Nano-Launcher: Dedicated Nanosatellite Payload Delivery Service

2010 CubeSat Developers' Summer Workshop | 07-08 August 2010 | Logan, Utah USA

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Nanosatellite Revolution

- Sputnik shock => Gagarin shock => Man on the moon => CubeSat shock?
- Globalizing and Internationalizing ORS Standards and Technology (GIST)
- PnP spacecraft architectures accelerate modularization and standardization
- Advances in nanosatellite technologies, developers, and missions
- Strong demand for an affordable nano and micro-sat dedicated launch vehicle

Image sources: Aerospace Corp, U-Tokyo, Titech, Calpoly, SSTL, Boeing, NASA, UTIAS, tudelft, U3P, US-Army, Boeing, DARPA, AFRL, INSA, Northrop Grumman

Nanolaunch capability is critical to the sustaining the innovation wave in nano-space

Number of Attempted Small Satellites Launches:
2000-2009 for 1-500 kg Satellite Class
Source: SpaceWorks Commercial Global Small Satellite Launch Database

Yearly Launch History:
2000-2009 for 1-50 Kg Satellite Class
Source: SpaceWorks Commercial Global Small Satellite Launch Database

Long term forecasting (2010-2014) indicates growing market for launch services

More detailed paper to be presented at AIAA Space 2010 on market assessment:

Notes:
• The database contains all attempted launches. Unless otherwise indicated all data points mentioned below refer to attempted launches.
• It should also be noted that the number of satellites launched may not equal the number of launches in any given year since many satellites are multiple-manifested (i.e. more than one satellite on a particular launch).
• Many times in this presentation, the term “launch” or “launches” may refer to the number of satellites launched (even though they may be multiple-manifested).
NanoLauncher
Dedicated Nanosatellite Delivery to Low Earth Orbit

Existing Aircraft + Mostly Existing Solid Rocket

suborbital

orbital
Vision

- Develop a customer-oriented, dedicated small payload launch service that is robust, reliable, and scalable to service an underserved niche of the launch market
  - Orbital (NanoLauncher Black), Suborbital (NanoLauncher Blue)
- Air-launch offers potential interesting launch and range capabilities
  - Initial launch site in U.S. with potential for global expansion
- Use lessons learned from past incomplete programs
  - Base system on mostly existing elements wherever possible (aircraft, rockets, payload integration), evolution of technology
  - Design to general capability and not requirement ("flexible path")
  - Leverage other development projects (aircraft, range, avionics)
  - International partnerships to allocate overall risk over multiple parties, leverage best range, global customer marketing
    - IHI Aerospace (IA), SpaceWorks Commercial, USEF, and CSP Japan

Note: SpaceWorks Commercial, a division of SpaceWorks Engineering, Inc. (SEI) is registered with the U.S. State Department (DDTC) as an exporter of defense services and as a broker, SEI is in the process of obtaining a Technical Assistance Agreement (TAA) for the NanoLauncher project
SpaceSpike-1 and 2: Solid Rocket Elements of NanoLauncher

<table>
<thead>
<tr>
<th>Existing</th>
<th>Under Consideration</th>
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<tbody>
<tr>
<td>S-520</td>
<td>SS-520</td>
</tr>
<tr>
<td>NS-520</td>
<td>NL-520</td>
</tr>
<tr>
<td>SpaceSpike-1</td>
<td>SpaceSpike-2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>S-520</th>
<th>SS-520</th>
<th>NS-520</th>
<th>NL-520</th>
<th>SpaceSpike-1</th>
<th>SpaceSpike-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Length</td>
<td>8.0 m</td>
<td>9.65 m</td>
<td>10.7 m</td>
<td>12.7 m</td>
<td>5.4 m</td>
<td>10.0 m</td>
</tr>
<tr>
<td>Diameter</td>
<td>0.52 m</td>
<td>0.52 m</td>
<td>0.52 m</td>
<td>0.52 m</td>
<td>0.52 m</td>
<td>0.52 m</td>
</tr>
<tr>
<td>Weight</td>
<td>2.1 ton</td>
<td>2.6 ton</td>
<td>2.9 ton</td>
<td>3.4 ton</td>
<td>1.2 ton</td>
<td>3.2 ton</td>
</tr>
<tr>
<td>Stages</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Ground Launch

- **Current Capability**
- **Capability A**
- **Capability B**

Air-Launch

- **Capability C**
Candidate Air-Launch Carrier Aircraft Options

- Various candidate aircraft are being examined with various rocket combinations
- Factors of lease versus buy options and applicability to orbital and suborbital missions

F-104  F-15D  SU-27  F-4

Final aircraft + rocket combination under assessment

NanoLauncher Trajectory Profile:
SU-27 + SpaceSpike-2 Configuration

Final aircraft + rocket combination under assessment
NanoLauncher Blue (suborbital): F-104 / F-15 D + SpaceSpike-1

Final aircraft + rocket combination under assessment
Payload Accommodation

Current Standards
- P-POD, NPSCul, RocketPods, SPL, ISIPOD, A-POD
- Independent Japan systems (T-POD, PHS, X-POD)

Future Standards
- Next generation P-POD (1U to 6U+)
- Nanosatellite Launch Adapter System (NLAS)

A. Minimum Service Concept
- Deployment Signal Only
- Payload-Provided Separation System

B. Full Service Concept
- Power & Telemetry
- Launch Vehicle-Provided Separation System

International cooperation on standards is key, fully treating nanosatellites as primary payloads may unlock greater mission capabilities
Technology Development: B0 Motor

- Used to accelerate the NS-520 and the NL-520 to subsonic velocity
- Static firing test was successfully conducted in 2010

**B0 MOTOR Specification**

<table>
<thead>
<tr>
<th>Item</th>
<th>Design</th>
<th>Test Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>$\phi 524$ mm</td>
<td>$\leftarrow$</td>
</tr>
<tr>
<td>Length</td>
<td>2,580 mm</td>
<td>$\leftarrow$</td>
</tr>
<tr>
<td>Propellant</td>
<td>445 kg</td>
<td>444 kg</td>
</tr>
<tr>
<td>Maximum Thrust</td>
<td>288 kN</td>
<td>330 kN</td>
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</table>

(Sea Level)
Technology Development: 
Miniaturized and Low-Cost Avionics System

- Proactive use of COTS components/parts including semiconductor relay and MEMS

**Size of Avio-Section**

**Requirement of Avionics Box**
- Size
  - 50 (max) x 100 (max) x 120 (max) UNIT: mm
- Mass: less than 1kg/each

**Avionics System Target Mass**

<table>
<thead>
<tr>
<th>Item</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GN &amp; C</td>
<td>8</td>
</tr>
<tr>
<td>Data Acquisition and Telemetry</td>
<td>11</td>
</tr>
<tr>
<td>Power Control and Supply</td>
<td>8</td>
</tr>
<tr>
<td>Flight Termination RT &amp; Command</td>
<td>19</td>
</tr>
<tr>
<td>Flight Termination Power Supply</td>
<td>6</td>
</tr>
<tr>
<td>TOTAL</td>
<td>52</td>
</tr>
</tbody>
</table>

**Avionics System Functional Block Diagram**

**Prototypes of Miniaturized and Low-Cost Avionics**
Roadmap: IA Rockets to NanoLauncher Service

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<tbody>
<tr>
<td><strong>Capability A</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preliminary Design</td>
<td>Critical Design</td>
<td>Manufacturing</td>
<td>NS-520-1 Launch</td>
<td></td>
</tr>
<tr>
<td>NS-520 Avionics component manufacturing and test</td>
<td>Including development test</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **Capability B** |        |        |        |        |
| Preliminary Design | Critical Design | Manufacturing | NL-520-1 Launch |
| NL-520 Development of upper stage |
| Development of GN&C avionics for Nano Launcher |

| **Capability C** |        |        |        |        |
| Commercialization & Business Model | Partnership & Financing | Incorporation | Launch Service |
| SpaceSpike-1 (SS1) | ATP Separation Test from Aircraft | Launch Test from Aircraft |

Note: ※ Japanese fiscal year: from April 1 to March 31.
NanoLauncher Summary

- The nanosatellite wave will be an important force in the 21st century space launch environment (Historical and anecdotal evidence indicates growth)
- A dedicated NanoLauncher for such satellites is currently being designed to service such a market
  - The NanoLauncher is air-launch nano-satellite orbital payload delivery system
  - Based upon multi-stage derivatives of ISAS/JAXA’s S-520 solid rocket coupled with an existing aircraft
  - Potentially for nano and micro satellites orbital delivery
  - Secondary missions for suborbital payloads
- International partnerships with private companies and institutional bodies is deemed to be a key strategy for overall risk reduction, global operability, schedule reduction and customer marketing
- Status
  - On-going technical and economic design proceeding (aircraft and rocket combinations including F-104, F-15D, SU-27, and F-4),
  - Customer pricing forthcoming
  - Solid rocket hardware and avionics development in Japan
  - Systems integration analysis and business development in the U.S.
  - Open to discussions with customers on payload accommodations
  - Open to discussions with potential risk-sharing partners
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