NEW PATHWAYS TO ORBIT

CUBESAT DEVELOPERS WORKSHOP

APRIL 24, 2019

Tyvak
A Terran Orbital Corporation

COMPANY OVERVIEW

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Tyvak Nano-Satellite Systems, Inc. was created to address unfulfilled and growing small spacecraft needs

- Founded in 2011
- Headquartered in Irvine, California, USA
- ~120 employees
  - Blend of Industry Innovators and Experienced Professionals
- We develop miniaturized custom spacecraft, launch solutions, and aerospace technologies for commercial, defense, intelligence, and scientific programs

Tyvak Launch Office in San Luis Obispo, CA

- Independent line of business from satellite development
- NASA, DoD, International, and Commercial launch customers
- Located 30 minutes from Tyvak's manufacturing facility
- Located 45 minutes from Vandenberg AFB

LAUNCH SERVICES

Redefining the path to orbit

Tyvak is the premiere launch integrator for nanosatellites and microsatellites for commercial and government organizations. We coordinate and secure launch opportunities with nearly every launch provider in the world. We have a proven track record of delivering 203 satellites to orbit with 100% success.

Utilizing our flight-proven satellite deployers and the expertise of our launch integration services team, we tailor our service to your specific launch program needs. This includes:

- Conducting the full complement of launch integration analysis
- Accommodating spacecraft-unique requirements
- Range Safety Approval (including propulsion systems)
- Interface control documentation and verification
- Executing agile launch services in as little as 90 days

TYVAK LAUNCH HISTORY

TYVAK LAUNCH HISTORY

Launch Vehicles

- Arianespace Soyuz
- Arianespace Vega
- Eurockot Rockot
- ISRO PSLV
- Kosmotras Dnepr
- Orbital Sciences Minotaur C
- Orbital Sciences Minotaur 1
- Orbital Sciences Minotaur 4
- Orbital Sciences Taurus XL
- SpaceX Falcon 1
- SpaceX Falcon 9
- SpaceX Falcon Heavy (in work)
- ULA Atlas V
- ULA Delta II
- NASA SLS (in work)
- RocketLab Electron

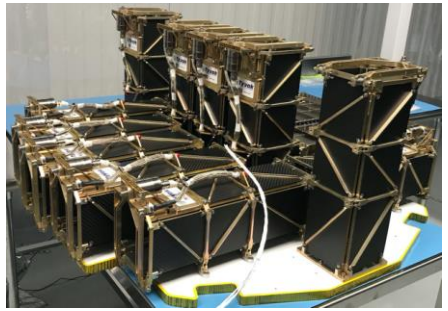


Photo courtesy of Rocket Lab

Space Ports

- Vandenberg AFB, USA
- Cape Canaveral AFS, USA
- NASA Wallops, USA
- Reagan Test Site, Kwajalein
- Guiana Space Center, Kourou
- Baikonur Cosmodrome, KZ
- Yasny Launch Base, Russia
- Plesetsk Cosmodrome, Russia
- Satish Dhawan Space Centre, India
- Mahia Peninsula, New Zealand

Customers

- NASA LSP
- NASA MSFC
- NASA JPL
- NRO
- DoD
- ESA
- ULA
- RocketLab
- Various US Commercial
- Various US Universities
- Foreign Govt./Comm./Univ.

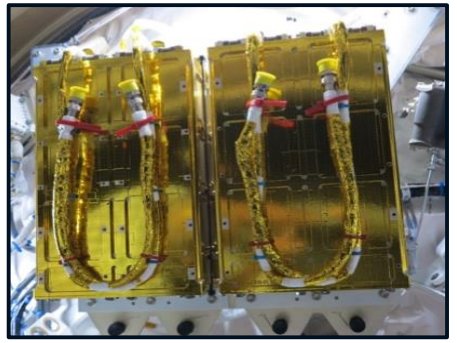
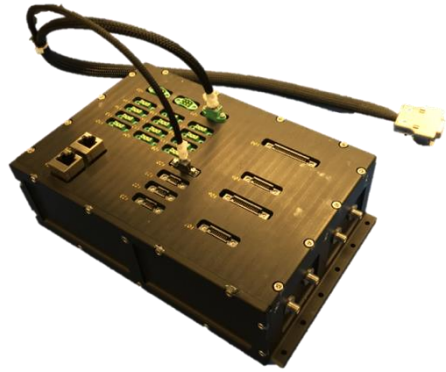


Photo courtesy of ULA

Photo courtesy of Northrop Grumman



AGGREGATED TYVAK LAUNCH SYSTEMS

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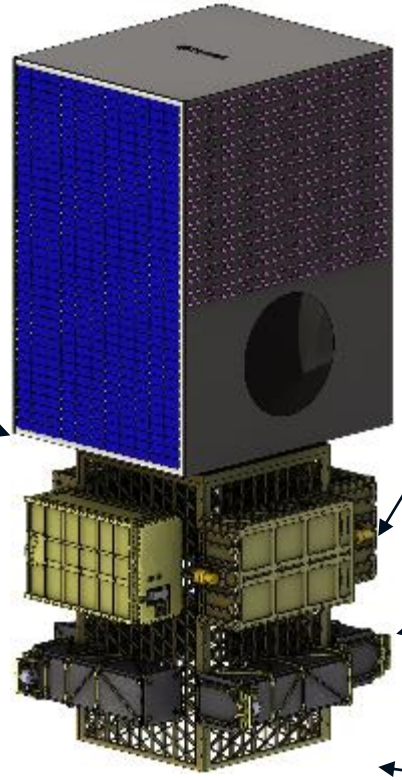
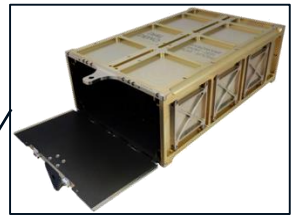
Small Launcher Payload Stack (INCA)

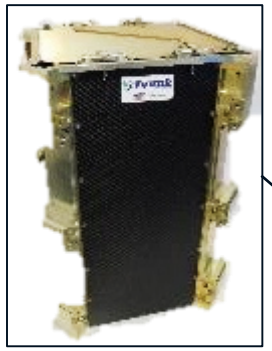


Tyvak ESPA Mount

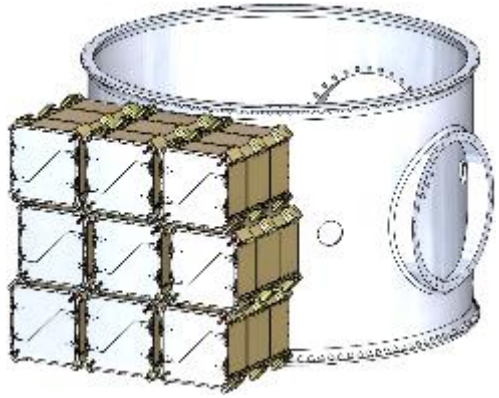
Tyvak 6U



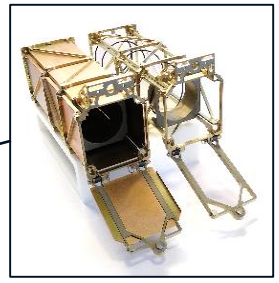
Tyvak 12U



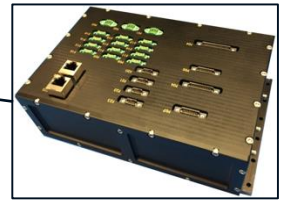
ESPA Grande Accommodations



Tyvak 3U



Tyvak Avionics/Sequencer



TYVAK LAUNCH SOLUTIONS

Government Launch Solutions

- Partnered with Parsons on the Launch Manifest Systems Integrator contract in support of U.S. Air Force (USAF) Space and Missile Systems Center's (SMC) Launch Enterprise Directorate.
  - Partnership leverages Tyvak's history of:
    - CubeSat integration on medium and launch vehicles with EELV/NSS class primary Payloads
    - Integration of payload on small launch vehicles similar to VCLS class launches
- Continuing CubeSat integration support of STP and LSP missions on Falcon Heavy and SLS

Commercial Launch Solutions

- Providing Launch solutions for nearly all of our current spacecraft customers
  - Includes 20+ satellites to be launched in the next 18 months
- Commercializing formerly government launch solutions such as ULA's CubeSat Express
- Offering Launch solutions as a separate service for non-Tyvak built spacecraft

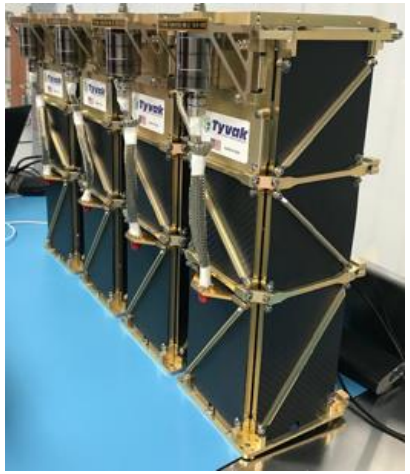
TYVAK SATELLITE DEPLOYMENT SYSTEMS

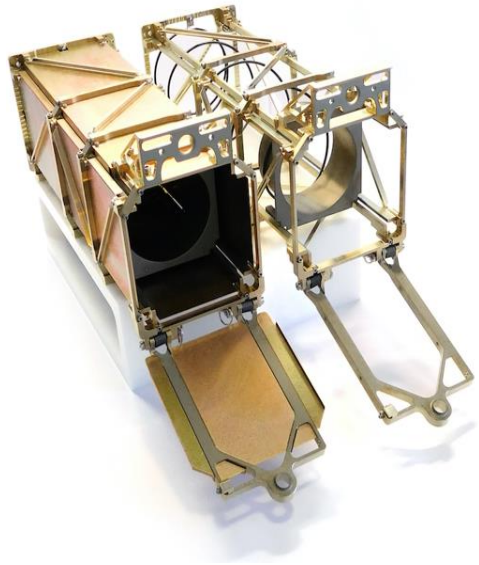
RailPOD 1U-3U

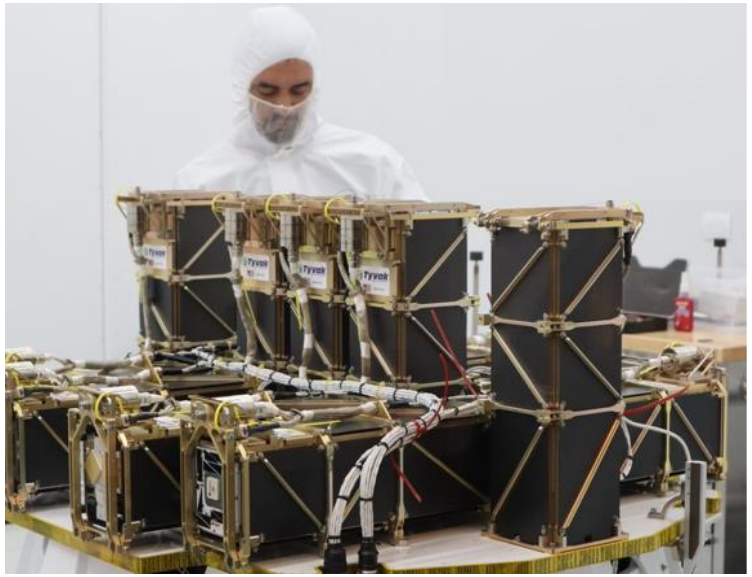
Tyvak RailPOD (1U-3U)

- Developed for use on small launchers with a strong structural chassis while maintaining light weight and low cost
- Incorporates carbon fiber composite technology and aluminum manufactured parts optimized for rapid call up.
  - On the Minotaur-C/Planet launch, Tyvak manufactured and delivered five flight RailPODs in six weeks from request
  - Can be easily configured and re-configured for horizontal or vertical mounting to LV
- Flight history includes Minotaur-C, PSLV, and Electron

3U RailPODS Separation on Orbit
Photo courtesy of Rocket Lab



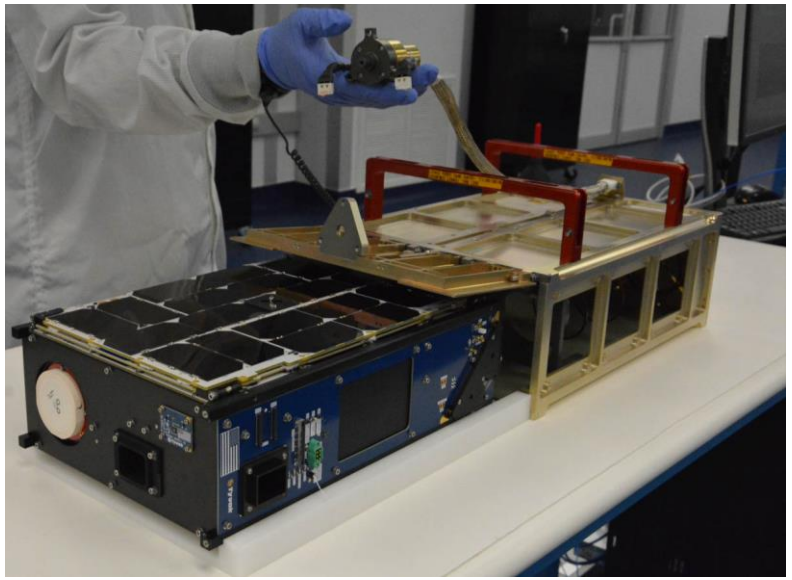




3U RailPODS Readied for flight
Photo courtesy of Rocket Lab

6U DEPLOYER - NANOSAT LAUNCH ADAPTER SYSTEM (NLAS)

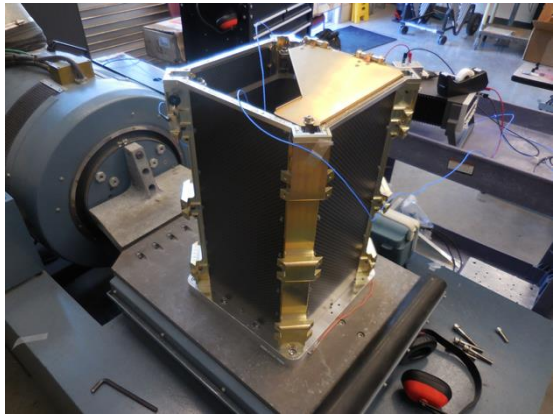
- Tyvak's 6U NLAS deployer and launch integration service team is the first to send CubeSats to Mars
- Can be configured to deploy two 3U satellites
- Developed in partnership with NASA
- Flight heritage since 2016 on multiple commercial and US Govt/DoD launch vehicles



12U DISPENSER - OVERVIEW

- The Tyvak 12U Dispenser was developed for highly sensitive spacecraft and builds on customer feedback combined with Tyvak flight heritage
- The Dispenser is designed with a 3-axis isolation system built directly into the dispenser chassis – eliminating the need for expensive, volume-consuming external isolation system
  - Uses elastomeric isolators, low outgassing aerospace-qualified silicone
- The dispenser employs 4-corner pivoting smooth and continuous rails which move in to cradle the spacecraft during launch and retract to release and deploy
  - Creates an analyzable boundary condition between payload and dispenser
- An optional door allows for expansion into previously unusable volume. The satellite is supported by the four rails in all axis, and the door is not load bearing
- Single hold down and release mechanism to actuate deployment
  - Payload is spring ejected upon deployment
  - Tunable with low tip-off rates
- Completed performance characterization and flight certification
- Launch of the 12U Dispenser is set for later this year

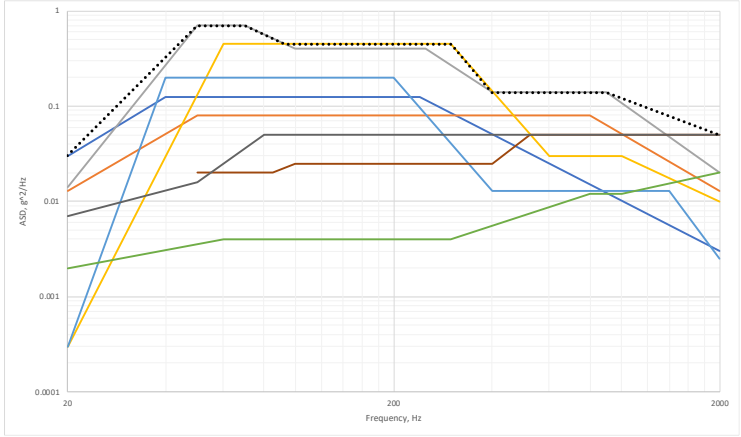
Tyvak 12U Dispenser



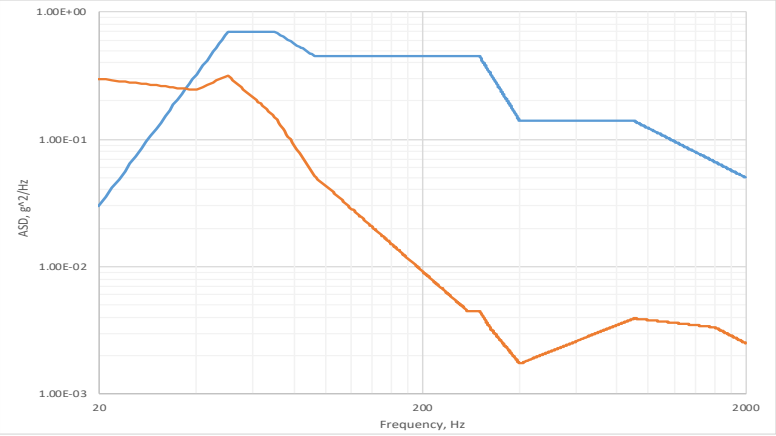
DISPENSER SUMMARY

- Tyvak Internally Isolated Dispensers provide reduced satellite response
  - NLAS Dispenser (1U-6U) typically ~ 20-90%. Attenuation starts around 70Hz. Some amplification at low frequency
  - 12U Dispenser: ~70-90%. Attenuation starts around 40Hz. Some amplification at low frequency
  - Also eliminates the need for customized, expensive, volume-consuming external isolation system
- Tyvak 12U solves the problem of “floating” rail CubeSat with nonlinear response
  - Cradling rails create an analyzable boundary condition
- Significant for developer
  - Can focus on the space mission rather than surviving launch
  - Reduce satellite structural mass: accommodate more payload
  - Higher probability of surviving test regiment and launch

Enveloping Levels (Black dotted line)



Enveloping Levels, Isolated Prediction



MicroSatellite Separation System (ESPA and ESPA Grande)

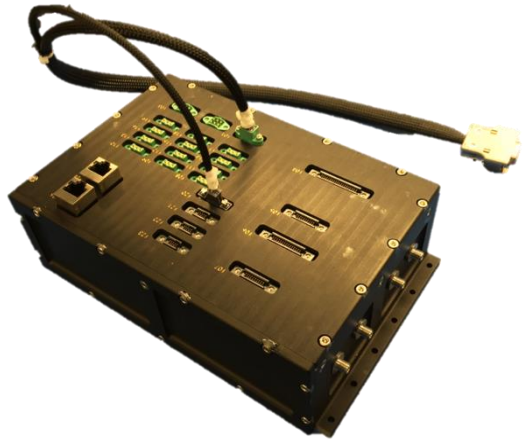
Tyvak Multi-Point Microsatellite class Separation System - PODS

- Tyvak's Multi-Point ESPA class pod mount system in development and allows for flexible placement of discrete launch vehicle interface attach points
- This system allows the spacecraft to place launcher interface points where load paths optimize the space mission and accommodate large CG offsets – and not design everything around launch loads
- Minimizes residual mass and hardware on the spacecraft post deployment
  - Nearly all of mechanism mass remains on the launch vehicle post separation
- First launch manifested for 2020

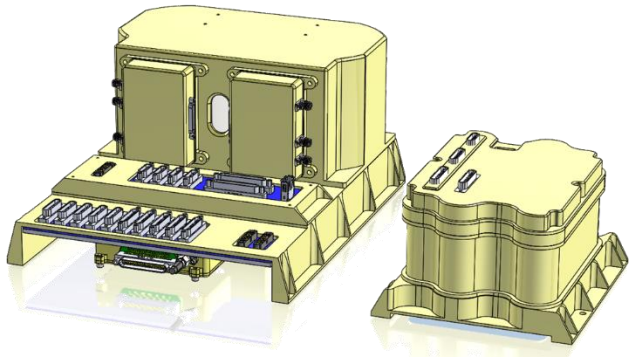
TYVAK NEXT GENERATION AVIONICS

Micro-Avionics Multi-Purpose Platform (MicroAMPP)

- Tyvak's Micro-Avionics Multi-Purpose Platform (MicroAMPP) is a complete avionics package designed for launch vehicles and orbital carrier vehicles
- Based on Tyvak's microsatellite avionics architecture, MicroAMPP provides maximum performance for less Size-Weight-and-Power (SWaP) and Cost than other avionics packages.
- MicroAMPP provides vehicle GN&C, TT&C, and multiple actuation / separation / deployment events.
- MicroAMPP ensures mission success with:
  - Single or Dual-String Command and Data Handling and radiation hardened watchdog
  - Redundant MEMS Inertial Measurement Unit
  - Upgradable to use Tyvak Star Trackers
  - Uplink/downlink over S-Band and/or UHF



Heritage design taken to TRL 7



Evolved Form Factor Currently in Development

QUESTIONS?

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