Quick-Turn, Low Cost Spacecraft Development Principles

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Logan, Utah
Tyvak Introduction

- We develop miniaturized custom spacecraft, launch solutions, and aerospace technologies for defense, intelligence, and scientific programs.

- We provide cost-effective solutions by utilizing agile aerospace processes and leveraging advanced commercial-off-the-shelf (COTS) electronic components.

- We design and manufacture sophisticated embedded software electronic devices such as avionics systems.

- Our team represents the leaders in aerospace miniaturization.

- We have supported 56 programs to date with 100% customer retention.
Tyvak: Satellite Solutions for Multiple Organizations

- **Facts and Figures**
  - Tyvak Nanosatellite Systems founded in 2011
  - Holding Terran Orbital Corp. founded in 2014
  - Tyvak International founded in 2015
    - Fully independent European establishment

- **3 locations, > 40 employees**
  - Irvine, CA
  - San Luis Obispo, CA
  - Torino, Italy
Current Complexity Trends for Tyvak

- Lots of applications
  - GPS Radio Occultation
  - Advanced Optics Demonstrations
  - Atmospheric Science
  - RF Signal Processing
  - Technology Demonstrations

- Challenges faced
  - Large variety of mission requirements
  - Delivering to a variety of customers
  - Satellites growing in complexity, size and numbers concurrent with company growth.

- Launching 15 satellites in 2016 and 2017
Addressing these challenges

• Company Structure, Processes, and Mission Assurance are key to addressing these challenges
• The design itself is usually fine, as it's the area that gets the most attention
• A tool is needed to comprehensively track the following during AIT:
  – Budget (materials and time-keeping)
  – Purchase Orders
  – Schedule
  – Requirements
  – Risks
  – Document Control and Approvals
  – Inventory
    • As-Run Procedures
    • Supplier Non-Conformance
    • Digital Traveller
Assembly Integration and Test Mission Assurance

Contract & SOW

Requirements

Schedule

Budget

Document Control

Assembly Procedures

Test Procedures

Schedule and Status Updates

Requirements

Risks

Inventory Control (QR Code)

Quality Inspections

Digital Traveler

As-Run Procedures

Real-Time

Budget Status

Timekeeping

PO Generation

Issue Documentation

and Resolution

ITAR

Compliant Servers

Program Managers

VPN

Design Engineers

VPN

AIT Personnel

VPN

Accounting

VPN
Satellite Testing Approach

- How do we maximize the effectiveness of hardware and software testing to achieve high levels of mission assurance at a lower cost?
- Three areas need to be considered:
  - Maximize test coverage throughout the AIT process.
  - To the greatest extent possible, test as you fly.
  - Ensure data produced during tests is accessible and easily analyzed for anomalies.
Test Coverage and Test Flow – Is the as-built unit functional as designed? Is functionality degraded at any point during qualification or acceptance testing?

The final satellite build QR code includes a nested list of every assembly, and component contained within it, tracing a complete time-tagged history of hundreds of parts.
Test as you Fly – Hardware in the Loop (HITL) and Ground Software. Will the current system configuration (HW and SW) complete the mission?

- AIT vehicle level testing uses ground operations software during all functional checkouts
- Flight Software verifications through HITL simulations.
  - Below is an example of V-Bar hops from 20m, to 7m, to 0.5m with station-keeping between hops.
  - During the run, the navigation filter diverged, and the Fault Detection system issued (correctly) an abort command.
  - The same models can be deployed for Monte-Carlo analysis.

A config file parameter was changed over a UHF command from the ground station

Truth Models Include:
- Gravity, and Gravity Gradient
- Solar Pressure
- Atmospheric drag and torques
- Magnetic Field
- Earth Rotation, Nutation, and Precession

The simulation was re-run and the system held at 0.5m for several hours.
Data Review – Who reviews the data, and how?

- During a 3 day TVAC test with two vehicles, each with >200 sensors, the data volume is massive.
  - Excel is not the tool for this level of analysis. Python is much better suited.
  - All sensors must have operational ranges defined.
  - Smarts to pick out telemetry points operating outside acceptable range.
  - Ability to easily query telemetry database for custom plots.
  - Generate basic analytics on the data (max / min, averaging windows, etc).

Docking Magnet Turn On  
S-Band File Downlink  
Propulsion Sims

![Graph showing temperature changes over time for CPOD FLT1 TVAC External TCs](chart.png)
Closing Comments

• The mission assurance aspect of nanosatellites is ripe for innovation
• This innovation is iterative from program to program. Rapid program turn-over offers a short feedback loop.
• There is no agreed to standard for nanosatellite mission assurance currently. Different customers have different expectations. I believe the approach discussed gains the same benefits of traditional mission assurance (or maybe 97% of the way) with significantly reduced overhead.
  – The cost delta to achieve that final 3% is potentially enormous. It’s the cost to address the perceived risk on the program. e.x. Is this particular lot code from this one manufacture suitable for flight, or is it a program risk that requires it be tracked, and discussed on a weekly call. The only actionable risk reduction is to redesign the board, or parts from the lot be radiation tested. Neither are practical.

• Our approach is to focus time, money, and effort on mission assurance aspects that offer measurable benefits, while producing tools to streamline team communication and documentation. The last 3% will be gained when large numbers of complex nanosatellite launch and operate. The perceived risk is then evaluated against flight historical data, and likely deemed unnecessary.
• The value proposition to this new approach for large constellations is readily apparent, and necessary. Enforcing the 3% is ironically (in my opinion), the number one risk for a large nanosatellite constellation program.