Tyvak's Approach to Mission Assurance

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SmallSat Reliability Technical Interchange
Pasadena, CA

Re-statement of the Challenge

- The potential for SmallSats to enable or enhance mission objectives or to provide other meaningful benefits is attracting broad interagency interest. The performance of these platforms however, often precludes infusing them and their systems into missions where significant risk of failure is unacceptable. This, and the inability to quantify SmallSat mission risk or mission confidence are barriers to infusion.

Initial Thoughts / Reactions to Challenge: RISK

- How do we define “significant risk?”
  - If the ideal mission has a 0.5% chance of failure (for arguments sake), at what cost / complexity / size reduction is a 5% chance of failure acceptable, if ever?
  - If the $100m program produces a 0.5% failure rate, with a single spacecraft launched. Is that equivalent to a $10m program that launches 10 satellites, each with a 5% chance of failure?
- Simple argument, but over-simplification due to common-mode failures.

Methodical Approach to Risk Reduction

- Start with what's within our control, and provide tangible, measurable cost, schedule, and risk reduction.
  - Implement AS9100 with less overhead.
  - Ensure a tight feed-back loop among engineers from program to program.
  - Focus on program test flow, and look for ways to innovate.
- Institutional knowledge is built over program life-cycles.
  - How do we expedite this?
  - What telemetry is considered "invaluable" from a risk assessment stand-point?
  - Program life-cycles will help address the Long Term Challenges.
- Long Term Challenges
  - Thermal cycling in tough environments
  - Tin whiskers (when does this become a big concern? What types of packaging should be avoided?)
  - Radiation and COTS components. (A radiation hardened processor does not make your system rad-hard. What is powering that rad-hard processor?)
- These challenges are made difficult with 3rd party procurements.

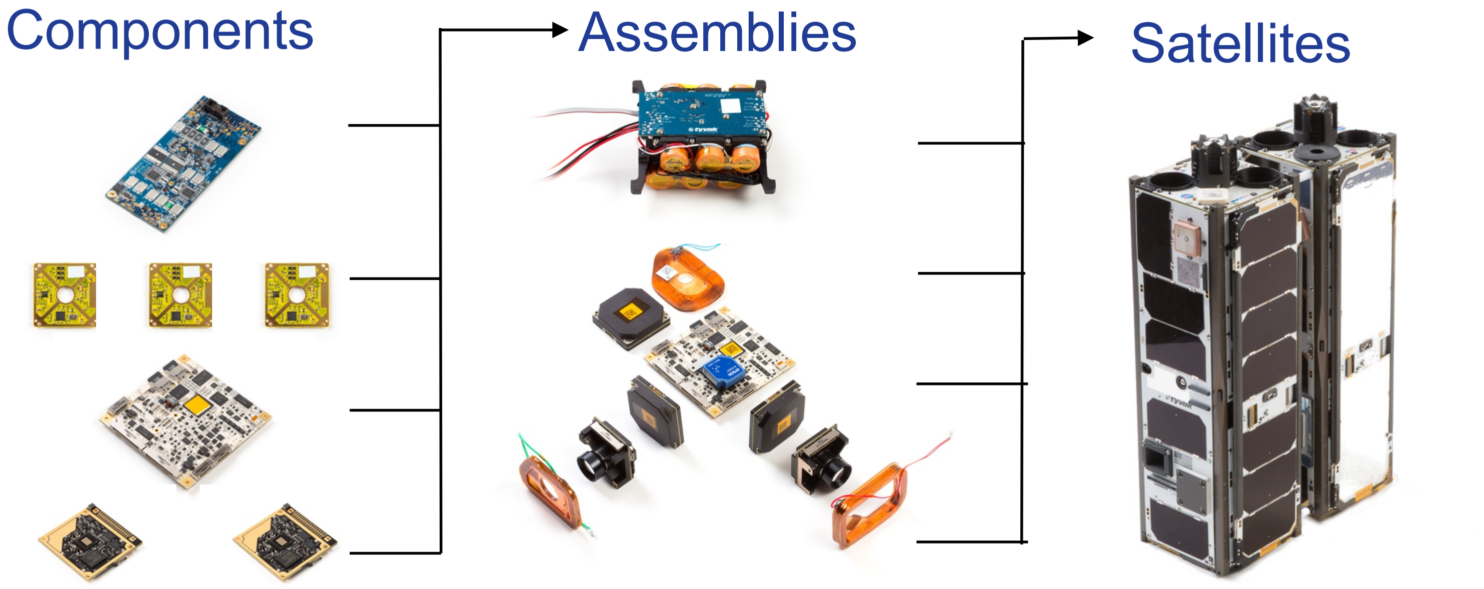
Radiation

- Performing operationally relevant missions in tough radiation environments requires the right combination of:
  - Mission profile (long duration or disposable secondary's?)
  - Funding
  - Development timeline
  - Ability to test as you fly
  - Control of parts selection
  - Control of system design, and sub-system element interactions
  - Gusto (risk tolerance)
- Finding the right combination of the above enables a mission. Learning from those missions over time is the holy grail for this community.
- How do we make that happen?
- Anybody want to go to GTO?

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?



Components

Assemblies

Satellites

Incoming Quality Control (Mechanical Parts, PCBs, Solar Cells, COTS Items)

1. Assign QR Code (digital traveler)
2. Visual Inspection
3. Assign to Inventory or Project
4. Record component specific info
5. Attach as-run test or modification procedures

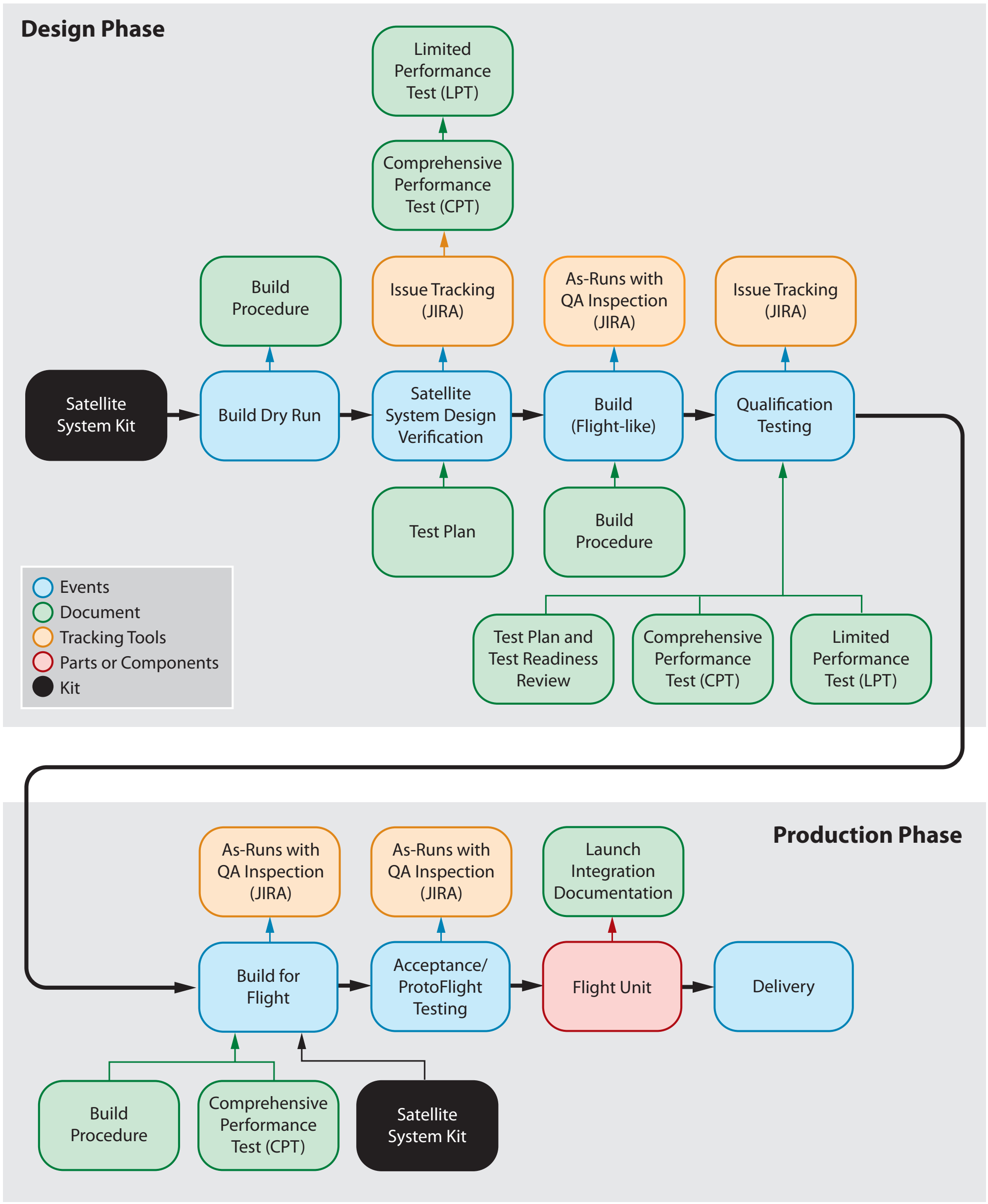
Higher-Level Assemblies

1. Assign QR Code (digital traveler)
2. As-run Assembly Procedures
3. As-run Test Procedures

Final Vehicle Assemblies

1. Assign QR Code (digital traveler)
2. As-run Assembly Procedures
3. As-run Test Procedures

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.



Design Phase

Limited Performance Test (LPT)

Comprehensive Performance Test (CPT)

Build Procedure

Issue Tracking (JIRA)

As-Runs with QA Inspection (JIRA)

Issue Tracking (JIRA)

Satellite System Kit

Build Dry Run

Satellite System Design Verification

Build (Flight-like)

Qualification Testing

Test Plan

Build Procedure

Test Plan and Test Readiness Review

Comprehensive Performance Test (CPT)

Limited Performance Test (LPT)

○ Events
○ Document
○ Tracking Tools
○ Parts or Components
● Kit

Production Phase

As-Runs with QA Inspection (JIRA)

As-Runs with QA Inspection (JIRA)

Launch Integration Documentation

Build for Flight

Acceptance/ ProtoFlight Testing

Flight Unit

Delivery

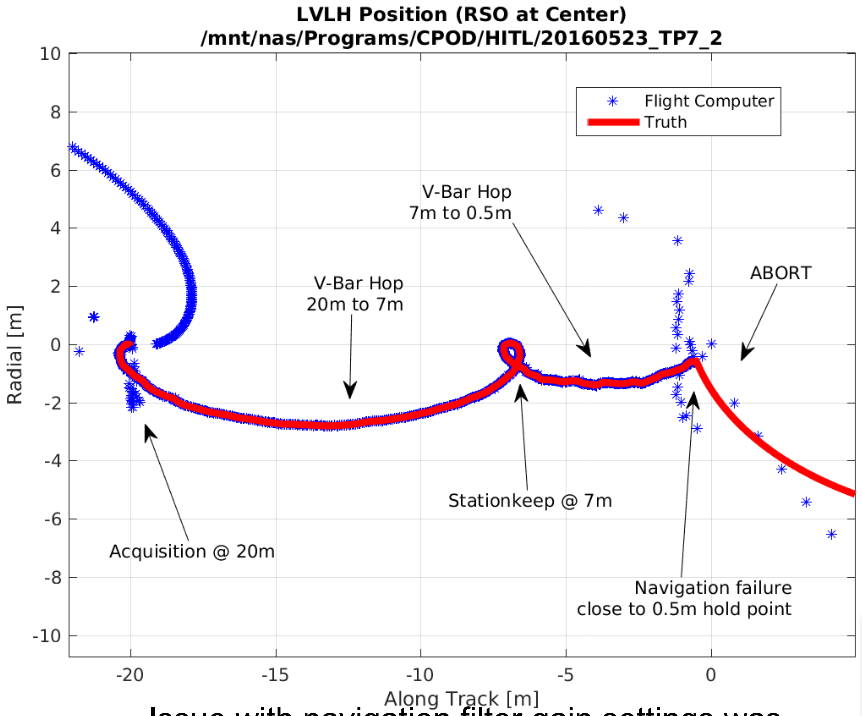
Build Procedure

Comprehensive Performance Test (CPT)

Satellite System Kit

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



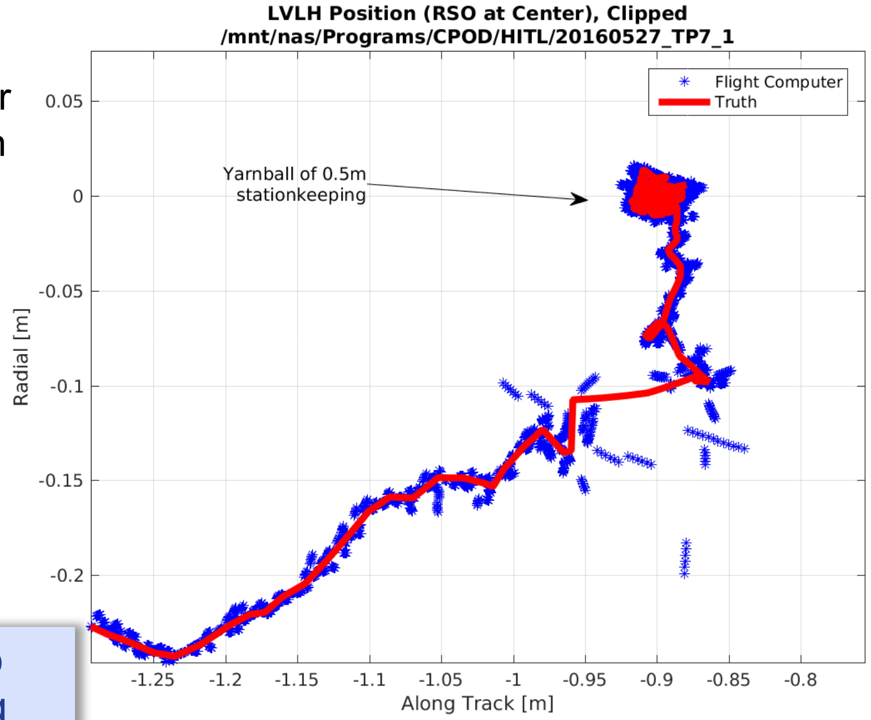
Issue with navigation filter gain settings was identified which caused an abort at 0.5m hold point

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

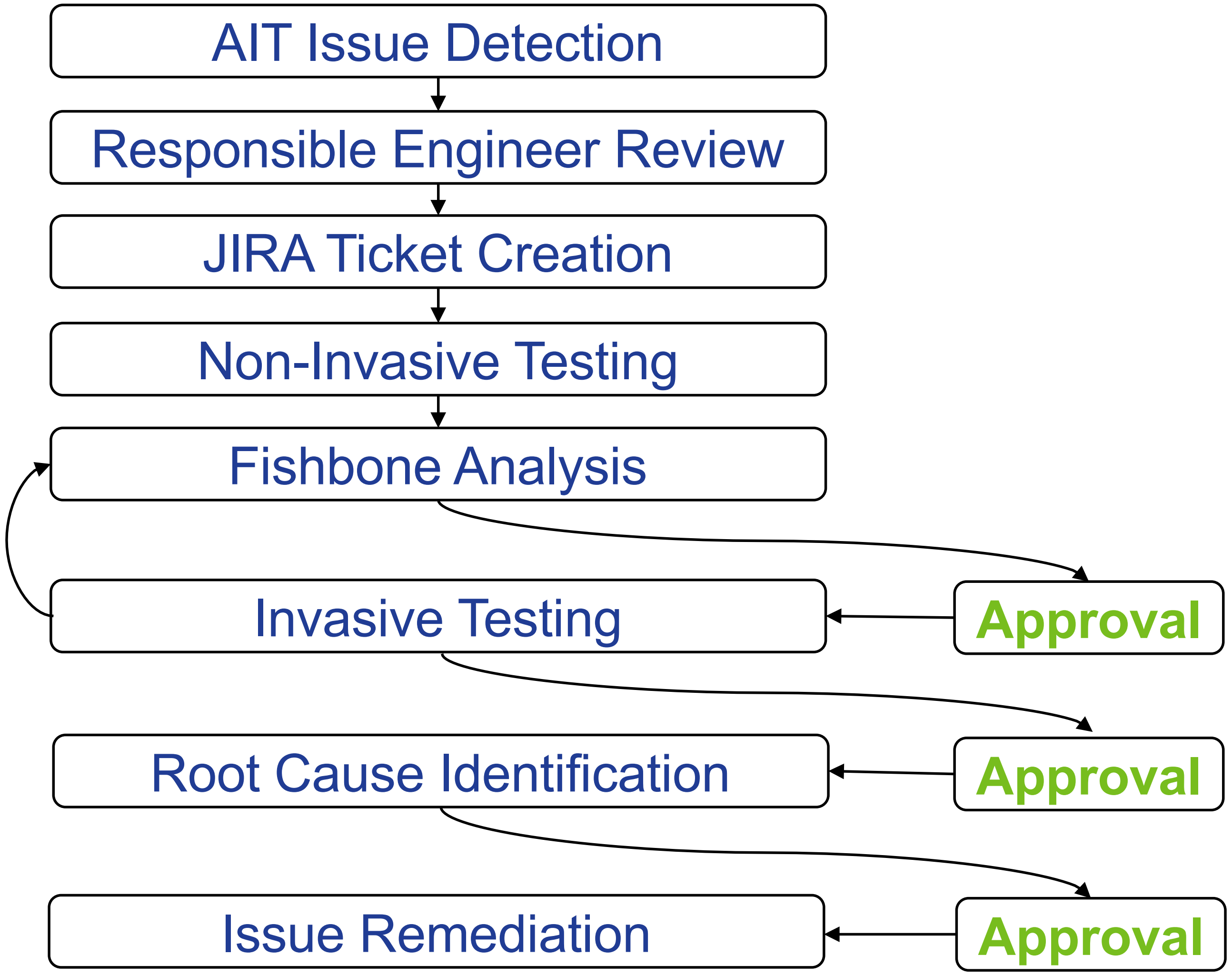
A combination of HITL, Monte-Carlo analysis, and Day in the Life Testing on Flight Units and Engineering Units are primary means of final software verification



The simulation was re-run and the system held at 0.5m for several hours

Issue Resolution

- When working with flight hardware, anomaly detection and resolution must be formalized.
- One mistake could lead to weeks or months of delays at the vehicle level.
- All plans for path forward, and approvals, are stated as comments in the tickets.
- JIRA is the ultimate repository for the investigation. It is 100% transparent and fully traceable with many media attachments.



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.
- 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.