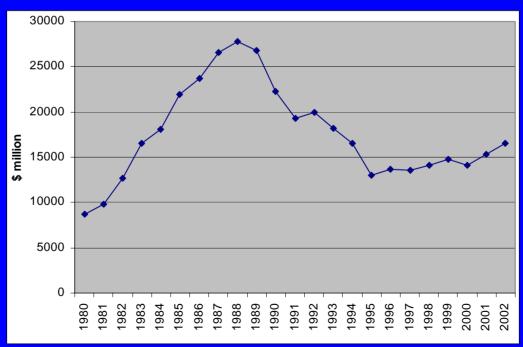


- Many of the systems are in highly elliptical or high altitude (e.g. GEO) orbit
 - Dictates the use of large launch vehicles even if the spacecraft are relatively small
 - Secondary launches are not an option for operational systems
- Power/aperture problem
 - Systems typically require high power (communications) and/or large apertures (communications and reconnaissance)
- Clusters of small spacecraft could theoretically perform the function of some large spacecraft
 - Technology is still too immature
 - Cost-effectiveness not sufficiently demonstrated

Military Space—Market Growth Potential



- Market is very large, but growth is modest (3.5% p.a. 1995-2002)
- Government funding will almost never show a large long-term growth rate



Military Space Budget Authority (constant 2005 dollars)

Military Space—Growth Opportunities



- Military showing increased interest in small satellites
 - Responsive capabilities
 - Space situational awareness
 - Space control
- Numerous efforts undertaken by the military or with military potential
 - Air Force XSS-10 and XSS-11
 - NASA Demonstration of Autonomous Rendezvous Technology
 - Surrey SNAP-1
 - Office of Force Transformation TacSat-1, TacSat-2
- DARPA FALCON program (separate from SpaceX Falcon-1 launch vehicle) aims to provide low-cost, responsive space lift capability for small satellites
- Interest is being shown, but funding is very small compared to the expenditures for large space systems

Civilian Space—Addressable Market



- Much of NASA's budget devoted to items other than spacecraft
 - \$5.8 billion of Science,
 Aeronautics, and Exploration available
 - \$450 million of Space Flight Capabilities available
- The \$6.25 billion must cover much more than spacecraft:
 - Science/research
 - Launch vehicles
 - Technology development
 - Mission and science operations
- Exploration Initiative is not likely to help small satellites

NASA 2004 Budget

Budget Line Item	Budget			
~	(US\$m)			
Science, Aeronautics, and Exploration	7,853			
Space Science	3,994			
Solar System Exploration	1,302			
Mars Exploration	596			
Astronomical Search for Origins	914			
Structure and Evolution of the Universe	456			
Sun-Earth Connection	726			
Earth Science	1,606			
Earth System Science	1,513			
Earth Science Applications	92			
Biological and Physical Research	986			
Biological Sciences Research	368			
Physical Sciences Research	357			
Research Partnerships & Flight Support	260			
Aeronautics	1,037			
Space Flight Capabilities	7,498			
Space Flight	5,890			
Space Station	1,494			
Space Shuttle	3,928			
Space and Flight Support	468			
Crosscutting Technology	1,608			
Space Launch Initiative	938			
Mission and Science Measurement	452			
Innovative Tech. Transfer Partnerships	218			
Inspector General	27			
TOTAL	15,378			

Civilian Space—Displacing Large Satellites

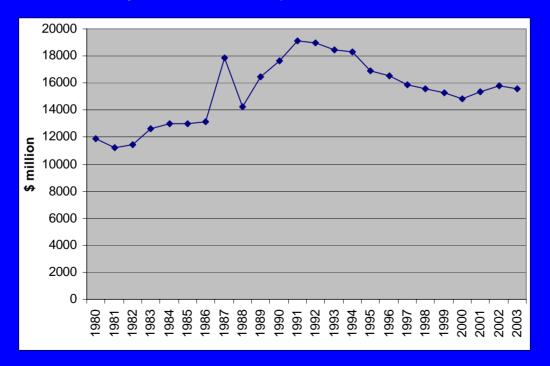


- A review of NASA's 2004 budget shows that most satellite expenditures are directed towards large spacecraft such as MER, JWST, EOS
 - Power/aperture problem makes it difficult to use small satellites
 - Interplanetary spacecraft require high-energy trajectories that discourage the use of small satellites
 - Need to precisely co-locate/co-align multiple instruments
- UNEX cancelled after approving two missions (one flown)
- MIDEX competition delayed by at least one year, overall Explorer program expected to see lower flight rates

Civilian Space—Market Growth Potential



- NASA budget has been trending downwards for more than a decade
- Budget increase sought for FY 2005, but Congress is resisting due to a tight budget environment
 - Additional money slated for Exploration Initiative



NASA Budget History (constant 2005 dollars)

Civilian Space—Growth Opportunities



- Some small satellite activity under way
 - ST-5
 - THEMIS (5 satellite MIDEX program)
 - Magnetosphere constellation (~100 micro-/nano-satellites)
 - Ongoing SMEX competition
- Overall, little near-term opportunity seen

Commercial Space



- Disruptive technologies typically gain acceptance and growth by enabling new capabilities and applications rather than by simply displacing existing technology
 - PC initially took hold because of word processing and spreadsheet applications; partial displacement of mainframes was a by-product
- This type of innovation is more likely to occur in the commercial marketplace than in government space programs
 - Especially true in the current risk-averse environment
- Therefore, commercial space is the most likely route for the emergence of disruptive small satellite technology

Commercial Space—Displacing Large Satellites



- Commercial space expenditures dominated by geosynchronous communications satellites
 - High orbit forces the use of large launch vehicles, which makes larger spacecraft far more cost-efficient
- New and growing market for high-resolution imaging
 - Aperture problem for small spacecraft

Commercial Space—Growth Potential



- LEO communications systems were technical successes but financial disasters
 - Iridium, Globalstar used mid-size spacecraft (690kg, 450kg, respectively)
 - ORBCOMM used micro-spacecraft (42 kg)
 - All three went bankrupt and were bought for a few pennies on the dollar; all now appear to be financially viable
 - ORBCOMM is pursuing next-generation spacecraft
- Surrey-led Disaster Monitoring Constellation suggests the presence of a modest market for medium-resolution imagery
- However, truly disruptive applications capable of generating billions in revenue have yet to be identified

Launch Cost Impact on Commercial Small Space



- Getting there is NOT half the battle
- ORBCOMM example:
 - \$800 million invested
 - Launch costs represent
 9% of total investment

ORBCOMM Estimated Launch Costs

S/C	Launch Vehicle	Year	Est. Cost
FM1-2	Pegasus (w/ MicroLab-1)	1995	\$10m
FM5-12	Pegasus	1997	\$14m
FM3-4	Taurus (secondary)	1998	\$5m
FM13-20	Pegasus	1998	\$14m
FM21-28	Pegasus	1998	\$14m
FM30-36	Pegasus	1999	\$15m
35 spacecraft, 6 launches			\$72m

- IRIDIUM example:
 - 93 spacecraft launched prior to bankruptcy
 - Assuming \$10,000/kg, \$690 million in launch costs
 - Delta 2 (5 spacecraft) \$34.5 million
 - Long March (2 spacecraft) \$16 million
 - ~\$5.5 billion invested prior to bankruptcy
 - Launch costs represent 13% of total investment
- Venture capitalists typically look for >30% annual return on investment, so even if launch costs were zero, they would only make a marginal system look viable
- The problem is on the revenue, not the cost side of the balance sheet

Educational Institutions—Another "Market"



- Small satellites have been a disruptive impact to space education
- CubeSat program lists 66 universities and four high schools participating
 - 16 countries on 6 continents
- Other government-sponsored efforts aimed at educational institutions
 - UNEX
 - University Nanosatellite-2
 - University Nanosatellite-3

Conclusions



- At present small satellites are a complementary technology in the military, civilian, and commercial space marketplace
 - Small satellites are making very valuable contributions
 - Total expenditure dwarfed by that spent on large satellites
- Although small satellites have some growth potential, explosive growth consistent with a disruptive technology is unlikely
 - Military space spending shows only a modest growth rate
 - NASA spending has been declining
 - Within at least the commercial market, launch vehicle costs are not a primary roadblock
- Small satellites will remain a complementary technology for the foreseeable future