Practical Microsat Launch Systems: Technology and Economics

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Overview

- Introduction
- The MLS: Status and Requirements
- Recent History and Current Initiatives
- Technology: Factors and Lessons Learned
- Cost Factors and Cost Survey Results
- Costs and Markets
- Guidelines for MLS Development
- Conclusion
Introduction

- What is the MLS?
  - MLS: An affordable, responsive, reliable, dedicated Microsat Launch System
  - MLS Payload capacity: Goal of NASA’s 1996 Bantam program (150 kg to polar LEO)
    is a good definition

- Given potential of U.S. market and difficulties of exporting payloads, a dedicated American-built MLS is vital to realizing the potential of microsatellites
  - Accordingly, focus of this paper is an American MLS

- Can a low-cost MLS be built, and how?
  - Several American efforts in last two decades have failed – not built, or not cheap
  - Need to learn lessons from these programs, or success is unlikely

- True MLS solution must cut costs enough to expand the microsat market, remove launch cost as a constraint
MLS: Status and Requirements

- So far, market has supported only one U.S. small launcher at a time
  - NASA-developed Scout was primary for 30 years
  - Privately-developed Pegasus has been primary last 13 years
    - Pegasus reliable but costly – 280kg (polar LEO) for ~$20M (.071 $M/kg)*

- Current launch options for microsats
  - Shared space only works for certain orbits, schedules
  - Many US payloads have trouble being exported
  - Shuttle rides rarely available
  - Dedicated launchers too expensive for most academic, government programs
  - Hard to keep programs alive while waiting for launch opportunity

- Bottom Line:
  - NO ONE on payload side thinks current situation is good

* NOTE: All cost figures in this briefing converted to Fiscal Year 2004
MLS: Status and Requirements

- Hard to quantify number of microsat projects NOT pursued for launch reasons, but demand is real
  - Examples:
    - DoD Space Test Program can launch only 20% of approved payloads
    - Other DoD projects (Picosat, XSS-10) delayed years for a launch
    - DoD - University Nanosatellite Initiative (planned as 10 satellites on shuttle in 2001) now three missions, but no launch dates
    - Other satellites (CATSAT, Starshine 4/5) in storage, no launch dates

- ASCENT Study (for NASA by Futron, 2003):
  - Small payload market most affected by launch costs
  - Science payloads will show some increase if price is cut moderately
  - A 75% cut in launch costs = 200% increase in science flights through 2021

- Bottom Line:
  - There IS a substantial market for more microsat launches – but NOT at current prices
Lessons from Recent History

- What recent efforts failed, and Why?
  - SSI Percheron – financing failed after first test vehicle exploded
  - EER Conestoga – financing failed after first launch attempt failed
  - PALS Liberty – Financing failed after Pegasus won a DARPA small-launcher contract
  - MicroSat Launch Systems Orbital Express – unable to land contracts, secure financing
  - AeroAstro PA-X – canceled as economically unfeasible
  - NASA Bantam – Goal of 150 kg to 370km polar LEO for $1.65M (FY04 $)
    - Four study contracts let, but NASA felt none would meet cost goal
  - Minuteman-based MSLS (Lockheed-Martin) – severely restricted by DoD policy, Air Force ended up placing no orders
  - Orbital/Suborbital Program (Orbital Sciences) – succeeded, but didn’t cut costs

- Common Threads
  - Inadequate financial resources
  - Inability to recover from initial failure
  - Inability to meet cost targets
Current Initiatives

- Several efforts have reached at least initial hardware development or test.

- Current examples, with performance (approx. to Polar LEO) and cost (total price to customer) goals:
  - Microcosm Sprite – liquid-fuel, modular “pod” design, 220 kg for $2.5M*
  - SpaceDev Streaker, hybrid motor, 315 kg for under $10M
  - Space-X Falcon – liquid fuel, reusable 1st stage, 350 kg for $6M
  - AFRL/VS F-15-launched microsat launcher, solid fuel, 100 kg for $5M
  - DARPA RASCAL – radical high-performance aircraft launch, 110 kg for est. $1.25M

- Other efforts in planning stages include:
  - Balloon-launch systems – JP Aerospace, HARC, Starhunter
  - Ground-launch: Rocket Propulsion Engineering, Thurber Space Systems, E’

- New factor – DoD interest - DARPA pursuing FALCON Small Launch Vehicle
  - Interest in responsive, cheap small launcher offers possible source of R&D funding

*NOTE: Manufacturers’ cost estimates were accepted as given, except to add range and FTS costs if not included
MLS Technology

- **Launch Mode:**
  - All launch modes investigated
  - Pads offer lowest infrastructure costs, with tradeoffs in flexibility
  - Most successful small launchers pad-launched, but Pegasus shows exceptions possible

- **Rocket Design:**
  - Solid, liquid, and hybrid all in development, with 2-5 stages
    - Basic Scout and Pegasus launchers were all-solid
    - Russian/Ukrainian small launchers successful with all liquids
  - Other debates: pressure fed v. pump-fed, composite tanks v. aluminum, all-expendable v. partly reusable, conventional stages v. grouped “pods,” etc.
  - So far, no clear “best practice” in MLS design
MLS Costs

- Small launchers v. large launchers: lower per-mission costs, higher costs per kg
  - Small launchers must be compared in their own category, NOT to larger launchers

- Surveyed for this study: Nine MLS vehicles (two in service (Pegasus and Minotaur), seven in development)
  - Ancillary cost (e.g., range use, licensing, range-accepted FTS) yields a fixed cost of ~$1M range for any MLS launch price

### Small Launcher Cost Breakdown

<table>
<thead>
<tr>
<th>Item</th>
<th>% of Launch Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propulsion</td>
<td>25.7</td>
</tr>
<tr>
<td>Mission Support Labor</td>
<td>25</td>
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<tr>
<td>Amortization of DD&amp;E</td>
<td>21.4</td>
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<tr>
<td>Assembly Labor</td>
<td>8.6</td>
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<tr>
<td>Avionics</td>
<td>8.6</td>
</tr>
<tr>
<td>Flight Termination System and Range</td>
<td>7.1</td>
</tr>
<tr>
<td>Structures</td>
<td>4.3</td>
</tr>
</tbody>
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Components of Cost for a Hypothetical “Minimum-Cost” Small Launcher

Source: Presentation by Dr. Antonio Elias, Orbital Sciences, 3 Apr 2003
Microsat Launchers: Payload Weight vs. Cost

Weight vs Cost

R² = 0.4617

(Includes flight-proven systems)
Microsat Launchers: Payload Weight vs. Cost

Weight vs Cost

R² = 0.5567

Capacity to Polar LEO in kg

Cost (FY04$M)

0 5 10 15 20 25

0 100 200 300 400 500

$1.5 $1.3 $2.5 $2.8 $5.0 $10.0

(Excludes flight-proven systems)
Microsat Launchers: Desires of Payload Developers

MLS Developer Estimates of Cost and Performance needs
(Data: Bantam goal, 6 payload developers, one payload market study by a launch company)
Microsat Launchers*: The Possible vs. The Desirable

MLS Developer Estimates of Cost and Performance compared to Payload Developer Desires

*Does not include the flight-proven launches
Analysis: Costs and Markets …The Chicken or the Egg ???

- As demonstrated by the tradespace, there is a demand for an affordable MLS which is not met by the supply.

- There is market elasticity in both directions:
  - If the satellite developers had affordable launches, they would develop more.
  - If the launch developers were assured of more payloads, the cost would decrease.

- What else do the surveys indicate?
  - Need to examine technology to reduce risk (cost and technical).
  - Lower R&D costs would have major impact on the MLS costs.
  - This demonstrates that tension exists between possibly advantageous new technology and the investment needed to develop it.
  - Nevertheless, consistency of cost/payload estimates from different companies using different designs indicates projections on new vehicles are fairly reliable.

MLS development is possible w/in a cost range appealing to the Payload developers’ expectations.
Guidelines

- No single technology path to success:
  - Advantages of technology vs. risk require careful balance
  - Design to cost (including operability, low mission support labor cost) is more important than maximizing performance
  - MUST keep the project simple – no forcing of “pet” requirements or technologies

- Reliance for R&D costs on investors who need near-term payback from launch revenue is unworkable
  - Per Elias estimate, such payback adds over 20% to cost of a launch
  - Breaking cost paradigm requires internal or government R&D funding which will not affect launch prices

- Rules for the Successful MLS Developing Organization:
  - Be lean, dedicated organization with minimal overhead
  - Have access to secure funding without fluctuations
  - Be able to withstand first-launch failure
  - Be able, after demonstrating vehicle, to wait for market to respond
Conclusion

- There is a demand for MLS
- No evidence a lower-cost small booster is NOT possible
  - Challenge: Make MLS cheap enough to expand the market
  - Keys are design and management to minimize cost
- Cost estimates indicate that developers, payload builders can find common ground
- Bottom Line: MLS CAN be done – if done right!

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