Evolutional Launch Concept for Pico/Nano Satellites

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**Mr. Seiji Matsuda, Mr. Nobuhiro Sekino, Mr. Kazuhiro Yagi, Mr. Yasunobu Segawa**
IHI AEROSPACE CO., LTD.  |  matsuda-s@iac.ihi.co.jp  |  Tomioka-shi, Gunma, Japan

**Mr. A.C. Charania**
SpaceWorks Commercial  |  ac@sei.aero  |  Washington, D.C., U.S.A.

**Mr. Takayoshi Fuji**
Institute for Unmanned Space Experiment Free Flyer (USEF)  |  fuji@usef.or.jp  |  Tokyo, Japan

**Mr. Hideki Kanayama**
CSP Japan, Inc.  |  kanayama@csp.co.jp  |  Tokyo, Japan

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
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
IHI Aerospace Co. Ltd. (IA) Overview

- IHI Aerospace Co., Ltd. (IA) is Japanese Solid LVS Manufacturer
  - Employees: 1,000 (approx.)
  - Revenues: US$400 million (approx.)
  - Major Customers: JAXA, MOD, METI (NEDO, USEF)

- History:
  - 1924 Aircraft engine plant of Nakajima Aircraft Industries. Co., Ltd.
  - 1945 Fuji Sangyo Co., Ltd.
  - 1950 Fuji Seimitsu Kogyo Co., Ltd.
  - 1961 Prince Motor Co., Ltd.
  - 1966 Nissan Motor Co., Ltd.
  - 2000 IHI Aerospace Co., Ltd.

IHI Aerospace Co. Ltd. Mission Statement:
We respect originality, innovation, and harmony with society, and contribute to realization of the human beings' dream, social peace and development with the rocket related technologies.
IA Solid Rocket Heritage

- IHI Aerospace Co. Ltd. (IA) has been a leading company in solid rocket Launch Vehicle System (LVS) development within Japan
  - Sounding rocket flights: Over 1400
  - Satellite orbital rocket flights: 27

**Launch Campaigns**

<table>
<thead>
<tr>
<th>L-4S-5</th>
<th>S-310</th>
<th>S-520</th>
<th>SS-520</th>
<th>M-V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japanese first satellite LVS (1970)</td>
<td></td>
<td></td>
<td>NanoLauncher Rocket Sources</td>
<td></td>
</tr>
</tbody>
</table>

Launch Campaigns:
- L-4S-5: 39
- S-310: 24
- S-520: 2
- SS-520: 7
- M-V: 7

Image Source: NanoLauncher
SpacE Spike-1 and 2: Solid Rocket Elements of NanoLauncher from IA

<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>
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<tr>
<td>Diameter</td>
<td>0.52 m</td>
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<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>
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<tr>
<td>Stages</td>
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<td>2</td>
<td>4</td>
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</table>

**Ground Launch**

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

**Air-Launch**

- **Capability C**
Candidate Air-Launched 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

NanoLauncher Black (orbital) Preliminary Capability (payload to LEO):
SU-27+ three-stage SpaceSpike-2
20 kg to LEO
(to 250 km Circular LEO, 28.5 degree inclination launch site)

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

NanoLauncher Blue (suborbital) Preliminary Capability (time above 100 km):
F-104 + two-stage SpaceSpike-1

Final aircraft + rocket combination under assessment
Payload Accommodation

Current Standards
- P-POD, NPSCuI, 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
- Payload Provided Separation System

International cooperation on standards is key, fully treating nanosatellites as primary payloads may unlock greater mission capabilities.

NanoLauncher
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>
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<tbody>
<tr>
<td>Diameter</td>
<td>ø524 mm</td>
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</tr>
<tr>
<td>Length</td>
<td>2,580 mm</td>
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<tr>
<td>Propellant</td>
<td>445 kg</td>
<td>444 kg</td>
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<tr>
<td>Maximum Thrust</td>
<td>288 kN</td>
<td>330 kN</td>
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(Time: Thrust vs. Time; Measurement vs. Prediction)
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) mm
  - 100 (max) mm

- Mass: less than 1kg/each

**Avionics System Target Mass**

<table>
<thead>
<tr>
<th>Item</th>
<th>Mass (kg)</th>
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<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</td>
<td>RT &amp; Command 19, Power Supply 6</td>
</tr>
<tr>
<td>TOTAL</td>
<td>52</td>
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</table>

**Avionics System Functional Block Diagram**

**Prototypes of Miniaturized and Low-Cost Avionics**
Technology Development: Avionics Testing Process

- New functional and environmental testing method
- Simplified vehicle health check using self-diagnosis system
- Reinforcement of system integration technology

Environmental Testing
Highly Accelerated Life Testing (HALT)

System Functional Testing
Use an Integrated Simulation Platform (with HALT)
# Top-Level Roadmap: IA Rockets to NanoLauncher Service

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<td>Team Formation</td>
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<td>Ground Launch</td>
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<td>Test: NS-520</td>
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<td><strong>Capability B:</strong></td>
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<td>Capability C.1</td>
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<td>SpaceSpike-2</td>
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<td>✭ Flight or Demonstration</td>
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<td>☀ Operational Milestone</td>
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**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
Seiji Matsuda, Nobuhiro Sekino, Kazuhiro Yagi, Yasunobu Segawa
IHI AEROSPACE CO., LTD.
900 Fujiki Tomioka-shi Gunma Japan; +81-274-62-7684
matsuda-s@iac.ihi.co.jp

A.C. Charania
SpaceWorks Commercial, a division of SpaceWorks Engineering, Inc. (SEI)
ac@sei.aero

Takayoshi Fuji
Institute for Unmanned Space Experiment Free Flyer (USEF)
Kanda-ogawamachi Chiyoda-ku, Tokyo Japan; +81-3-3294-4834
fuji@usef.or.jp

Hideki Kanayama
CSP Japan Inc.
2-2-2 Uchisaiwai-cho, Chiyoda-ku, Tokyo Japan; +81-3-3508-8105
kanayama@csp.co.jp