Quality Perspective on Commercial GEO vs USG National Asset and “New Space” Satellites

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Agenda

- SSL overview / product make up
- Perhaps for different reasons; but both USG National Asset and Commercial GEO satellites require high quality
- High quality takes focus and constant vigilance
- Some unique Commercial GEO aspects compared to USG National Asset
- Two Commercial quality initiative examples
- Quality Practices for “New Space”

SSL History

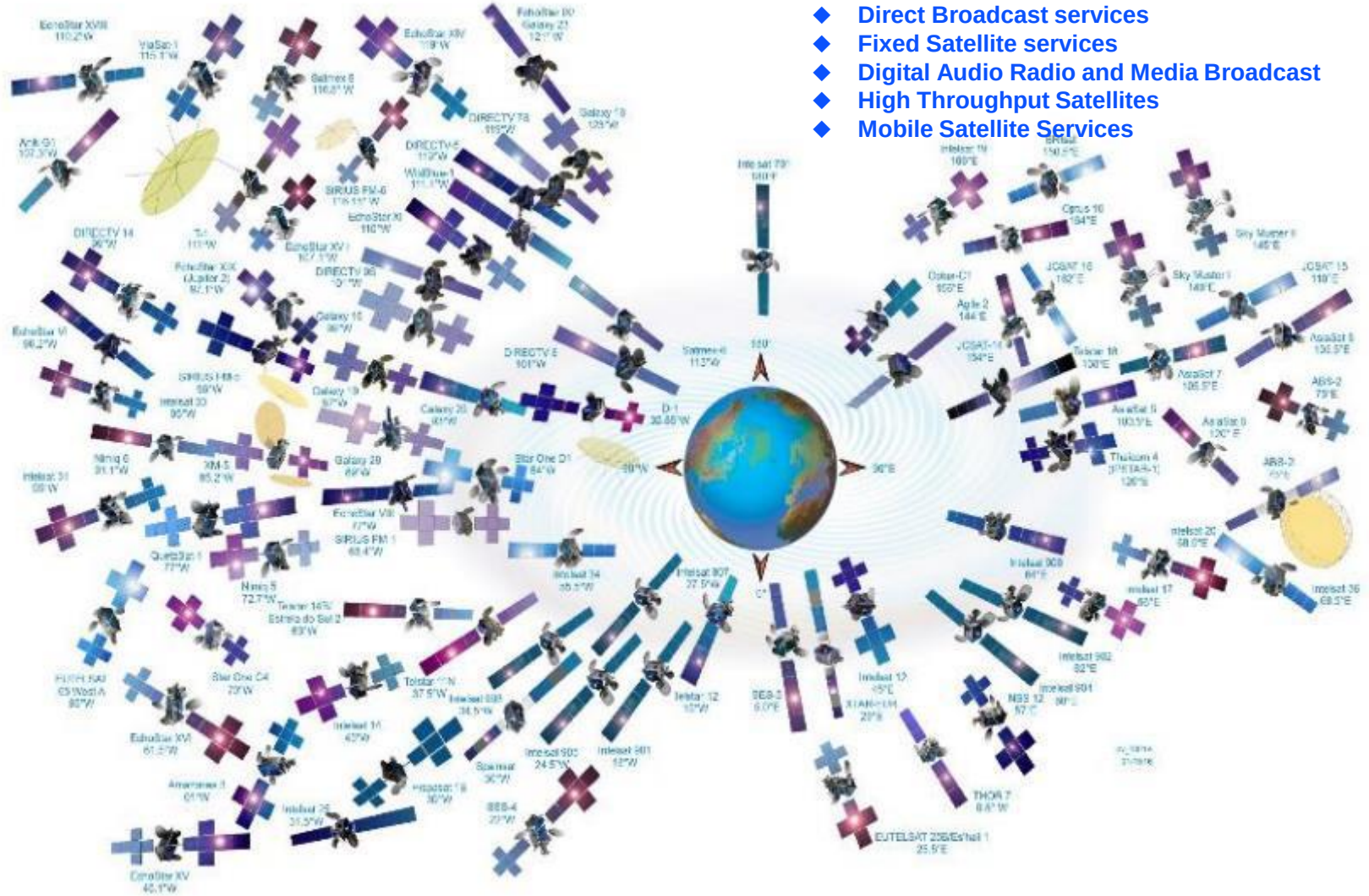
- 1957 — Western Development Laboratories of Philco
- 1966 — Philco-Ford
- 1976 — Ford Aerospace, Space Systems Division
- 1990 — Space Systems/Loral (acquired by Loral Space & Comm)
- 2012 — SSL (acquired by MDA)

Courier 1B; world's first active repeater satellite. Launched in 1960.

Jupiter 2 / Echostar XIX; highest throughput satellite (greater than 200 Gbps) on-orbit. Launched in 2016.

269 satellites launched
16 GEO and 17 LEO satellites in current backlog

83 SSL GEO Satellites Currently On-Orbit



Commercial GEO Markets:

- Direct Broadcast services
- Fixed Satellite services
- Digital Audio Radio and Media Broadcast
- High Throughput Satellites
- Mobile Satellite Services

Availability of 99.9996 in 2016 validates Commercial Mission Assurance approach

USG National Asset and Commercial GEO: Both "High Stakes"

- Quality is essential for USG National Asset satellites:
  - Availability for the warfighter, early warning, etc. is critical
  - Billion dollar systems must work; accountability to tax payers
  - Lifesaving missions; supporting natural disaster prediction and relief

- Quality is essential for Commercial satellites manufacturers:
  - Highly competitive market – history of high quality essential to winning business
  - Customer business success depends on reliable service
  - Customer has numerous US and international alternatives if they lose confidence in manufacturer's Quality Management System
  - Insurance claims tarnish a manufacturer's reputation
  - On orbit anomalies result in reduced revenue
  - Only 90% of contract value is typically paid upon on-orbit handover, flawless performance required for final 10%
  - Fleet wide on-orbit issues can put both manufacturer and operator out of business

Both USG National Asset and Commercial GEO satellites require high quality

High Quality Takes Focus and Constant Vigilance

How many times does the letter "F or f" (count both upper & lower case) appear in the following sentence?

High Quality Takes Focus and Constant Vigilance

Finished files are the result of years of scientific study combined with the experience of many FEMA projects.

There are seven "f's"

…A good example of how hard Quality is and that it takes focus and constant vigilance to achieve it to a high degree

Unique Business Aspects of Commercial GEO

- **Both** Customer and Manufacturer are in business for profit:
  - Customer loses revenue if a satellite takes too long to get to orbit
  - Manufacturer loses millions of dollar of liquidated damages if a satellite does not meet contractual schedule requirements
- Some Commercial features as a result:
  - Manufacturer develops new technology (survival imperative) off-line of tight program schedules
  - Detailed Design, Development and Qualification Plans for new hardware that has been mutually agreed to for development during a program
  - Robust Qualification by Similarity assessments for heritage hardware
  - Requirements nailed down prior to contract award
    - Launch vehicle, beam patterns and antenna "shaping" within agreeable parameters
  - Customers imbedded / part of the team: real-time on-site decisions for most issues

Customer and manufacturer mutual interest to take calculated risks, but not at the expense of mission failure

Common and Perhaps Unique Quality Attributes

- **Both USG and Commercial GEO have standard Quality attributes**
  - **QMS systems based on standards, training certifications, work instructions, documentation**
  - **Mission Assurance Plans tailored by Mission Category to ensure repeatable standard approach**

- **Commercial GEO attributes that may be unique:**
  - **High, relatively consistent, volume leads to: personnel and process stability, long term purchase agreements with subcontractors and vendors**
  - **Global supplier choices**
  - **New product developments in IRAD, HALT when appropriate, prior to insertion**
  - **Huge on-orbit telemetry streams used to monitor performance and feed back lessons learned into the design, test, and quality programs**
  - **MIL-STD-1540 tests, tailored based on trend analysis and performance results**
    - **Can add as well as reduce (example on subsequent page)**
  - **Quality oversight always for critical operations, but case-by-case assessment for everything else depending on assessment of value added and trend analysis**
  - **Anomaly trending or detailed root cause analysis and corrective/preventive actions based on priority score (example on subsequent slide)**

Test Effectiveness Example

- Slight increase in number of unit failures post unit AT in 2009
  - Unacceptable to have issues at satellite integration and test level
  - Integrated Product Team (IPT) formed to recommend test robustness improvements
- Recommendations that were implemented
  1. Doubled number of powered-on unit level thermal vacuum cycles
  2. Added 100 hours of burn-in testing at unit level and/or tray level
  3. Added unpowered rapid thermal cycling at the tray level
     - New thermal chambers purchased for this
     - Solved problem of not being able to increase Unit AT Delta T
  4. Added 100 On/Off cycles for DC/DC power converters
- Ran this "grand experiment" for over three years
- Tested hardware for 20 satellite programs

New chamber to cycle trays at 10°C / minute

Sample added test results on next slide

Test Effectiveness Example (Continued)

- Sample test results for item #3, burn-in:

Tray / Unit	Test Articles	Failures
15W Converter Trays	500	None
50W Converter Trays	317	One
105W Converter Trays	132	None
ACE/DHE Units	49 / 48	None
LVC Trays	64	None
PCU Discharger Trays	259	None
BCE Units	59	None
ICU Units	15	None
CCU Units	8	None
Total	**1451**	**One**

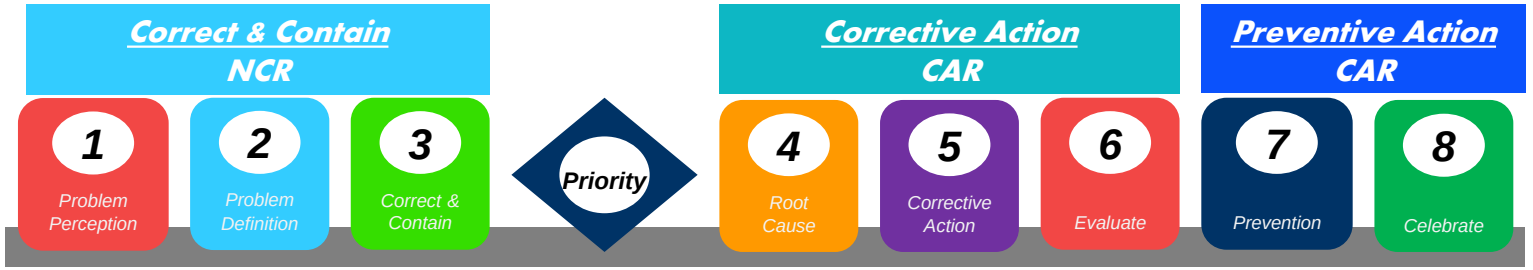
Improved capacitor screening for heritage units, replaced tray with improved design for new programs

- After three years of effort:
  - Fixed some root cause issues,
  - Kept 100 On/Off cycles for DC/DC power converters,
  - Discontinued other test additions based on data review and conclusion of no value added
- Unit level AT test escapes found at satellite level and 1st year on-obit failures have decreased even though satellite complexity has increased

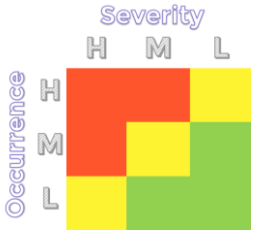
Moral of the story, experiment to improve effectiveness:
Keep what works, don't waste time and money on anything that doesn't

Anomaly Trending or Detailed Root Cause Analysis and Corrective/ Preventive Actions Based on Priority Score

- **Problem: If detailed root cause and corrective / preventive action is required on all hardware nonconformances, a poor job will probably be done on all of them**
- **Solution: Use priority score, based on Severity and Occurrence rate, to determine appropriate action**



- **Performed on all nonconformances**
- **Trended for more accurate occurrence rate prediction if it continues to happen**



- **Required for all High (Red) priority scores**
- **Performed or not for Medium (Yellow) at discretion of quality engineer and other members of corrective action review board**
- **Not required for Low (Green), but trended for future occurrence rate calculations**

Results in efficient resource allocations, better (focused and effective) root cause determination and corrective actions, and preventive actions on important issues which drive long term factory improvements

Quality Practices for "New Space"

- New Space; no clear definition that I know of, but to paint a picture of the landscape:
  - Universities fielding surprisingly capable cubesats at a very low cost
  - Entrepreneurial start ups with small but capable satellites
  - Constellations on the drawing board (some funded and being designed) taking advantage of new technology, commercial parts, and lower launch costs
- A 2013 study* on the first 100 Cubesats showed very low success rates: 25% for academia and 34% for industry
- Although they may have improved since 2014, they must improve further for US government missions of importance (may be fine for experiments) and start ups with Venture Capital business case paybacks expected
- Quality approaches:
  - No "one size" fits all
  - Risk profiles / tolerance beyond traditional Class A, B, C, D
  - Some on-orbit failure tolerance actually planned for (redundancy built into constellations)
  - Commercial parts, test sampling plans, self (QD)-inspection, etc. that are not acceptable for commercial GEO being used successfully in most cases
- What we have learned so far:
  - For "Skunk Works" approach: Core team MUST be cross trained and know who and when to bring in extra help
  - Using new (expected lower overhead) systems can result in LESS efficiency than if heritage / legacy systems would have been used

The pendulum will swing…and learning will go in both directions

** The First One Hundred CubeSats: a Statistical Look by Dr. Michael Swartwout*

Brian on Summer Vacation

USG National Asset, Commercial GEO, New Space… everyone must "count the F's."

2016 – 10 Launches, 15 More Healthy Revenue Generating Satellites On-Orbit