Agilent Technologies Speeds Payload Test for Space Systems/Loral

Case Study

From left to right: Duncan Blanks, Jean Bodine and Bill Pirie.

“Among the reasons that we selected Agilent was the fact that our challenges posed no obstacles to them. They have been in the RF business for many years, they’ve worked closely with us, and they understand our business, so overcoming these challenges was for them very easy. Any other company that hadn’t had the exposure to this business would have found it much more difficult.”

Duncan Blanks
Deputy Director of Spacecraft Engineering Test Operation
Space Systems/Loral

Customer:
Space Systems/Loral (SS/Loral)
Palo Alto, CA

Challenges:
Improve test times per pathway

Simplify test system calibration

Ensure scalability

Provide for future upgrades

Solutions:
Collaboration with SS/Loral to develop a new Payload Test System with desired features.

Relief to SS/Loral from needing to develop the system entirely on their own.

Remote control of multiple test systems from a single workstation.

Results:
Test time reduced from 3 1/2 – 4 minutes to 2 1/2 minutes per pathway.

Simultaneous testing of two pathways accomplished through remote test system control.

Test system calibration skill level, time and effort significantly reduced.

New test systems are backward compatible, scalable and upgradable.

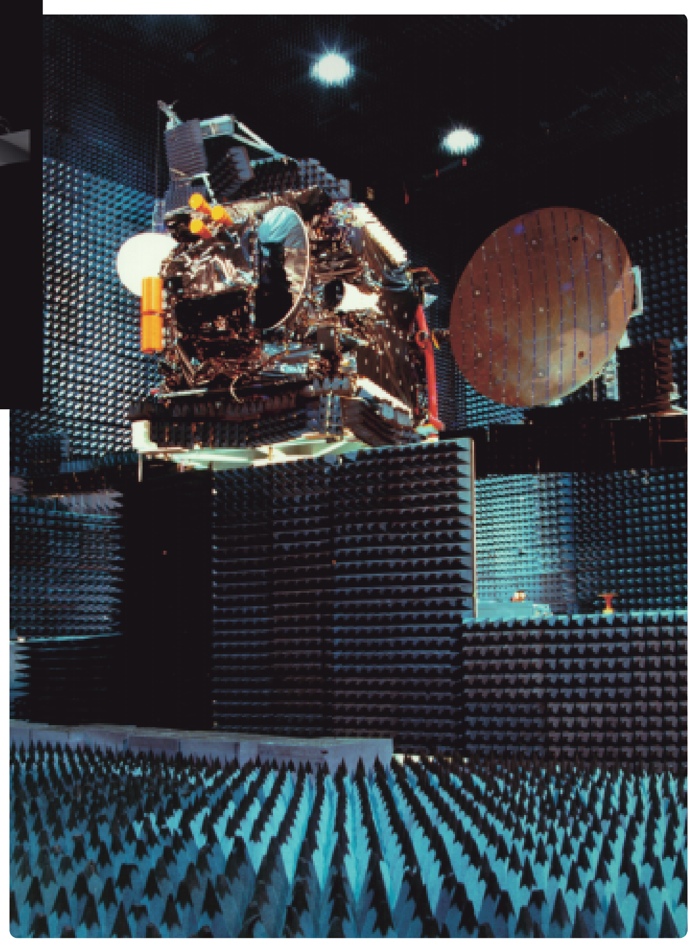
Agilent Technologies
Innovating the HP Way

The design and manufacture of communication satellites is a multi-billion dollar industry. One of the prime players in this industry is SS/Loral, a $1.4 billion operation with some 200 satellites to its credit. A subsidiary of Loral Space and Communications, SS/Loral designs, builds and tests satellites, subsystems and payloads at its Mission Control Center in Palo Alto, California.

SPACE SYSTEMS LORAL

Irrespective of their mission, satellites don't fly until they have undergone comprehensive pre-launch testing. This holds true whether the satellite will provide telephone and business communications, weather imaging services or direct-to-home digital television systems. But satellite manufacturers are continually challenged by aggressive production schedules and rigorous performance requirements. Rather than build payload test systems (PTS) in-house, they seek the assistance of test and measurement experts who free them to focus on what they do best—producing state-of-the-art satellite systems.

This was the case when SS/Loral contracted with Agilent Technologies (formerly Hewlett-Packard Test & Measurement Organization) in 1998 to build a new payload test system. The result was an automated, robust, user-friendly, algorithm-based payload test system for evaluating the RF performance of communications satellite transponders, telemetry transmitters, and command receivers. Agilent's system has simplified and reduced standard processing time, and ensured high-performance satellite delivery. The test system's modular design also permits easy upgrade and reconfiguration.



Sirius FM-01 (a high-power Digital Audio Radio satellite) spacecraft mounted on the test positioner is prepared for it's final full power testing. The test range is used to perform high accuracy measurements of the radiation pattern coverage that the spacecraft will send.

System-level testing before launch

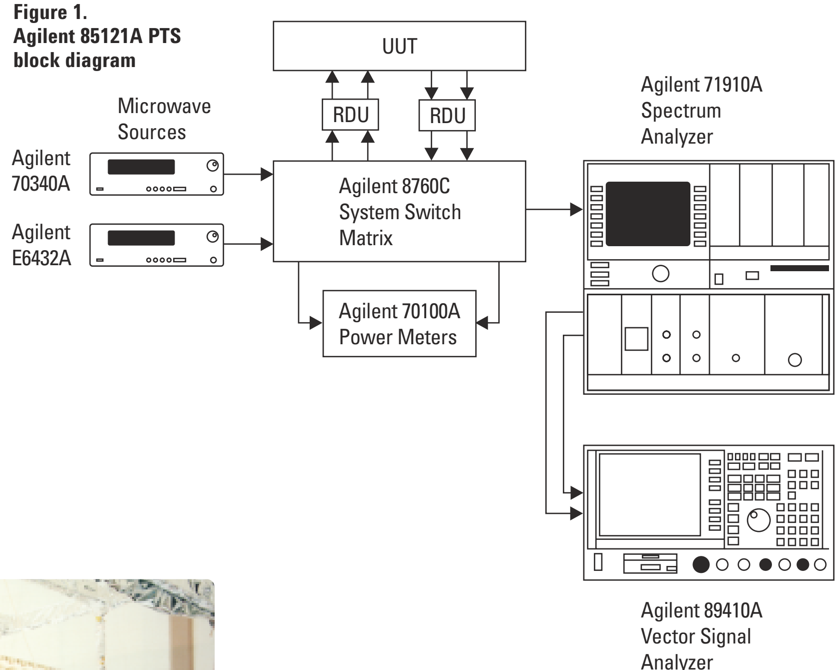
Systems-level testing plays a critical role in ensuring spacecraft performance and on-orbit reliability. For system-level testing–prior to launch–hardware, software, and engineering come together in an integrated package. Because penalties are immense for late delivery to the rocket provider, the pressure for on-time delivery is relentless. Nevertheless, reliable performance on orbit depends on thorough testing of every signal pathway through the spacecraft, and testing shortcuts are out of the question.

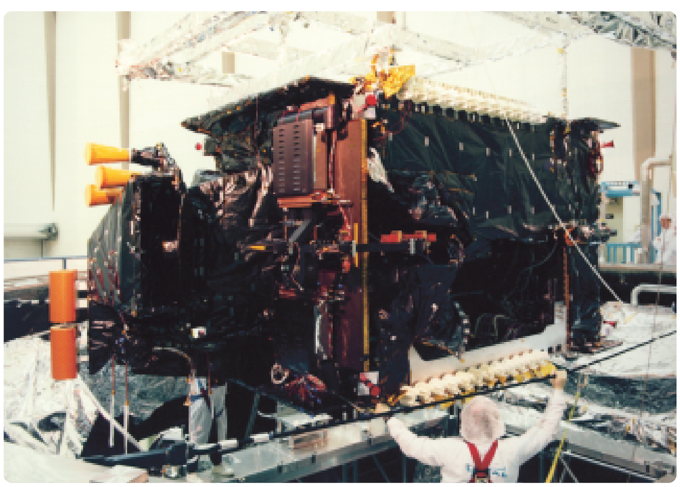
It takes about 9½ months to perform a full system test. The first three or four months of that time involves integrating all parts on the spacecraft. Issues that have remained unresolved to this point eat away at the allowable testing time. Any analysis that may not have been done–modeling of how the receiver and the filter function together in the transponder, for example–will precipitate out during system-level testing. Having the tools to perform troubleshooting and problem solving is key.

Ultimately, a full spacecraft arrives at a state of readiness for transponder testing. The spacecraft will typically contain 48 transponders or repeaters, although this number is set to increase in future configurations. These are effectively "mirrors in the sky," each receive a signal at a certain frequency, downconvert it, filter, amplify and then re-broadcast it over the satellite's footprint. The route that a signal takes through the satellite is the pathway being tested by the PTS. There are about 160 paths, and for each path a suite of perhaps six different tests must be performed.

From transponder testing, the spacecraft enters an environmental test phase: it is placed in a thermo-vac chamber and the temperature varied. At different plateaus of hot and cold, SS/Loral will run another

Figure 1.
Agilent 85121A PTS block diagram



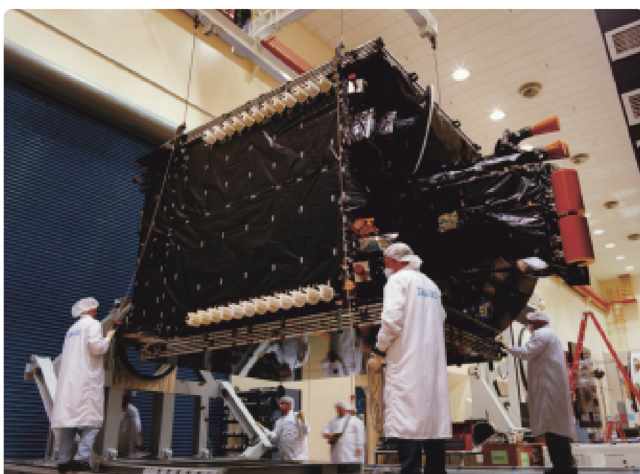


SS/L technicians prepare to place Sirius FM-1 into a Thermal Vacuum Test Chamber to simulate the conditions that the spacecraft will encounter during its on-orbit lifetime.

subset of tests, different from those run as reference performance at ambient. After thermo-vac comes another set of ambient tests and then the spacecraft goes on to the vibration table or acoustic chamber. In each case beyond ambient, fewer tests are run. The final tests are run in SS/Loral's compact antenna range, where tests previously performed in hardline are now performed through an antenna. SS/Loral can then simulate the performance of the entire system to verify its integrity. Results are compared with the hardline information previously collected as baseline data.

Prior to 1998, SS/Loral built their own test systems, but the test equipment was not meeting the needs of the company by providing them with informative test results in a reasonable time. RF testing of the payload transponder was considered "the long pole in the tent" and was scrutinized for improvement. Test programs required approximately $3\frac{1}{2}$ to 4 minutes per pathway to run—and that was after a long, complex and arduous calibration of the PTS.

Ultimately, SS/Loral decided that its core competence was building spacecraft, not test equipment, and sought Agilent's help with its next generation payload test system. Their considered opinion was that the PTS is a very complex system and needs to be built by the right people. Agilent had built test systems for other spacecraft vendors, and thus had significant experience to reference for meeting SS/Loral's requirements.



SS/L technicians place Sirius-1 spacecraft in position on to the structure support mount of a shipping container at a spacecraft assembly facility. The spacecraft will be taken to another facility for acoustic testing.

SS/L integration technicians have completed communication panel integration on Sirius FM-01. Sirius FM-02 continues to receive harness routing and lower bus electrical systems testing. Sirius FM-03 was delivered to the assembly floor after completion of propulsion systems integration.

The system provided to SS/Loral, the Agilent 85121A PTS, consisted primarily of Agilent's own commercial off-the-shelf (COTS) equipment, see Figure 1. Using COTS equipment results in a system with high reliability, high mean time between failures, and low mean time to repair.

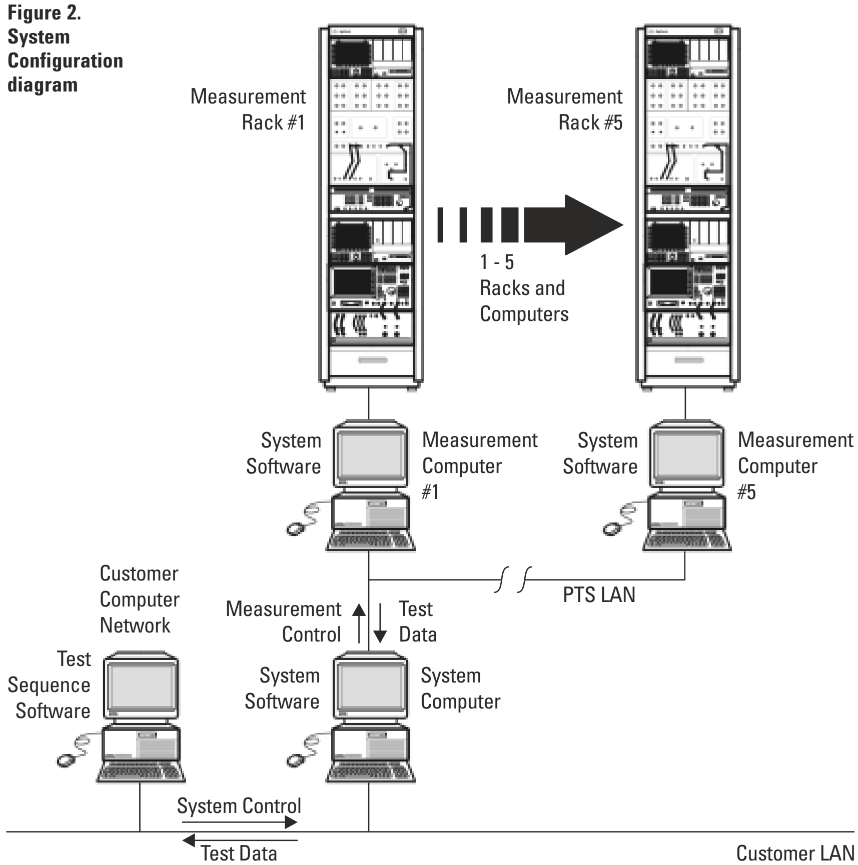
Proprietary

Customization was accomplished primarily in the software. Test algorithms were designed with HP Visual Engineering Environment (VEE) software, an easy-to-use graphical test development tool. HP VEE instrument drivers provide system interfacing between the test instruments and the measurement software. Still, SS/Loral worked with Agilent to bring the generic PTS to new levels of hardware and software performance, resulting in SS/Loral's owning a proprietary interest in this particular system.

One of the problems SS/Loral asked Agilent to address was test system calibration. Historically, calibration was a time sink–complex, difficult and arduous. It required the use of highly sensitive network analyzers, which in turn demanded a skilled and trained engineer to calibrate and use, merely to perform the calibration of the test system. Worse, it allowed errors to creep in. SS/Loral insisted that the new PTS be capable of simple, quick and stable calibration.

Agilent found a way to simplify SS/Loral's approach to calibration. SS/Loral had been employing vector analysis in their calibration procedure but there was a faster alternative using scalar analysis, which looked at only power levels and

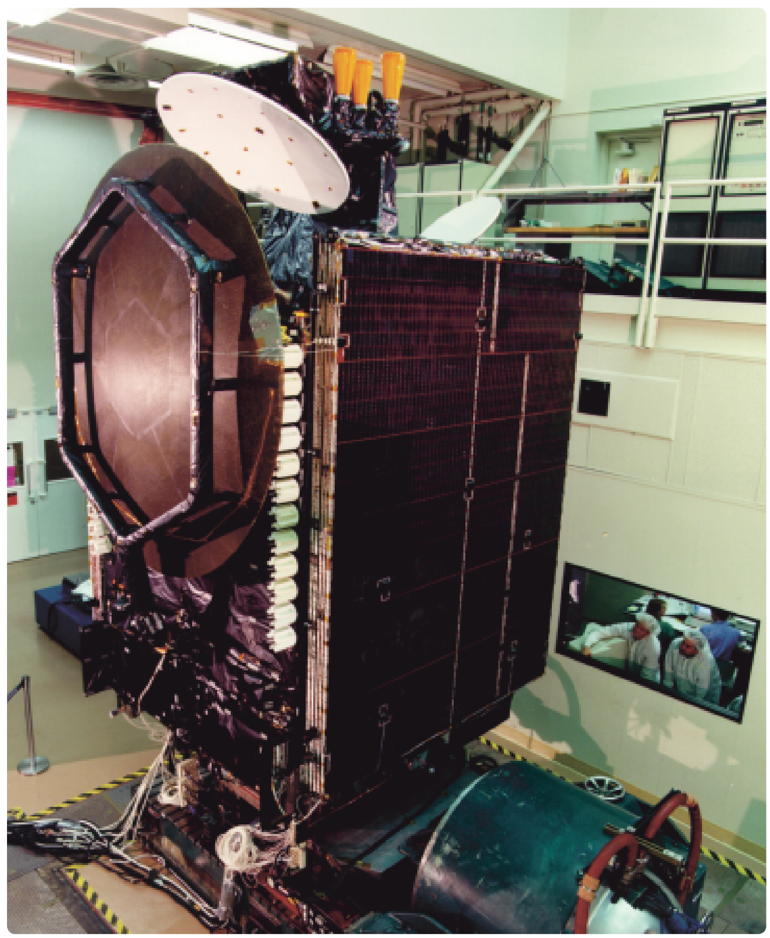
Figure 2. System Configuration diagram



eliminated phase and vector considerations. Agilent applied the scalar technique, employing only RF power meters, and simplified the process considerably, to the point where a skilled technician can now perform the calibration procedure. The new procedure resulted in significant time and cost savings in the overall test process.

Another fixed requirement was maximum measurement speed and accuracy. The system Agilent delivered now provides a rigorous pathway test in just 2½ minutes. But Agilent's 85121A PTS has another feature that improves on that time enormously—simultaneous remote control of up to five systems, see Figure 2. Some of SS/Loral's satellites are built in two sections with a logical division between them. Test engineers now operate with a dual PTS configuration, doing two measurements simultaneously in 2½ minutes. Only a certain amount of overhead prevents an actual doubling of the test speed.

SS/Loral has purchased a total of six PTSs from Agilent, operating in the 2–18.5 GHz range. New requirements call for UHF at approximately 200 MHz, with carriers in the 30 GHz range. SS/Loral and Agilent are currently (Spring 2000) addressing the issues associated with these new requirements while ensuring the test systems will be backward compatible with previous systems. SS/Loral has ordered two more systems and is retrofitting two older systems, with the result that they will eventually have four Ku band and four Ka band systems for a total of eight.



The Sirius-1 spacecraft sits atop the vibration table awaiting testing in the Y-axis position. The dynamic vibration test simulates the effects the spacecraft will encounter during the fist two minutes of launch.

Next generation

Not content with only providing a PTS for the present, SS/Loral and Agilent are already at work on the next version, which will be designed to meet a whole new level of complexity in satellites. The next generation of satellites will have on-board processors, primarily to provide direct Internet connections for high-usage customers. Signals will be digitized on the spacecraft, then re-upconverted and downlinked to the user.

The purpose of the new approach is to increase data speed and throughput, switching signals around very quickly at a baseband frequency, allowing the satellite to be tuned specifically to the needs of the customer. It will respond to customers who are asking for higher data rates or broader bandwidth by actually changing its personality to give the user a massive amount of capability.

On-board processors will also be used to fine-tune antennas, allowing SS/Loral satellites to focus this very valuable energy and shape the beam to radiate directly to the users who are paying for the service rather than providing coverage over the entire continental United States.

The teaming of SS/Loral and Agilent has resulted in significant improvements in the way SS/Loral tests its spacecraft. As SS/Loral moves forward with new developments in the art and science of spacecraft design, they will continue to call upon Agilent's ingenuity in payload test systems.

SS/L senior battery technician, Kenny Cox (left), and vibration test conductor, Ed Eckert (right), monitor an International Space Station Battery Orbital Replacement Unit (ORU) during qualification-level vibration testing. The test, which was successfully conducted, ensures that the Battery ORU will sustain the heavy launch loads of the Space Shuttle. Following this test, SS/L successfully completed qualification-level thermal vacuum, thermal cycling, and electrical performance tests.

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Printed in U.S.A. January 18, 2001
5980-2254E

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